

PROCEEDINGS OF THE  
SEMINAR ON  
CLAY BRICKS AND BLOCKS.

**Research, Development and Current  
Practice in Nigeria.**

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RESEARCH INSTITUTE

1985

**PROCEEDINGS OF THE SEMINAR ON THE USE  
OF  
CLAY BRICKS AND BLOCKS FOR THE PROVISION  
OF  
CHEAPER AND DURABLE HOUSING**

**ZARIA/OCTOBER 1985.**

*Edited by:*

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Nigerian Building and Road Research Institute.  
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## PREFACE

The Nigerian Building and Road Research Institute (NBRRI), right from its inception, had given highest priority to the development of alternative building materials from locally abundant resources. One of the first materials chosen for this programme was clay. Nigeria, however, is a vast country and contains large and varied deposits of clay materials. To try to cover a much wider area than would otherwise have been impossible from Lagos, a similar programme was sponsored by the Institute at the Civil Engineering Departments of Ahmadu Bello University and University of Benin. The research and development work done by the three organisations — Ahmadu Bello University, University of Benin and NBRRI — resulted in some significant achievements and trends. It seemed proper therefore to bring these to the notice of the building industry so that their influence on the industry can be assessed in their proper perspectives.

It was also observed that there were other aspects of the use of clay products which require serious consideration. Although many fired clay brick factories had been in operation for some time, they are yet to make the significant impact expected of them. It became clear that the seminar should address itself to all aspects of the use of clay bricks and blocks for low cost housing. Invitations were thus extended to all those who are intimately connected with the use of clay bricks and blocks for housing purposes — architects, research scientists and technologists, structural engineers, universities, polytechnics, brick making industries, housing corporations and ministries of works and housing. The response to this invitation has resulted in the papers contained in this bound proceedings.

I believe that these papers contain invaluable information and data covering virtually every aspect of this subject. I have no doubt in my mind that they will provoke useful contributions from participants in this seminar and lead to practicable and invaluable recommendations and positive plans for future action in the building industry as far as clay bricks and blocks are concerned.

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6 August, 1985.

## A SURVEY OF BRICK MAKING INDUSTRIES IN NIGERIA

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### ABSTRACT

*Although 22 factories are reported to be in existence, only 20 were identified in a survey conducted by the Nigerian Building and Road Research Institute in 1980 and which was updated in 1983. Ten of these factories are in operation while production in six has been suspended, two have been abandoned and two others have not been completed. The problems facing the factories are examined in relation to the poor impact of burnt clay bricks on the building industry. Suggestions are made on how these problems can be resolved or minimised.*

### 1.0 INTRODUCTION:

The construction boom of the mid-seventies resulted in the massive importation of cement to supplement local production level and the cost of cement since then has been on a continuous increase. It is in the bid to develop alternative local building materials and reduce the heavy dependence on cement that the Federal and some State Governments in partnership with some local entrepreneurs and foreign technical partners established a number of brick making factories in Nigeria since 1975.

Despite the laudable efforts, the impact which the brick factories have had in the construction industry has been disappointing. It is against this background that the Nigerian Building and Road Research Institute embarked on a survey in 1980 to not only identify the existing brick factories but also to examine the initial problems besetting the factories with a view to recommending appropriate solutions. Moreover, it was necessary to establish whether bricks are actually cheaper than sandcrete blocks. For this, quantitative analysis on a square meter wall was employed. The outcome of this survey is contained in a report published in 1981 with restricted circulation. To update the data on brick factories, a review was started in 1983. The data contained in this paper are valid up to July, 1985.

### 2.0 BRICK MAKING INDUSTRIES:

Brick Making Factories were established in the early seventies in order to reduce over-dependence on cement and to provide alternative and cheaper building materials. Though twenty-two brick factories have been reported to be in existence, only 20 of such were identified in the two surveys conducted in 1980 and 1983 respectively. The addresses, ownerships and the years of establishment of the different factories are shown in Table 1.

Seven of the factories are wholly owned by the Federal Government and managed by Nigerian Mining Corporation. Nine are owned by different State Governments in partnership with some financial consortiums, private entrepreneurs and foreign technical partners. Only one factory is privately owned, Brand Clay Products (Nig.) Ltd. Sixteen of the factories are or should be operating while four are yet to take off due to technical difficulties and financial constraints.

Each of the seven factories managed by the Nigerian Mining Corporation has the Hoffman kiln which is the semi-automated type while the other factories have the fully automated type. The major advantage of the latter over the former is that burning is more uniform and hence bricks produced are more uniform in colour. However, the latter require skilled technical personnel.

The capacity production of the different factories range from 7.5 million to 20 million normal sized bricks per annum (Table 2). This would ensure a total annual production of about 300 million normal-sized bricks. Unfortunately, these factories without exception operate at less than half their capacities as a result of 'teething' problems which up to the moment have not been overcome.

### 3.0 PROBLEMS FACING THE FACTORIES:

There are quite a handful of problems that militates against the effective impact which the existence of these factories is supposed to have on the building industry. These in a nutshell range from poor market prospects from the Nigeria public, financial constraints to technical difficulties. The situation has forced all the factories to operate at less than half their annual production capacity. As at the time of visit to the factories, production had been suspended in six while similar action was being contemplated for one of the 20 factories. Moreover, two of the factories had been abandoned long after they were supposed to have been commissioned, while two other factories have not been completed.

The inadequate patronage from the potentially good Nigerian market has adversely affected these factories which usually have massive stockpiling of bricks at the factory sites. This condition is due mainly to the conservative tendency of the public most of whom still prefer sandcrete blocks. Moreover, the inadequate awareness of the overriding

advantages of burnt clay bricks over sandcrete blocks has contributed to the low level of confidence on the use of bricks by the public. Despite this however, it is significant to note that private individuals account for between 60 to 100 per cent of the poor patronage while government agencies account only for between 0–10 per cent (Table 2). This clearly shows that given the necessary encouragement, the Nigerian market can be easily penetrated. But it is indeed quite a paradox that the Federal and State Governments which pioneered and financed the establishment of these factories failed to enforce policies that would make the use of bricks mandatory in their different housing projects.

#### 4.0 ADVANTAGES OF BURNT CLAY PRODUCTS OVER SANDCRETE BLOCKS

Clay products have a number of advantages which make them preferable to sandcrete blocks. These advantages could be seen in the greater strength, better durability, greater aesthetic beauty, better thermal comfort and relatively cheaper costs. In the first instance the raw material, which is good quality clay, abounds in the country and are easily quarried at minimal costs.

When clay products are well laid, rendering of both sides of the wall become a luxury and can be avoided thereby leading to savings in costs. Similarly, painting is not needed as the brickwalls exhibit excellent matrix beauty. On the long term, minimum maintenance is required as there would be no need for periodic paintings. Buildings with sandrete blocks do not have these advantages.

The compressive strength of bricks is generally greater than 15MPa and this far exceeds the minimum strength of 2.8MPa specified in BS 2028 for precast concrete and also surpasses the minimum strength requirements of 2.5 N/mm<sup>2</sup> specified by the Nigerian standard NIS 74: 1976 U.D.C. 624, 012.8 for burnt clay brick unit. In fact, bricks with compressive strength of up to 50MPa have been encountered. Also burnt clay products are more durable than sandcrete blocks.

Clay products are burnt at temperatures greater than 900°C and are therefore fire resistant. In addition, only clay products have good insulation properties which contributes to greater thermal comfort.

#### 5.0 COMPARABLE COSTS OF CLAY PRODUCTS AND SANDCRETE BLOCKS

Apart from the advantages enumerated in the previous section, it is necessary to establish whether bricks are actually cheaper than sandcrete blocks. The analysis does not take into account rendering and painting costs which are only required on the inner face brick walls. This

approach is adopted because psychologically the public's first reaction is to consider the structural use of bricks and blocks in isolation to the finishes.

This comparison of relative costs is made in Tables 4 to 8. The quoted prices do not include transportation costs and handling charges to building sites. The price index is the ratio of the price of clay brick or block to that of sandcrete block for the same area of one square metre. The clay product is costlier than the sandcrete block when the price index is greater than 1.0. Conversely the clay product is cheaper when the price index is less than 1.0.

The clay blocks of Nigerian Brick and Clay Products Ltd., are comparably cheaper than sandcrete blocks, the price index ranging from 0.88 – 0.90 for load bearing walls (outer walls), Table 4. The price index is significantly less than 1.0 for partition walls, ranging from (0.61 – 0.71) and gives economic basis for the popularity of clay products as partition materials in high rise buildings. The indices are higher when the comparison is made against 460 x 150 x 230 mm (18" x 6" x 9") sandrete block.

The price index for the Brand Clay Products Ltd., Okigwe, ranges from 0.93 to 3.05., Table 5. This improves for purchases greater than 50,000 bricks where the price index falls significantly to 0.77 for a clay block of the attractive dimensions of 310 x 230 x 230 mm. However the constraint of a purchase of 50,000 clay blocks will limit patronage to private large state developers and housing corporations.

Lacon (Nig.) Ltd., Igbogbo, Lagos, markets a block of unusual dimension 300 x 175 x 225 mm with a low price index of 0.78, Table 6. The clay products for partitions and decking/floor slabs again attract very low price indices of 0.62 and 0.83 respectively.

For Borno Clay Products Ltd., Maiduguri, the price index shows that its clay products cost about the same as sandcrete blocks, price index ranging from 0.93 for partitions to 1.16 for load bearing walls, Table 7.

For the clay blocks for load bearing walls of Ondo State Brick Work, Ire-Ekiti, the price index is low, 0.71 to 0.80, Table 8. However again the dimensions, 320 x 180 x 235 mm and 240 x 160 x 235 mm are not the conventional ones used locally.

For the Chachanga Clay Products Ltd., Minna, the clay products are not cheaper than sandcrete blocks. The price index for load bearing walls range from 1.30 to 1.47 while for partition walls, it is 0.93. Table 9.

The general trend therefore is that clay bricks and blocks are in some factories cheaper than sandcrete

block. In others they are just comparable to sand-concrete blocks. However, for clay bricks to be popular they must be significantly cheaper because it costs more to lay bricks properly as was confirmed by actual field trials conducted by the Ghana Building and Road Research Institute. The cost of laying clay bricks can be reduced by retraining the modern Nigerian mason who is not familiar with this task.

## 6.0 GENERAL DISCUSSIONS:

Promotional strategies of all the factories is mainly by advertisements in the local radios, television stations and newspapers. The services of 'Dealers' or 'Distributors' are not usually employed by most of the factories. Understandably, this is to ensure that the bricks get to the ultimate consumer at the recommended prices. Instead, some of the factories appoint 'Agents' who scout around for customers for a fee that is usually pegged at a regulated percentage of the amount of bricks bought by the consumer.

The promotional style of Ondo State Brickworks Ltd., Ire-Ekiti need special mention. Market depots with beautiful small brick offices are located at strategic places within some local government areas of the State. This alone is bound to attract attention and generate interest from the public at large. Moreover, this factory also has a Low Cost Housing Scheme for the public. Here, the factory supplies all the bricks required for the building project to the customer. The customer pays 50% of the cost of bricks supplied and thereafter pays the balance on an agreed monthly instalmental basis. While this loan scheme may guarantee the factory a continuous outlet for the clay products, it would have been more attractive if the scheme covers the whole building structure including the roof, windows, sanitary wares, wash basins and bath.

None of the factories have Quality Control Laboratory. The need for this cannot be too well over-emphasized as clay should be plastic and consistent enough to prevent development of shrinkage cracks during drying and burning. Periodic testing of parameters such as compressive strength, durability, thermal conductivity, shrinkage cracks etc. are necessary to ensure high quality products, that are devoid of defects such as cracks etc. There is also the need to standardise all the testing procedures while taking into account the technical peculiarities of bricks.

At the moment most of the factories produce bricks and blocks with different dimensions. There is need for the dimensions to be standardised after consultation with all the professionals connected with the building industry and the Standards Organisation. Standardisation will facilitate design and detailing of building drawings, promote flexibility and encourage competition between production units

Laying of bricks and other clay products require special skill to ensure a beautiful and presentable finish. As at the moment, there are only a few people with such skill and this results in high labour costs. However, the current practice in most of the factories is to provide skilled masons, free of charge, to customers for a period of between one to three weeks depending on the volume of the

customer's building project. The masons are usually expected to train the customer's masons within the short period. Laudable as this effort is, it is not enough to supplement the level of skilled bricklayers needed. Since direct labour approach is now adopted for most of government projects, it is desirable to train some of the artisans in the Ministries of Works and Housing in the art of good bricklaying.

The high initial capital cost of machinery and installation coupled with the attempt to recover this in a short time has placed a number of these factories in difficult financial situations and in some cases they have been forced to temporarily suspend production while seeking financial assistance from government and financial institutes. Factories managed by ENCON (Nig.) Ltd., which is a German-based technical partner, are the worst hit by this predicament. In addition to this, is the role played by some of the foreign technical partners who for one reason or the other abandon the factories. Fortunately, however, some of these factories are now being re-activated by various state governments and the management entrusted to Nigerians. Other factors which affect the operation of these factories are the irregular supply of electric power from the national grid and lack of spare parts for stand-by generators.

## CONCLUSION:

Experience in other countries, including so called developing countries like India, indicate that clay bricks are significantly cheaper than cement treated products. Some of the reasons for the poor demand for bricks from the Nigerian public were considered in the previous sections. To promote the use of bricks, thus ensuring a greater use of abundantly occurring clay, the following recommendations are proposed:

- (1) The Federal and State Governments should work out a financial arrangement to guarantee the high capital cost of investment incurred in the establishment of the fired clay brick factories. With this assurance, the foreign technical partners can be prevailed upon to reduce the rate of return of investment with consequent reduction in the price of clay bricks.

- (2) More of the clay products should be made in the largest possible size after taking the technical issues into consideration as is being done by some factories. This will make clay bricks competitive as the large size will reduce the number of bricks required per unit area of wall resulting in lower labour cost for laying them.
- (3) Closely linked with recommendation (2) above, is the necessity to standardise the various sizes of the bricks throughout the country after due consultation with the building industry and the Standards Organisation of Nigeria. The Standardisation of bricks will ensure a wider choice of makes for the users, flexibility and greater competition among the producers.
- (4) An intensive programme should be undertaken to train a large number of artisans and craftsmen skilled in the laying of bricks. With an adequate number of such skilled artisans in the market, the labour cost of laying bricks, if not reduced, will at least be stabilized. With the direct labour policy on government projects, the active participation of artisans of the Ministries of Works and Housing in the training programme would be highly beneficial.
- (5) Federal and State Governments should take the lead in using clay bricks in their housing schemes. This is particularly desirable in bungalows and two-storey buildings where they will be found to be especially suitable. Such an action will provide a very effective promotion of clay bricks and attract public attention and patronage as it did for sandcrete blocks in the nineteen fifties. This will result in increased production rate of clay bricks from the factories with the possibility of further bringing the prices of bricks down.
- (6) The individual brick factory should as a matter of policy embark on the establishment of market depots at strategic locations in the different local government areas of the State where the factory is located. These depots should wherever possible have at least a two-room office beautifully built with bricks to attract public attention and interest.
- (7) Government and private entrepreneurs should as a matter of deliberate policy consider the use of medium and small scale industries in the manufacture of building materials where this is appropriate. In view of the present economic climate, large scale factories require high initial capital and generally attract a high rate of return of investment. Besides, it necessitates considering a large market with the consequent additional cost arising from transportation which is passed on to the customer.
- (8) There is need to establish a quality control laboratory in each of the factories. This will enable each factory to check that all its products satisfy the specified standard and help in continuous development of its clay products.
- (9) Finally, it is desirable for all the burnt clay brick manufacturers to come under the umbrella of an association. Such a development will create the forum for mutual co-operation, standardisation and exchange of ideas amongst the factories. All the problems facing the factories could then be tackled more effectively to the mutual benefit of all.

#### ACKNOWLEDGEMENT:

The Nigerian Building and Road Research Institute acknowledges the co-operation of the Fired Clay Brick Manufacturing Companies who responded to our enquires. Without their invaluable co-operation and contribution, this survey would not have been possible.

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2. NIS 74: 1976 U.D.C. 624. 012.8 Nigerian Specification for Burnt Clay Brick Units.

TABLE 1: OUTLAY OF CLAY BRICK INDUSTRIES IN NIGERIA

Brick Factory	Address	Ownership	Year Established	Year Production Started	No. of Expartriate Staff
Nigerian Brick and Clay Products Ltd. Lagos.	Off Ibeshe Road, P. O. Box 541 Ikorodu, Lagos, Lagos State.	N. M. C. (Federal Government)	1978	N/A	1
Nigerian Brick and Clay Products (Borno) Ltd. Maiduguri.	Brickworks Project Gongolong – Maiduguri, P. M. B. 1467 Maiduguri, Borno State.	N. M. C. (Federal Government)	1979	—	1
Nigerian Brick and Clay Products Ltd., Kano.	Opposite Bagauda Late Hotel, Kano, P. M. B. 3138, Kano, Kano State.	N. M. C. (Federal Government)	1979	1981	None
Nigerian Brick and Clay Products Ltd., Jos.	Brickworks Project P. M. B. 2154, Bauchi Road Naraguta, Jos, Plateau State.	N. M. C. Federal Govt. — 75% Plateau Govt. — 25%	1978	1979	1
Nigerian Brick and Clay Products Ltd., Enugu	P.M.B. 1405, Akegbe - Ugwu Awkunanaw, Enugu, Anambra State.	N. M. C. (Federal Government)	1981	1981	None
Nigerian Brick and Clay Products Ltd., Kaduna	Kachia Road, Kaduna	N. M. C. (Federal Government)	Not yet commisioned	1982 (?)	None
Nigerian Brick and Clay Products Ltd., Ibadan.	Omi - Adio, Abeokuta Road, Ibadan.	N. M. C.	Not yet commission	1982 (?)	None
LACON (Nig.) Ltd., Ikorodu, Lagos.	Baiyeku Road, P. O. Box 238, Igbogbo, Lagos.	LASG NIDB ENCON	1979	None	None
Clay Products Ltd. Okigwe	P. C. Box 174, Ezinachi Okigwe, (Temporarily closed down)	ENCON IMSG Others	N/A	None	N/A
Borno Clay Products Ltd.,	Km 11, Jere Road, P. M. B. 1628, Maiduguri, Borno State.	BOSG NIDR NNDC NBCI ENCON	1978	1980	None
Ondo State Brick Works Ltd., Ire-Ekiti.	P. O. Box 111, Ire-Ekiti.	Ondo State Government	1980	1981	None
Chanchanga Clay Products Ltd.,	Chanchanga; Minna-Parko Road, P. O. Box 823, Minna.	NGSG NIDB ENCON	1981	N/A	None
Sokoto Clay Products Ltd.,	Talafa Mafara	SOSG ENCON OTHERS	Abandoned	—	—

Brick Factory	Address	Ownership	Year Established	Year Production Started	No. of Expartriate Staff
Oranmiyan Clay Products	P. M. B. 72, Ipetumodu	Oyo State Others	1981	N/A	None
Wurno Construction Materials Ltd.,	(1) Wurno, Sokoto State, — Factory. (2) 2 Kotangora Road, P. O. Box 672 Sokoto State. — Office.	Impresit Bakolori and Others	1982 (?)	N/A	N/A
Gateway Bricks Ltd.,	Lapeleke, Near Abeokuta, Ogun State	OGSG with Italian Interest	N/A	N/A	N/A
Brand Clay Products (Nig.) Ltd.,	Amuro, Okigwe Imo State.	Private	1972	1978	None
Benue Burnt Bricks Ltd., Otukpo	P. O. Box 450 Otukpo, Makurdi Office: P. M. B. 2278	BNSG Interkiln of U.S.A. and Others	N/A	N/A	N/A
Mubi Burnt Brick Industries Ltd., Mubi	Police Roundabout, Yola Road, Jimeta, P. M. B. 2238, Yola	GGSG CERIC of France	N/A	To be commission in January, 1986	N/A
Clay Products Ltd., Oregun, Lagos.	Oregun, Lagos	Private with Italian Interests	1962	1962	N/A

<b>N.B.</b>	N/A	Not Available	NNDC	Northern Nigerian Development Corporation.
	N.M.C.	Nigerian Mining Corporation	NBCI	Nigerian Bank for Commerce and Industry.
	BOSG	Borno State Government	LASG	Lagos State Government.
	NIDB	Nigerian Industrial Development Bank	SOSG	Sokoto State Government
	BNSG	Benue State Government.	NGSG	Niger State Government
			GGSG	Gongola State Government
			OGSG	Ogun State Government

**TABLE 2: PRODUCTION AND PATRONAGE OUTLAY OF THE CLAY BRICK FACTORIES IN NIGERIA**

Brick Factory	Annual Production Capacity (Bricks)	Press Annual Production (Bricks)	Patronage
Nigerian Brick and Clay Products Ltd., Ikorodu Lagos.	15 million (Normal Size)	7.5 million (Normal Size)	<u>Average:</u> Individual 60% Government Agency 10% Dealer 10% Others 20%
Nigerian Brick and Clay Products (Borno) Ltd. Maiduguri	15 million (Normal Size)	7.5 million (Normal Size)	<u>Average:</u> Individual 90% Government Agency 5% Dealers 5%
Nigerian Brick and Clay Products Ltd. Bagauda Kano.	15 million NS	7.5 million	<u>Average:</u> Individual 95%
Nigerian Brick and Clay Products Ltd; Jos.	15 million NS	7.5 million	Good: Individual 100%
Nigerian Brick and Clay Products Ltd., Enugu.	15 million NS	7.5 million	<u>Average:</u> Individual 90% Government Agency 10%
Nigerian Brick and Clay Products Ltd., Kaduna.	15 million NS	7.5 million	Mostly individuals Government Agency 10%
Nigerian Brick and Clay Products Ltd., Ibadan	15 million NS	7.5 million Bricks	Mostly individuals Government Agency 5%
LACON (Nig.) Ltd., Igbogbo, Lagos.	20 million NS	10 million	<u>Average:</u> Individual 100%
Clay Products Ltd., Ezinachi, Okigwe	20 million NS	15 million	N/A
Borno Clay Products Ltd., Maiduguri.	20 million NS	10 million	<u>Average:</u> Individual – Mostly Government – 5%
Ondo State Brick Works Ltd., Ire-Ekiti	20 million NS	2.5 million	N/A
Chachanga Products Ltd., Minna.	20 million NS	N/A	<u>Average:</u> Individuals – 100%
Sokoto Clay Products Ltd., Talata Mafara.	20 million NS	Abandoned	–
Oranmiyan Clay Products Ltd., Ipetumodu.	20 million NS	Abandoned	–
Wurno Construction Materials Ltd., Wurno, Sokoto State.	20 million NS	Production Suspended.	Very poor.

Brick Factory	Annual Production Capacity (Bricks)	Present Annual Production (Bricks)	Patronage
Gateway Bricks Ltd., Lapeleke, Abeokuta.	20 million NS	N/A	N/A
Brand Clay Products (Nig.) Ltd., Okigwe.	15 million NS	2.5 million	Average: Individual — 100%
Benue Burnt Bricks Ltd. Otukpo	20 million NS	N/A	N/A
Mubi Burnt Brick Industries Ltd., Yola	20 million NS	To be Commissioned in January 1986	N/A
Clay Products Ltd., Oregun	7.5 million NS	N/A	N/A

TABLE 3: SITUATION REPORT AS AT THE TIME OF VISIT TO THE CLAY BRICK FACTORIES

Brick Factory	Date of Visit	Situation as at time of visit	Type of Machinery	Technical Partners	Comments
Nigerian Brick and Clay Products (Lagos) Ltd. Ikorodu, Lagos.	05/07/84	Producing	Semi-automated (Hoffman type)	—	— Has limited market prospects.
Nigerian Brick and Clay Products Ltd., Maiduguri	03—04/04/84	Production suspended	Semi-automated (Hoffman type)	—	— Power problems — breakdown of generators — No spare parts — Has problems with market.
Nigerian Brick and Clay Products Ltd., Bagauda, Kano.	10/04/84	Contemplating stopping production	Semi-automated (Hoffman type)	—	— Clay from quarry too sandy — hence cracked bricks. — Market problems.
Nigerian Brick and Clay products Ltd., Jos.	22/03/84	Producing	Semi-automated (Hoffman type)	—	— Market problems — would want more patronage.
Nigerian Brick and Clay Products Ltd., Enugu.	22—23/05/84	Producing	Semi-automated	—	— Market problems.
Nigerian Brick and Clay Products Ltd., Kaduna.	10—12/09/84	Producing	Semi-automated (Hoffman typed)	—	— Not yet commissioned.
Nigerian Brick and Clay Products Ltd., Ibadan.	08—09/10/84	Producing	Semi-automated (Hoffman typed)	—	— Not yet commissioned.
LACON (Nig.) Ltd., Igbogbo, Lagos.	05/07/84	Production suspended	Fully automated (Stromiger Kiln)	ENCON Ltd. of W/Germany	— Financial constraints. — Poor market. — Lack of spare parts.
Clay Products Ltd., Ezinachi — Okigwe.	23—24/05/85	Production suspended.	Fully automated	ENCON Ltd., of W/Germany	— Financial constraints — Poor market. — Lack of spare parts.
Borno Clay Products Ltd., Maiduguri	03—04/04/84	Production suspended.	Fully automated	ENCON Ltd., of W/Germany	— Power problems — breakdown of generators. — Lack of spare parts. — Financial constraints — Poor market.

Brick Factory	Date of Visit	Situation as at time of visit	Type of Machinery	Technical Partners	Comments
Ondo State Brick Works Ltd., Ire-Ekiti, Ondo State.	09-11/10/84	Producing	Fully automated	ENCON Ltd., of W/Germany	- Factory just resuscitated. - Lack of spare parts. - Patronage is encouraging.
Chachanga Clay Products Ltd., Minna.	06/11/84	Production suspended.	Fully automated	ENCON Ltd., of W/Germany	- Technical partner absconded - Financial Liquidation.
Sokoto Clay Products Ltd., Talata Mafara, Sokoto State.	19/07/84	Abandoned	N/A	ENCON Ltd., of W/Germany	- Project abandoned by technical partner.
Oranmiyan Clay Products Ltd., Ipetumodu.	11/10/84	Abandoned	Fully automated	ENCON Ltd., of W/Germany	- Project abandoned by technical partner.
Wurno Construction Materials Ltd., Wurno, Sokoto State.	18/10/84	Production suspended	-	Impresit Bakolori Ltd., (Italian)	(1) Poor market.
Gateway Brick Ltd., Abeokuta.	22/06/84 22/06/84 23/07/84	Producing	Fully automated	ENCON Ltd., of W/Germany	N/A
Brand Clay Products Ltd., Amuro Okigwe	23-24/05/84	Producing	Fully automated	Private	(1) Financial constraints (2) Poor market for products.
Benue Burnt Bricks Ltd., Otukpo	-	Not completed	N/A	Interkiln of U. S. A.	-
Mubi Burnt Brick Industries Ltd., Yola	-	Not completed	N/A	CERIC of France	Will be commissioned in January 1986
Clay Products Ltd., Oregun	January 1985	Producing	N/A	Italian interests.	Good market

TABLE 4: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
NIGERIAN BRICK AND CLAY PRODUCTS (LTD.)

Type	Code Name	Size (mm) L X W X H	No. Regd. 1m <sup>2</sup> Wall (Units)	Price per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price = $\frac{\text{Price of Brick}}{\text{Price of Sandcrete}}$		Uses
						Price Index	Sandcrete	
Normal Size Bricks	NS	250 x 120 x 60	66	11	7.26	0.81	0.91	For wall construction - Decorative purposes.
						*	**	
Building Blocks	B10	250 x 100 x 135	29	19	5.51	0.61	0.69	Mainly for inside wall Mainly for inside wall Mainly for inside wall Outer walls construction Outer walls in storey Buildings Outer walls Outer walls Outer walls in storey Building Outer walls in storey Building
	B12	250 x 120 x 135	29	22	6.38	0.71	0.80	
	B12L	250 x 120 x 200	20	31	6.20	0.69	0.78	
	B15	250 x 150 x 135	29	28	8.12	0.90	1.02	
	B18	250 x 180 x 135	29	35	10.15	1.13	1.27	
	B15L	250 x 150 x 225	18	44	7.92	0.88	0.99	
	B15M	250 x 150 x 200	20	40	8.00	0.89	1.00	
	B18L	250 x 180 x 225	18	50	9.00	1.00	1.13	
B18M	250 x 180 x 200	20	45	9.00	1.00	1.13		
Non-load Bearing	HB8	300 x 105 x 200	17	35	5.95	0.66	0.74	Screening and Partition wall Screening and Partition wall Decorative purposes and screening walls Decorative purposes and screening walls Decorative purposes and screening walls
	HB12	300 x 150 x 200	17	45	7.55	0.85	0.96	
	DB1H	240 x 115 x 200	21	70	14.70	—	—	
	DB2H	240 x 120 x 160	26	80	20.80	—	—	
DB4H	300 x 120 x 145	23	60	13.80	—	—		
Special Products	Pan (Large) Facing Slips	250 x 120 x 60	33	20	6.60	—	—	Paving of floors
						—	—	
<b>SANDCRETE BLOCKS</b>								
Building Block	—	460 x 230 x 230	10	90	9.00	—	—	For building and partitioning For building and partitioning
						—	—	
		460 x 150 x 230	10	80	8.00	—	—	

**NOTE:**

(1) The price above applied to all the 7 brick factories owned by Nigerian Brick and Clay Products Ltd. at Jos, Maiduguri, Kano, Ikorodu, Enugu, Ibadan, and Kaduna.

(2) Compressive strength is not less 15 MPa.

\* When compared with (460 x 230 x 230mm) (18 x 9 x 9) Sandcrete block.

\*\* When compared with (460 x 150 x 230mm) (18 x 6 x 9) Sandcrete block.

TABLE 5: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
BRAND CLAY WORKS LTD., OKIGWE

Type	Code Name	Size (mm) L X W X H	No. Regd. for 1m <sup>2</sup> Wall (Units)	Price per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price = Price of Brick Index = Price of Sand- crete		Price per Unit for Quantity greater than 50,000 Bricks (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price = Price of Brick Index = Price of Sand- crete	
						*	**			*	**
Standard Bricks Hollow	SBH	230 x 100 x 75	58	20	11.60	1.29	1.45	16	9.28	1.03	1.16
	SBNV	230 x 100 x 100	44	22	9.68	1.08	1.21	18	7.92	0.88	0.99
	IBNF	230 x 100 x 100	44	24	10.56	1.17	1.32	20	8.80	0.98	1.10
Industrial Bricks Solid	IBHF	230 x 100 x 75	58	30	17.40	1.93	2.18	25	14.50	1.61	1.81
	IBFC	230 x 100 x 75	58	42	24.36	2.70	3.05	35	20.30	2.26	2.54
Block/Bricks — Hollow	BBH	230 x 230 x 100	44	42	18.48	2.05	2.31	35	15.40	1.71	1.93
	BBH	230 x 230 x 150	29	48	13.92	1.55	1.70	40	11.60	1.29	1.45
	BBH	230 x 230 x 150	29	52	15.08	1.68	1.89	43	12.47	1.38	1.56
	BBH	230 x 230 x 230	19	54	10.26	1.14	1.28	45	8.55	0.95	1.07
	BBH	330 x 230 x 230	14	60	8.40	0.93	1.05	50	7.00	0.77	0.88
Brand Clay Block	BCBB	460 x 230 x 100	21	54	11.34	1.26	1.42	45	9.45	1.05	1.18
	BCBB	460 x 230 x 150	15	60	9.00	1.00	1.13	50	7.50	0.83	0.94
	BCBB	460 x 230 x 230	14	60	8.40	0.93	1.05	50	7.00	0.77	0.88
Sun-breakers	SB	230 x 215 x 100	44	72	31.68	—	—	60	26.40	—	—
	SB	360 x 180 x 100	28	90	25.20	—	—	75	21.00	—	—
Floor Tile Bricks	FB(SB)	250 x 180 x 100	22	26	5.72	—	—	22	8.80	—	—

NOTE:— \* When compared (with 460 x 230 x 230mm) (18" x 9" x 9") Sandcrete block  
\*\* When compared (with 460 x 230 x 230mm) (18" x 6" x 9") Sandcrete block

TABLE 6: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
LACON (NIG.) LTD., IGBOGBO, LAGOS.

Type	Code Name	Size L X W X H	No. Regd. for 1m <sup>2</sup> (Units)	Price per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price =		(Wt.) Kg	Uses
						Price Index *	Price of Brick of Sand-crete **		
Standard Brick (NF)	001	240 x 115 x 71	58	18	10.44	1.16	1.31	3	<ul style="list-style-type: none"> <li>For in and outside Walling.</li> <li>For decorative inside facing.</li> <li>Used as fixed furniture e.g. table/chairs for schools or restaurants.</li> </ul>
Standard Brick	002	240 x 115 x 71	58	20	11.60	1.29	1.45	4	<ul style="list-style-type: none"> <li>For flooring especially in bakeries.</li> <li>Lining of incinerators and kilns etc.</li> </ul>
Big Block (BB1)	003	300 x 175 x 225	14	50	7.00	0.78	0.88	14	For building purposes.
Big Block (BB2)	008	N/A	N/A	33	N/A	—	—	—	For building purposes.
Partition Block	005	300 x 135 x 225	14	40	5.60	0.62	0.70	8	<ul style="list-style-type: none"> <li>For partitioning.</li> <li>For non-load bearing inner walls.</li> <li>For fencing.</li> </ul>
Ceiling Stone (CS) (Including Beam)	006	480 x 135 x 240	15	50	7.50	0.83	0.93	9	For 'Decking' (floor Slabs).
Sunbreaker (Single)	004	250 x 71 x 250	20	45	9.00	—	—	3	For ventilation and decoration.

NOTE:— \* When compared with (460 x 230 x 230mm) (18" x 9" x 9") Sandcrete block.  
\*\* When compared with (460 x 150 x 230mm) (18" x 6" x 9") Sandcrete block.

TABLE 7: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
BORNO CLAY PRODUCTS LTD., MAIDUGURI

Type	Code Name	Size (mm) L X W X H	No. Regd. for 1m <sup>2</sup> Wall (Units)	Price per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price Index = $\frac{\text{Price of Brick}}{\text{Price of Sand-crete}}$		Crushing Strength MPa	Water Absorption
						*	**		
Traditional Bricks	NF	240 x 115 x 71	59	20	11.80	1.31	1.47	33.21	16%
Building Blocks	LH1	320 x 300 x 180 (Long hole)	18	80	14.40	1.60	1.80	—	16%
	BB1	300 x 175 x 235 Standard Building Block	14	75	10.50	1.16	1.31	19.88	16%
	BB3	235 x 150 x 235 Medium Partition Block	18	60	10.80	1.20	1.35	37.26	15%
	3/4 BB	300 x 115 x 235 Partition Block	14	60	8.40	0.93	1.05	37.26	15%
	Sunbreakers	SB1	230 x 210 x 115	38	100	38.00	—	—	—
	SB2	260 x 180 x 115	34	100	34.00	—	—	—	—
	SB3	260 x 120 x 115	34	80	27.20	—	—	—	—
	SB4	260 x 210 x 115	34	110	37.40	—	—	—	—
	SB5	250 x 240 x 115	35	110	38.50	—	—	—	—
Special Bricks	F/T FS	260 x 130 x 35 310 x 160 x 100	110 33	20 20	22.00 6.60	—	—	—	—
SANDCRETE BLOCKS									
Building Blocks	—	460 x 230 x 230 460 x 150 x 230	10 10	90 80	9.00 8.00	—	—	—	—

NOTE:— \* When compared with (460 x 230 x 230mm) (18" x 9" x 9") Sandcrete block.  
\*\* When compared with (460 x 150 x 230mm) (18" x 6" x 9") Sandcrete block.

TABLE 8: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
ONDO STATE BRICK WORK, IRE-EKITI

Type of Bricks	Size L X W X H (mm)	No. Regd. for 1m <sup>2</sup> (Units)	Price per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price Index =		Uses
					Price of Brick *	Price of Sand- crete **	
BB1	320 x 180 x 235	12	60	7.20	0.80	0.90	— Foundation — Walling — Fencing
BB3	240 x 160 x 235	16	40	6.40	0.71	0.80	— Foundation — Walling — Fencing
BBS3	240 x 160 x 90	46	25	11.50	1.27	1.43	— Walling — Pillars — Fencing and Designs
NFL	250 x 120 x 235	17	35	5.95	0.66	0.74	— Fencing — Partitioning of Rooms — Walling — Pillars
BBS1	300 x 180 x 115	28	40	11.20	1.24	1.40	— Walling — Fencing — Designs — Verandar
NFL1	250 x 120 x 65	60	25	15.00	1.67	1.88	— Bakery Oven — Wall Designs — Incinerator — Tomb
Sunbreakers	400 x 200 x 115	21	60	12.60	1.40	1.58	— Decorations — Fencing
Solid Bricks	250 x 115 x 65	60	25	15.00	1.67	1.88	— Bakery Oven
SANDCRETE BLOCKS							
Sandcrete Block	460 x 230 x 230 460 x 150 x 230	10 10	90 80	9.00 8.00	—	—	— For building and partitioning — For building and partitioning

**NOTE:** \* When compared with (460 x 230 x 230mm) (18" x 9" x 9") Sandcrete block.  
\*\* When compared with (460 x 150 x 230mm) (18" x 6" x 9") Sandcrete block.

TABLE 9: SIZES AND PRICE OUTLAY OF CLAY PRODUCTS  
 CHANGHAGA CLAY PRODUCTS LTD., MINNA.

Type	Code Name	Size (mm) L X W X H	No. Regd. for 1m <sup>2</sup> Wall (Units)	Price Per Unit (Kobo)	Price for 1m <sup>2</sup> Wall (₦)	Price Index = $\frac{\text{Price of Brick}}{\text{Price of Sand-crete.}}$		Uses Strength Water Absorption
						Price Index * #	Price of Brick *** crete.	
Long hole Block	LH1	320 x 180 x 300	10	75	7.50	0.83	0.93	For light buildings
Big Blocks (Crushing Strength * 19.88 N/mm <sup>2</sup> )	BB1	300 x 175 x 175	19	70	13.30	1.47	1.66	For Strong Load bearing walls
Partition block	BB $\frac{3}{4}$	300 x 115 x 235	14	60	8.40	0.93	1.05	For Partition Walls
Traditional Brick (Crushing Strength = 33.21 N/mm <sup>2</sup> )	NF	240 x 115 x 71	58	20	11.60	1.30	1.45	Load bearing bricks for strongest walls
Sunbreaker	SB1	250 x 115 x 240	16	70	11.20	1.24	1.40	For fencing and decoration
	SB2	240 x 115 x 180	23	120	27.60	3.06	3.45	
	SB3	240 x 70 x 180	23	70	16.10	1.78	2.01	
Ceiling Stones	CS	320 x 235 x 160	13	100	13.00	1.4	1.63	For Flat roofs and decking in Storey Building.
Sandcrete Block	-	460 x 230 x 230	10	90	9.00	-	-	For building and partitioning
		460 x 150 x 230	10	80	8.00	-	-	

NOTE:— \* When compared with (460 x 230 x 230mm) (18" x 9" x 9") Sandcrete block  
 \*\* When compared with (460 x 150 x 230mm) (18" x 6" x 9") Sandcrete block.

## THE RELIABILITY OF CLAY PRODUCTS IN HOUSING DEVELOPMENT

By

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### ABSTRACT

*In Nigeria and other developing countries, efforts by governments to provide adequate shelter for the people have not yielded the desired results. This can be attributed to a number of reasons, prominent among which is the failure to base the execution of our housing programmes on the locally available materials. Most construction projects are carried out using cement, to the detriment of bricks and mud that are usually available at lower costs. Brick has been proven to be a reliable and cheap construction material for a very long time. Our policy makers have continued to ignore the good quality of bricks and are encouraging the intensive use of imported cement. This is in spite of the fact that houses in the countries from where the cement is imported are not built intensively with cement.*

*By using bricks for housing programmes, Nigeria and other developing countries will save their foreign exchange for the purchase of more essential items. In view of the current world economic recession, there is greater urgency for the change from cement intensive to brick/mud intensive construction. Governments should therefore legislate, if necessary, to ensure the use of bricks and 'other clay products' in all housing developments. This will help to achieve greater successes in the efforts to provide adequate and decent shelter for our teeming population.*

### INTRODUCTION

The need for shelter is universally acknowledged as basic for the physical and psychological comfort of mankind. It is the next most important requirement after the provision of good health and food. It is therefore natural that the phenomenon dates back to the stone age and transcends all civilizations. From the Chaldean Empire, nearly four thousand years before Christ, through the ancient empires of Mesopotamia, Egypt and Rome, the struggle for the provision of shelter has been a continuous battle. Despite the technological advancement of the present generation, shelter remains inadequate for the majority of the world's population. The seriousness of the situation varies from country to country, with the developing countries worse affected.

The responsibility of providing shelter was, initially, that of the individual or family unit. With the emergence of recognized authorities and the formation of governments, part of the responsibility has been taken over from the individuals. The extent to which this responsibility has been taken over depends on the

level of development of a country. In view of the various erection processes and the multiplicity of the component materials, housing cannot be regarded as standardized. According to G.H. Beyer\* "...housing is more than a complex product. It is both an economic and a social process." The materials used for the structure as well as the furnishings are as varied as the countries of the world. Different kinds of parts and facilities may be incorporated depending on the complexity of the house unit.

The extent to which housing is a "social process" is based upon the development, culture, tradition as well as the religion of the peoples concerned. It relates to the complete societal way of life. It is on this basis that reference is sometimes made to Egyptian architecture, Roman architecture, African architecture or Hausa architecture. Each of these housing systems has something unique about itself which makes it different from the others. The uniqueness of the systems could be as a result of the environment, the materials used, the form (including shape) of the elements, or the finishings.

The "economic" aspect of housing is a universal factor which is not only affected by development and culture but also by the economic advancement of a society. The total cost of any building can be basically divided into two components. These are: the direct and the indirect costs. The cost of materials and labour necessary for erecting a building constitute the direct cost. The indirect cost is made up of the overhead and other charges not covered by the direct cost.

The concern of this paper is to examine the reliability of using bricks and other clay products in housing development for the greatest social and economic advantages of Nigeria.

### HISTORICAL DEVELOPMENT OF CLAY PRODUCTS:

The use of clay products is the oldest of the present day construction methods. However, stone is probably the first material to be used in constructing and although it is still used today, other materials have been developed and are used alongside with it.

\*Beyer, C. H. "Housing and Society" Macmillan Company New York, 1965, 595 pp.

Some of these materials are brick, timber, concrete and steel. Since the manufacture of the first clay product (brick), it has passed from one civilization to another, experiencing modification and improvements along the way. From the sun-dried clay tablet of Akkad, founder of the Chaldean Empire, through the ancient empires of Mesopotamia, Egypt, and Rome to the present day mechanical products, brick has helped man in his effort to provide decent shelter.

It is believed that the ancient and honourable art of brick-making originated on the Mesopotamian plains. Eastward, it spread to Persia, India and China. Westward, it spread to Egypt, Asia Minor, Greece, and Rome. From Rome to Europe and the Western World. The earliest recorded reference of brick is in the Bible, Genesis 11.3, where in 2247 BC it was written that the descendants of the sons of Noah said "Come, let us make bricks, and burn them thoroughly"

Historical records make no mention of the design or construction methods of masonry. It is reasonable to assume that the design and construction techniques were based on the long years of experience of the builders rather than any theoretical analysis. It is probable that, until recently, only the simplest bonds (running and stack) were used in construction. Standardized design and construction methods were not achieved because each empire or civilization developed its method independent of others.

As man became more civilized and economic consideration became more important, it was necessary to coordinate the dimensions of building materials and devise a rational method of design, to minimize construction cost. The problem of coordinating the dimensions of building materials (particularly bricks) and correlating building plans with such dimensions attracted greater attention at the beginning of this century. The campaign for change to the modular method started in the 1920s and 30s. Pioneers in this field include Fredrick Heath Jr. who recommended that the dimensions of masonry units should be fixed in relation to a standard mortar joint thickness. However it was not until 1943 that the Structural Clay Products adopted the modular sizes for bricks and tiles.

In Nigeria, the art of using bricks can be traced to the eighteenth century. By the beginning of the 19th century, the first British Governor of the then Northern Nigeria, Lord Lugard had his house built with bricks in the village of Baro (Niger State). Such houses in towns like Kano, Kaduna, Ilorin and Baro are still intact and habitable. The spread of Islam into parts of Africa by the tenth century brought along with it the spread of modern architec-

ture. Similarly the Fulani Jihad led by Usman Dan-Fodio brought the art of brick making to the northern parts of Nigeria. After the Fulani conquest, clay, mud and bricks were used in building palaces, mosques and city security walls, prominent among which are those of Kano, Zaria and Sokoto. It is interesting to note that some of these city walls are still standing today.

## THE NATURE OF HOUSING DEVELOPMENT IN NIGERIA

### Traditional House Types

A traditional building type is that for which purely traditional concepts of planning, construction and materials are employed. This category of buildings are prevalent in the house types classified under mudwall/mud roof or mudwall/thatch roof construction types. A traditional building has greater relevance in modern times than has been acknowledged. First, it shows the living pattern of the people who use it. Secondly, it is often developed in response to climatic conditions, arrived at by trial and error over a long period of time. Traditional building usually illustrates what the cheapest and most readily available materials are, though such materials may not be suitable for modern construction.

A semi-traditional building type is that which blends the traditional concept of planning with the use of modern construction materials. This category of buildings take the form of mud wall/galvanised iron or asbestos roof structure, or cement rendered mud wall/galvanised iron or asbestos roof structure, or sandcrete block/galvanised iron or asbestos roof structure. They are prevalent in most parts of Nigeria. No building plans are usually required for this category of houses and the local carpenters/masons rely on their experience and the rule of thumb when erecting these structures. The perfection of their relatively simple technology over the years has enabled a rather satisfying aesthetics which characterises most traditional buildings.

In terms of materials, mud accounts for more than ninety five percent (95%) of the buildings erected in rural areas.\* The use of the term "mud" is somewhat derogatory and unfairly creates an impression of impermanence. It has been estimated that mud buildings can last a period of 100 years if adequate maintenance is carried out regularly.

Because of the structural weakness of mud, construction elements are usually massive. Its biggest advantage is that it is cheap and generally available. It does not involve the cost of transportation and can be obtained, prepared and used with unskilled manual

\*Adeyemi E.A. et al "Final report on Rural Housing", Federal Ministry of Housing and Environment, Faculty of Environmental Design, Ahmadu Bello University, Zaria, June 1981.

labour. The traditional roofing materials are clay and thatch. The technology of thatched roof is very simple, involving a framework of plant stems and bamboo or raffia. The dominant shape of thatched roof is conical, especially suitable for roofing round huts and granaries.

Despite the contempt for traditional materials, majority of the world's population, particularly in developing countries, live in houses built with such materials; and they will continue to do so for a long time to come. Poor people have no choice since other modern building materials, usually imported, are too expensive and therefore beyond their reach.

### Modern house types

A modern building type is that which utilises currently available knowledge in building design and technology in its planning and construction irrespective of spatial organization. Materials are critically related to both the cost and efficiency of the building. It is also important to know what materials are ideally suitable for various purposes as well as their availability and price. This can help the designer to decide on sensible economic specification of materials.

### Clay Products Manufacture in Nigeria

The use of bricks and other clay products in Nigeria declined with the introduction of portland cement by the colonialists between 1861 and 1900. Since then the importation of cement has been on the increase. By the end of the civil war in 1970 and with the "oil boom" era of the 70s the Federal Government embarked upon the programme of providing shelter for the people of the country. The aim of the government was to provide low cost houses in all the states of the Federation. This resulted in the importation of large quantities of cement and other building materials, since local production could not meet the demand. By the year 1975, Nigeria witnessed an unparalleled port congestion caused by large number of ships bringing in cement into the country. The situation was so bad that a panel was set-up to find ways of averting a similar situation in the future. One of the key recommendations of the panel was that the government should, with immediate effect, embark on the establishment of alternative sources of local building materials so as to cut down on the dependency on imported cement.

In 1977, the Federal Military Government, through the Ministry of Mines and Power commissioned the Nigerian Mining Corporation (Jos) to set up seven brick factories to be located in Plateau, Borno, Anambra, Oyo, Kano, Kaduna and Lagos states. It was intended that each of the states in the Federation would eventually have one of such factories. Most of these factories have been completed, and have since gone into production. Additional factories have been built at such places as Otukpo, Ekiti,

Mubi and Wurno. These factories are jointly producing a large quantity of bricks and other clay products for the Nigerian building industry.

Available information, however, indicate that these brick factories are not receiving the desired patronage from the private as well as the public sectors of the construction industry. As a result of this, majority of them have been operating below their capacity and in fact some of them have had to close down in the past due to the poor sales of their products. This is an unfortunate situation, in view of the numerous advantages derivable from such factories. Not only will the existence of these factories provide substantial employment to Nigerians, but also a huge foreign exchange can be realised, if well developed, to meet local need and as export commodity. Substantial savings could also be made by reducing the importation of such other building materials as cement and lime. It is therefore in the interest of this country that these factories are kept working at full capacity so as to produce the much needed local building material. This is particularly important at this time of austerity when our foreign exchange should be used for the purchase of absolutely essential items.

### The Application of Clay Products for House Building.

Two major kinds of materials, viz concrete and steel have dominated the construction industry in this country. The concrete usually takes the form of reinforced concrete, unreinforced concrete or ordinary sandcrete blocks.

Most structural forms may be classified as being a member (framed) structure or a panel structure. A framed structure consists of one or more members which are connected in some way at their ends. Each member of such a structure is relatively long compared with its cross sectional dimensions. Normally a framed building structure is composed of several frames parallel to each other connected by longitudinal elements of secondary importance. A panel structure consists of one or more panels connected together continuously along their edges. Each panel of such a structure may be either flat or curved but of a thickness which is small compared with the length of its edges. All structural elements can be grouped into load bearing and non-load bearing members. The load bearing elements may include walls and suspended floors as in a panel structure. Non-load bearing elements may be partitions and cladding in a framed structure. The properties of clay products will now be considered to find out whether or not they can be suitable for the construction of any of these structural units.

The important physical properties of clay products are: compressive strength, weather resistance, water absorption, density, hardness, weight and thermal expansion. These are laid down by international codes and the British Standard BS 3921: 1974. These

properties are of much more consequence in application to block masonry than individual clay hollow block. The raw materials and the manner and degree of burning influence the physical properties of the products. For the purpose of this paper, only the compressive strength of the blocks is considered.

**Crushing Strength**

Although the strength of a block is only a fraction of the strength of a wall structure, it is necessary to investigate the compressive strength of the individual block since it can form the basis for comparison between different kinds of products. Clay blocks are

usually tested flatwise as they are most often laid in that manner. In recent tests on the properties of ceramic hollow blocks conducted at the Department of Building, Ahmadu Bello University, Zaria, the compressive strength of various kinds of clay blocks were tested. Some of the results obtained are presented in tables 1 – 7. From these investigations it was found that some of the ceramic blocks are suitable for the construction of load bearing walls, while others could be used as partition or in-fill wall in a framed structure. Available information from the various manufacturers shows that most of them have a range of products that can be effectively utilized in the following forms:

**TABLE 1: RESULTS OF DRESSED (WITH MORTAR) CERAMIC HOLLOW BLOCKS – B.1**

Serial	Identification Mark	Sizes of Hollow Block mm LXBXH	Weight of Hollow Block (KG)	Test Date	Failure Load KN	Block Strength N/mm <sup>2</sup>
1.	B. 1	292 x 225 x 225	14.1	14-5-84	100	1.52
2.	B. 2	292 x 230 x 230	17.2	14-5-84	90	1.4
3.	B. 3	292 x 230 x 230	15.13	14-5-84	100	1.5
4.	B. 1	300 x 230 x 230	16.9	14-5-84	100	1.5
5.	B. 1	295 x 225 x 225	13.6	14-5-84	100	1.5
6.	B. 1	295 x 230 x 230	17.0	14-5-84	120	1.8
7.	B. 1	295 x 227 x 225	15.8	14-5-84	125	1.9
8.	B. 1	293 x 225 x 225	17.0	14-5-84	90	1.4
9.	B. 1	290 x 225 x 225	16.0	14-5-84	115	1.8
10.	B. 1	300 x 225 x 225	16.8	14-5-84	112	1.7

**TABLE 2. : STATISTICAL ANALYSIS OF DRESSED, B. 1 (BLOCK)  
USING STUDENT 'T' TEST FORMULA**

BLOCK STRENGTH N/mm <sup>2</sup>	CLASS MARK X	FREQUENCY F	FX	$X - \bar{X} =$ $X - 1.62$	$(X - \bar{X})^2$	$F(X - \bar{X})^2$	STRENGTH'S SAMPLES
1.4 - 1.6	1.5	6	9.0	-0.12	0.0144	0.0864	1.4 N/mm <sup>2</sup> 1.4 " 1.5 " 1.5 "
1.7 - 1.9	1.8	4	7.2	0.18	0.0324	0.1296	1.5 " 1.52 " 1.7 " 1.8 " 1.8 " 1.9 N/mm <sup>2</sup>

$$M = f = 10$$

$$FX = 16.2 \quad F(X - \bar{X})^2 = 0.216$$

$$\text{Arithmetic mean } \bar{X}, = \frac{FX}{F} = \frac{FX}{N} = \frac{16.2}{10} = 1.62 \text{ N/mm}^2$$

$$\text{Standard deviation } S, = \sqrt{F(X - \bar{X})^2} = \sqrt{0.216} = \sqrt{0.024}$$

$$S = 0.1549 \text{ N/mm}^2$$

**TABLE 3: RESULTS OF DRESSED BLOCK, B. 2 CRUSHED HOLES PARALLEL  
TO THE COMPRESSION MACHINES' TOP AND BOTTOM PLATES**

Serial Number	Identification Mark	Sizes of Hollow Bloc (mm) L X B X H	Weight of Hollow Block Kg.	Test Date	Failure Load KN	Surface Area (LXB)mm <sup>2</sup>	Block Strength N/mm <sup>2</sup>
1.	B. 1	300 x 150 x 225	9.1	28-4-84	200	45,000	4.4
2.	B. 2	300 x 150 x 225	9.6	28-4-84	120	45,000	2.7
3.	B. 2	300 x 150 x 225	1.2	28-4-84	180	45,000	4.0
4.	B. 2	300 x 150 x 225	11.5	28-4-84	148	45,000	3.3.
5.	B. 2	300 x 150 x 225	9.0	28-4-84	180	45,000	4.0
6.	B. 2	300 x 150 x 215	9.1	28-4-84	180	45,000	4.0
7.	B. 2	300 x 150 x 215	12.3	28-4-84	120	45,000	2.7
8.	B. 2	300 x 150 x 225	12.0	28-4-84	120	45,000	2.7
9.	B. 2	300 x 150 x 215	13.4	28-4-84	136	45,000	3.0
10.	B. 2	300 x 150 x 215	11.6	28-4-84	160	45,000	3.6
11.	B. 2	300 x 150 x 225	9.8	28-4-84	130	45,000	2.9

**TABLE 4: DRESSED CERAMIC HOLLOW BLOCK – B. 2 (ANALYSIS OF RESULT)**

STRENGTH N/mm <sup>2</sup>	CLASS MARK X	FREQUENCY F	FX	(X - $\bar{X}$ = X - 3.43	(X - $\bar{X}$ ) <sup>2</sup>	F(X - $\bar{X}$ ) <sup>2</sup>	SAMPLES OF B. 2 STRENGTHS
2.7 - 2.9	2.8	4	11.2	-0.63	0.3969	1.5876	2.7 N/mm <sup>2</sup> 2.7 " 2.7 "
3.0 - 3.2	3.1	1	3.1	-0.33	0.1089	0.1089	2.9 " 3.0 "
3.3 - 3.5	3.4	1	3.4	-0.03	0.0009	0.0009	3.3 " 3.6 "
3.6 - 3.8	3.7	1	3.7	-0.27	0.0729	0.0729	4.0 " 4.0 "
3.9 - 4.1	4.0	3	12.0	0.57	0.3249	0.9747	4.9 "
4.2 - 4.4	4.3	1	4.3	0.87	0.7569	0.7569	4.4 N/mm <sup>2</sup>

$$N = F = 11 ; FX = 37.7 , F(X - \bar{X})^2 = 3.5019$$

$$\text{Mean } \bar{X} = \frac{FX}{F} = \frac{FX}{N} = \frac{37.7}{11} = 3.43 \text{ N/mm}^2$$

$$\text{Standard deviation, } S = \sqrt{F(X - \bar{X})^2} = \sqrt{3.5019} = \sqrt{0.35019} = 0.5918$$

$$\text{Coefficient of variation } V, = \frac{S}{\bar{X}} = \frac{0.5918}{3.43} = 0.1725 = 17.3\%$$

**TABLE 5:- RESULTS OF DRESSED BLOCKS, B. 3 CRUSHED WITH HOLES PARALLEL TO COMPRESSION MACHINE'S PLATES**

Serial Number	Identification Mark	Size of Block	Crushing Area (mm <sup>2</sup> )	Weight of Block (Kg.)	Test Date	F/Load KN	Block Strength N/mm <sup>2</sup>
1.	B. 3	300 x 100 x 220	30,000	6.0	28-4-84	138	4.4
2.	B. 3	300 x 100 x 220	30,000	6.8	28-4-84	108	3.6
3.	B. 3	300 x 100 x 220	30,000	6.6	28-4-84	128	4.3
4.	B. 3	300 x 100 x 225	30,000	7.9	28-4-84	90	3.0
5.	B. 3	300 x 100 x 225	30,000	7.0	28-4-84	128	4.3
6.	B. 3	300 x 100 x 225	30,000	7.4	28-4-84	118	3.9
7.	B. 3	300 x 100 x 225	30,000	7.2	28-4-84	124	4.1
8.	B. 3	300 x 100 x 225	30,000	8.0	28-4-84	128	4.3
9.	B. 3	300 x 100 x 220	30,000	6.8	28-4-84	112	3.7
10.	B. 3	300 x 100 x 225	30,000	7.4	28-4-84	96	3.2
11.	B. 3	300 x 100 x 225	30,000	8.1	28-4-84	116	3.9
12.	B. 3	300 x 100 x 220	30,000	5.6	28-4-84	100	3.3

**TABLE 6: ANALYSIS OF DRESSED B. 3 (RESULT) USING STUDENT AND NORMAL (STATISTICS) FORMULAE**

BLOCK STRENGTH N/mm <sup>2</sup>	CLASS MARK X	FREQUENCY F	FX	X-X= X-3.88	(X-X) <sup>2</sup>	F(X-X) <sup>2</sup>	SAMPLES -B. 3. STRENGTHS
3.0 - 3.2	3.1	2	6.2	-0.78	0.6084	1.2168	3.0 N/mm <sup>2</sup> 3.2 " 3.3 " 3.6 " 3.7 " 3.9 "
3.3 - 3.5	3.4	1	3.4	-0.48	0.2304	0.2304	3.9 " 3.9 "
3.6 - 3.8	3.7	2	7.4	-0.18	0.0324	0.0648	4.1 " 4.3 "
3.9 - 4.1	4.0	3	12.3	0.12	0.0144	0.0432	4.3 " 4.3 "
4.2 - 4.4	4.3	4	17.2	0.42	0.1764	0.7056	4.3 " 4.4 N/mm <sup>2</sup>

$$F = N = 12, FX = 46.5, F(X-\bar{X})^2 = 2.2608$$

$$\text{Arithmetic Mean, } \bar{X} = \frac{FX}{F} = \frac{FX}{N} = \frac{46.5}{12} = 3.88 \text{ N/mm}^2$$

APPLYING STUDENT 'T' TEST FORMULA

$$\text{Standard deviation } S = \sqrt{\frac{FX(X-\bar{X})^2}{F}} = \sqrt{\frac{2.2608}{12}} = \sqrt{0.2055}$$

$$S = 0.4534 \text{ N/mm}^2$$

$$\text{Coefficient of variation } V = \frac{S}{\bar{X}} = \frac{0.4534}{3.88} = 0.1169$$

$$V = \frac{S}{\bar{X}} \times 100\% = 11.7\%$$

**TABLE 7: COMPRESSION STRENGTH TEST**

**RESULTS AND CONCLUSION OF CONFIDENCE INTERVAL FOR U ACTUAL MEAN ON DRESSED CERAMIC HOLLOW BLOCKS**

Indentification Mark	Arithmetic Mean ( $\bar{X}$ ) N/mm <sup>2</sup>	Actual Mean Interval 95% Confidence, U N/mm <sup>2</sup>	Confidence Mean Interval 99% U N/mm <sup>2</sup>	Calculated 0.05 Limits N/mm <sup>2</sup>	Comment
B. 1	1.62	1.51 < U < 1.73	1.46 < U < 1.78	1.4 to 1.53	Not Suitable for Load Bearing Wall
B. 2	3.43	3.03 < U < 3.83	2.86 < U < 4.0	2.8 to 3.1	Suitable for Load-Bearing Wall
B. 3	3.88	3.59 < U < 4.17	3.47 < U < 4.29	1.4 to 6.4	Partition Wall
½B. 1	2.75	2.40 < U < 3.10	2.26 < U < 3.24	1.4 to 2.45	Not Good for Load Bearing Wall.

- (i) As load bearing structural elements in building where they could also act as decorative elements simultaneously.
- (ii) As non-load bearing cladding and partition in steel and concrete-framed buildings.
- (iii) As decorative facing blocks and screen walls.
- (iv) As void formers, ceiling stones or congested rib fillers in hollow clay pot floor construction.

Considering the strength of these clay products and their range of application, one may expect that they will provide a realistic solution to the housing problem in the country. Unfortunately, this is not so, as our policy makers, or planners for some curious reason, have continued to execute our housing programmes with imported building materials. As a result of this, government housing schemes appear to have failed in tackling the problem of providing adequate low-cost and decent houses for the people. It is therefore not surprising that although huge investments are made every year in the building industry, what comes out is not always satisfactory.

In most developing countries, (which Nigeria is one) governments play a key role in the provision of adequate housing for the populace. What then is the reason for our leaders not having been able to look inwards for the materials required to execute our housing programmes? According to Dr. M.N. Tetteh (6) "The soul of society, revolves around built-in habits: habits which are handed down from generation to generation and which yield to change only through the combined forces of social and economic revolutions." He went further to talk on "colonial mentality, as a type of habit that has held sway and continues to hold sway over the attitude of top government officials in policy matters since the days of colonial rule up to the present".

Most developing countries were, at some stage in their histories, colonies of the so called advanced countries of Europe. Because of these historical ties with the "colonial masters" the leaders of these countries

have developed a peculiar attitude towards their development problems. They look up to these countries for direction and see nothing good with what they have locally.

The principal interest of the colonial rulers was in promoting trade even to the detriment of the interests of the natives. They introduced Portland cement as an excellent building material meant to replace the locally available materials. This was in spite of the fact that houses in such countries like Britain, France and Portugal (to mention a few) were not being built intensively with cement. Soil bricks were used and cement was only used as mortar to hold the bricks together. Portland cement was introduced to the colonies as an intensive building material for making blocks, mortar and plastering. The traditional idea of mud buildings was quickly dissipated and the new concept firmly established.

The "Buy-British-Cement" mentality was thus instilled in us. Whenever a housing programme is proposed, the first thing that comes to mind is cement. Since most of this cement has to be imported, a serious drain of our scarce foreign exchange resources results.

#### ELEMENTAL COST ANALYSIS

From the economic point of view, bricks and other clay products perform better when compared with their closest rival (i.e. sandcrete blocks). The result of a cost analysis between these two products, based on January 1982 market rates is presented in table 8. From this table, it can be seen that a saving of 32.59% and 31.64% respectively may be achieved by using burnt bricks in the construction of outer and inner walls. The current prices of 230mm and 150mm sandcrete blocks are ₦1.00 and ₦0.85. This increase in prices will result in greater savings when burnt bricks are used in place of sandcrete blocks. This is a further proof that burnt bricks and clay products are the key to Nigeria's housing problems and indeed, the problems of other developing countries.

**TABLE 8: COST COMPARISON BETWEEN BRICKS AND SANDCRETE BLOCKS (BASED ON JANUARY 1982 PRICES)**

I. OUTER WALLS	Burnt Brick	Sandcrete
Materials Used	Type B 15	230mm blocks
Unit Price	(a) 28k	(a) 70k
Nos. Used per sq. m. of wall	26 Units	12 Units
Cost of the Product	₦7.28	₦8.40
Cost of sand and cement for mortar joints	₦0.90	₦1.20
Laying Cost per sq. m.	₦2.50	₦2.00
Plastering walls (Labour only)	₦2.00	₦4.00
	(Inside only)	
Cost of materials for Plastering 1:5	₦6.20	₦12.40
Total Cost/SQM	₦18.88	₦28.00

SAVING/SQM OF WALL = ₦9.12, SAVINGS ON USE OF BRICKS: 32.57%

II. INNER WALLS	Burnt Brick	Sandcrete
Materials Used	Type B 12	150mm blocks
Unit Price	22k each	60k each
No. per SQM of wall	26 units	12 units.
Cost of materials for mortar joints	₦5.72	₦7.20
Cost of materials for mortar joints	₦0.90	₦1.20
Laying Costs	₦2.50	₦2.00
Cost of materials for plastering	₦6.20	₦12.40
Labour For Plastering	₦2.00	₦4.00
Total Cost/SQM	₦17.32	₦26.80

SAVING/SQM OF WALL = ₦8.48, SAVINGS ON USE OF BRICK: 31.64%

SOURCE: Nigerian Brick and Clay Products Limited.

## CONCLUSIONS AND RECOMMENDATIONS

It is evident that the availability of cheap and reliable building materials is the prerequisite for effective execution of any housing programme. In Nigeria today, as in most other developing countries, housing programmes are being executed with the intensive use of cement to the detriment of traditional building materials. The resulting effects of this practice include the high cost of buildings and the non-realization of governmental housing objectives. With the decline of oil revenue and the present world economic recession, it is more difficult for the government, and indeed, the people of these countries, to make any headway in the provision of adequate shelter. In this circumstance, the only option for the government and people of this country is the de-emphasising of the intensive use of cement and other imported building materials. With the establishment of so many brick factories in the country, and the extensive use of mud in the rural areas, greater successes will be recorded in the execution of housing schemes. The following recommendations are put forward as

necessary to aid the change from cement intensive construction to bricks and mud intensive.

- (i) The government should, as a matter of urgency, legislate on the use of bricks and clay blocks in all her construction projects.
- (ii) State and local governments as well as all parastatals should, similarly, be directed on the use of clay products in their construction works.
- (iii) A campaign on the use of clay products and other locally available building materials should be embarked upon to enlighten the people of this country.
- (iv) The negative effects of using cement and other imported materials in the execution of our housing should also be highlighted.
- (v) Research should be intensified on how to improve on the locally building materials, particularly mud, and on the technology of construction.

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## THE UTILIZATION OF BRICK & CLAY PRODUCTS IN NIGERIAN CONSTRUCTION INDUSTRY

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### SYNOPSIS

*Clay bricks have been used since the time of the colonial administration in Nigeria. Evidence abound today in the Government Reservation Areas (GRAs) of major towns.*

*Present generation of modern brick plants were initially promoted by private interests in Lagos and Kano before the Federal Government of Nigeria and the State Governments pioneered the development of several brickplants at the same time. The combined installed capacity of the brickplants in Nigeria now must be in excess of 300 million standard bricks or their equivalent in various sizes.*

*Despite the clear advantages of these products over other available walling materials in the country, a lot of resistance has been experienced by the present generation of brick makers in selling loadbearing bricks to the building industry, professionals and laymen alike. When this problem is combined with other technical production problems elaborated upon in this paper, it is apparent that a lot of effort is required to ensure that the advantages of utilizing bricks in the Nigerian construction industry does not elude us.*

*Recommendations are therefore made concerning the nature and variety of assistance that the claybrick manufacturing industry can receive in terms of legislation, provision of infrastructural facilities and supporting services.*

### HISTORY OF THE SUPPLY SITUATION

A brick is usually defined as a rectangular shape of fired earth, the width of which can be spanned by one hand. Its length is normally twice the width and its height a little over half its width. Accordingly the approximate dimensions of the early bricks in use in Nigeria and other parts of the developed world were as follows (mm) (1 x b x h):

Nigeria	277 x 100 x 66 (9" x 4 $\frac{3}{4}$ " x 2 $\frac{5}{8}$ " )
United Kingdom	277 x 100 x 66 (9" x 4 $\frac{3}{4}$ " x 2 $\frac{5}{8}$ " )
France	220 x 110 x 60
Federal Republic of Germany	240 x 115 x 71
Italy	250 x 120 x 55
Switzerland	520 x 120 x 60
United States	202 x 95 x 79

The clay bricks which were in use since the colonial administration in Nigeria were solid bricks, clamp fired and more often than not made from any manageable earth material. The production method

did not guarantee any uniform firing temperature or any strength of the material. Even though the standard size was the British standard, the dimensions vary widely from batch to batch. Despite these shortcomings, several buildings put up, using these early bricks can still be seen in the Government Reservation Areas (GRAs) of most Nigerian towns today. This is perhaps one of the evidences that one can see even as a lay man that bricks made anyhow can be extremely durable.

The present generation of the modern brick plants in Nigeria were initially promoted by private interests in Lagos and Kano. Later on, from the period starting from 1975 to now, the Federal and State Government authorities had pioneered the development of several brick plants. The rapidity and spontaneity in the development of those plants contrasts with the enthusiasm with which the products were later received by user government authorities and the public at large. However, Nigeria now has an annual installed capacity of brickplants in excess of 300 million standard bricks or their equivalent in various sizes. See Appendix I for a list of the brickplants currently installed or being installed in Nigeria. It must be noted that the rapid development of bricks followed the period when the massive importation of cement caused the sensational and first ever port congestion in Nigeria.

### HISTORY OF THE DEMAND SITUATION & BRICK AS THE IDEAL BUILDING MATERIAL IN NIGERIA

The period between the early use of clamp fired claybricks and the establishment of the modern brickplants witnessed the entrenchment of sand-cement blocks as the major walling material in Nigeria. Consequently the first two of the modern brickplants did their home work and produced mainly non-load bearing bricks such as facing slips and decorative bricks for screen wall construction. However, it is not that the other ones being government sponsored did not do their home work. They did. In fact the housing programmes of the Federal and State Governments on the scale envisioned in the past 8 - 10 years assured these plants of government patronage. It was also imagined that the demonstration effect of the utilization of

bricks by Government coupled with the propagation of the masonry skills even to the local government areas would sell the bricks to the members of the public during and after the expiration of the government projects. Unfortunately, it turned out that when these government housing programmes took off, a negligible proportion of the available production of bricks was utilized. This was the beginning of the problems associated with the use of claybricks in Nigeria.

Another major misfortune of the modern clay industry was the scepticism of members of the public as to the quality and even advantages of using bricks. Many well informed people even up to now cannot resist comparing clay bricks albeit unfairly with sand-cement blocks. At its price, the brick is one of the most versatile and useful building materials. Structures built in Nigeria with early and modern bricks like others in any part of the world have 'liveable' interiors. This quality of 'liveability', very difficult to define or explain has been described by technical people as the result of a combination of characteristics that other building materials do not possess. It is frequently asserted that bricks breathe because the open pores of bricks are large enough to permit the passage of water vapour and air, but so small as to impede the penetration of rain water. Consequently, bricks possess remarkable heat and sound insulating properties yet to be matched by any known building material within the reach of foreign exchange starved Nigerians.

In spite of the clear advantages of the utilization of bricks in Nigerian climate conditions, the resistance of consumers to the product is amazing. Up to now, several strategies had been adopted to encourage the use of bricks by the various producers. Although the methods employed by each brick maker were those it could afford, the following are representative:

- Trade exhibitions, which provide opportunity to demonstrate use of the products, meet people who have varying interests as users, specifiers and distributors and recording their particulars for future follow-up.
- Provision of after-sale-service of advisory service of trained masons to customers. For example the Nigerian Mining Corporation group of seven brickplants started their own advisory service in 1978. Special seminars and courses were organized in Jos, Kano and Kaduna sometimes with the help of the Industrial Training Fund to upgrade the skill of bricklayers to enable them use claybricks correctly and with the appropriate speed.

Records of customers' bricklayers who have benefited directly from the advisory service of masons and have become proficient are given in appendix II.

A few daring brickplants ventured into turn-key construction of buildings at the request of their customers to guarantee the cost of the erection of the structures as claimed in their advertisement — The Borno Clay Products of Maiduguri and the Nigerian Mining Corporation Brickworks in Jos are examples of this.

- Advertisement in the newspapers, on the radio and the TV have also been employed.
- Brochures have also been prepared and mailed to building contractors and specifiers by some brickplants.

However there are certain areas where encouragement is required in the promotion of the use of bricks which would be difficult for the brick-makers go into at the moment. As can be seen from the list of brickplants in appendix I, some of the brickplants are associated with W. German partners, while some are associated with Italy, France and U.S.A. Consequently and, as there is no Nigerian standard specifications for claybricks, the dimensions of the bricks made vary among the groups of brickplants. In a situation where specifiers are still being persuaded to design in bricks, the lack of standard cannot help. Also because almost all the brickplants are yet to find their feet in terms of capacity utilization and sales, there is no manufacturers' association to provide a forum for discussion and decision on this kind of issue.

Many specifiers have requested for the crushing strength of bricks, before they would recommend them. However, the methods used to test the bricks vary from one place to the other and it would be unfair to compare such results.

## CONCLUSION

The Nigerian Building and Road Research Institute should consider looking into the various shapes and sizes of bricks being manufactured in Nigeria and recommend standard dimensions for all the load bearing bricks.

The brickmakers themselves must strive hard above their present-time-problems to establish a manufacturers association. This will help to centralize the tackling of such problems as the upgrading of brick masonry skill, advertising and public relation and standardization of some basic products.

APPENDIX I

24 KNOWN BRICKPLANTS IN NIGERIA

S/L	LOCATION	INSTALLED PRODUCTION CAPACITY	REMARKS
1.	NARAGUTA – JOS	15 million NS p.a.	Owned by NMC and Plateau State. In production.
2.	MAIDUGURI	15 million NS p.a.	Owned by NMC. In production
3.	KANO	15 million NS pa.	”
4.	KADUNA	”	”
5.	ENUGU	”	”
6.	IBADAN	”	”
7.	IKORODU–LAGOS	”	”
8.	IZOM–ABUJA	60 million NS p.a.	Owned by NMC and Federal Capital Development Authority. Not yet completed.
9.	IKORODU–LAGOS	20 million NS p.a.	Operational. Owned by Lagos State Govt. and ENCON of W. Germany.
10.	MAIDUGURI	20 million NS p.a.	Operational. Owned by the Borno State Govt. and ENCON of W. Germany.
11.	OKIGWE	20 million NS p.a.	Operational. Owned by Nigerian private interests.
12.	IRE – EKITI	20 million NS p.a.	Operational. Owned by Ondo State Govt. and ENCON of W. Germany.
13.	CHANCHANGA – MINNA	20 million NS p.a.	Operational. Owned by ENCON of Western Germany and the Niger State Govt.
14.	ORANMIYAN – IFE	20 million NS p.a.	Not yet completed. Owned by Oyo State Govt. and ENCON of W. Germany.

APPENDIX I

24 KNOWN BRICKPLANTS IN NIGERIA

S/L	LOCATION	INSTALLED PRODUCTION CAPACITY	REMARKS
15.	TALATA MAFARA – – SOKOTO	20 million NS p.a.	Not yet completed. Owned by Sokoto State Govt. and ENCON of W. Germany.
16.	LAPELEKE – ABEOKUTA	20 million NS p.a.	Operational. Owned by Ogun State Govt. and Unimorando of Italy.
17.	MUBI – GONGOLA STATE	20 million NS p.a.	Owned by CERIC of France and Gongola State Govt. Not yet completed.
18.	FUNTUA – KADUNA STATE	20 million NS p.a.	Owned by Kaduna State Govt. and Ceric of France. Not yet completed.
19.	OTURKPO – BENUE STATE	20 million NS p.a.	Not yet completed. Owned by Benue State Govt. and Interkiln of the U. S. A.
20.	OREGUN – IKEJA	7.5 million NS p.a.	Privately owned with some Italian interests
21.	KANO KILN	7.5 million NS p.a.	Privately owned with some Italian interests.
22.	WURNO – SOKOTO	20 million NS p.a.	Privately owned with some Italian interests.
23.	ILORIN	20 million NS p.a.	Not yet completed. Owned by Kwara State Govt. and probably ENCON.
24	OKIGWE	20 million NS p.a.	Owned by Imo State Govt. and ENCON.

**APPENDIX II**

**NIGERIAN MINING CORPORATION BRICKPLANTS**

**NUMBER OF BRICKLAYERS ASSISTED**

	1978	1979	1980	1981	1982	1983	1984
JOS	206	503	1,009	1,002	1,003	980	995
KADUNA	—	—	208	825	980	1,005	1,010
KANO	—	420	540	753	1,060	993	1,200
MAIDUGURI	—	415	570	700	976	460	440
IKORODU-LAGOS	—	—	—	451	480	695	906
ENUGU	—	—	128	682	630	592	480
IBADAN	—	—	183	460	619	750	2,040
TOTAL	206	1,338	2,638	4,873	5,748	5,475	7,071

## THE USE OF BURNT CLAY PRODUCTS IN CONSTRUCTION

By

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### ABSTRACT

*The origin and growth of the heavy clay industry has been examined. The problems facing the industry, and the reasons for its slow rate of growth and its poor performance were also studied. In general, there are striking similarities between the Nigerian situation and the situation in Europe at the end of the first world war.*

*In Italy, France and other parts of Europe, brick plants suffered severely from competition by cement block makers. The European solution to these problems lay in improvements to the efficiency of the brick plants, in the introduction of new sizes and shapes of bricks and blocks, and in the development of prefabrication systems which could compete successfully with other systems executed in concrete. These developments were spearheaded by technical associations of brickmakers, and by companies that were both brickmakers and contractors. A similar series of solutions is recommended for Nigeria. These include the establishment of a Brick Manufacturers Association, and collaboration between the Association, the Nigerian Building and Road Research Institute, the Nigerian Mining Corporation and the Federal Capital Development Authority to develop and use suitable bricks, clay blocks, and prefabrication systems in the further development of the Federal Capital, and of other Federal Government projects.*

### 1. INTRODUCTION

Bricks are not new to Nigeria. Indeed prior to the establishment of the first cement plant at Nkalagu (Anambra State) in 1958, solid bricks were used extensively in building throughout Nigeria. Structures like the government secretariats in Enugu and Lagos, King's College, also in Lagos, and the Dennis Memorial Grammar School, Onitsha, provide examples of the use of bricks in prestigious buildings.

There was a proliferation of small, primitive brick works throughout the country. These works, located in places such as Maiduguri, Enugu, Ibadan, Ado Ekiti, and even Yaba (near Queen's College), Lagos used practically no machinery, and produced low quality, clamp fired, solid bricks which were used in preference to mud blocks by builders in their immediate vicinity. It is not generally known that a Western style brick factory was functioning at Ishiagu, a railway town about 75 kilometres south of Enugu before the first world war. This factory was said to be German owned, and closed down on the outbreak of hostilities. The ruins were still in evidence in 1950.

The general availability of cement, following the establishment of the Nigerian Cement Company at Nkalagu in 1958, and of the West African Portland Cement Company at Ewekoro shortly after, adversely affected the activities of the native brick makers. Sandcrete blocks could be made cheaply almost anywhere, and had technical and economic advantages over the low grade bricks produced by the small brickmakers. In consequence most of these small operators stopped production.

This situation is in fact similar to the situation in Europe at the turn of the century. Again brick predated other competing building products by many years. Competition from these other products as they became available posed great difficulty for the brick manufacturers, but determined efforts by them coupled, with the right policies, resulted in brick and other clay products holding their own.

### 2. CLAY PRODUCTS AND CONSTRUCTION

Bricks are only one of a number of products that can be made from red burning clays. The other products that can be made from a standard or modified brick factory are as follows:

- facing bricks or tiles
- hollow blocks
- perforated bricks
- hollow tiles
- sunbreakers
- roofing tiles
- stoneware pipes, fittings and other shapes
- quarry (floor) tiles.

The use of the above products in construction, and their main competing products, are as shown in Table I

**TABLE I**  
**CLAY PRODUCTS AND COMPETING MATERIALS**

Clay Product	Use	Competition
Facing bricks	Wall cladding	Aluminium panels, cement, paints
Solid and perforated bricks	Walls	Cement blocks
Hollow tiles/-blocks	Walls, floors, roofs	Cement blocks reinforced concrete decking slabs

Sun breakers	Screen walls	Cement blocks
Roofing tiles	Roofs	Asbestos cement sheets, Corrugated metal sheets.
Stoneware pipes	Sewage, drainage, irrigation etc.	Asbestos cement pipes, PVC pipes

(4) They are less porous than cement blocks. In the tropic this would mean that they would not require cladding or dressing. In temperate zones, this property would also be very important owing to the need to avoid frost damage.

(5) In addition, the solid brick is much stronger than cement. The respective Nigerian standards give  $24 \text{ N/mm}^2$  for the cement mortar cube and  $1.4\text{--}5.2 \text{ N/mm}^2$  for the brick.

### 3. LOCAL CONSUMPTION OF CLAY PRODUCTS:

So far, only bricks, hollow clay blocks, facing bricks and sunbreakers are used in Nigeria. The pattern of use is dictated by the properties of the products, and by local labour limitations. Thus the solid and perforated bricks are generally unsuitable for house construction in Nigeria because they are too heavy, too expensive, require too much skilled labour to lay, and are too hot when compared with their main competitor, the cement (sandcrete) block. Hollow clay blocks on the other hand, emerge favourably from the same comparison for the following reasons:-

- (1) They are lighter than a cement block of comparable volume, hence their use would bring about significant reductions in some aspects of building costs.
- (2) They are easier to lay than cement blocks.
- (3) They have a lower co-efficient of expansion hence would reduce cracking tendencies in walls.

These facts are responsible for its popularity in the Lagos area where it has displaced cement blocks for the walls and floors, (decking) of tall buildings. Examples of the use of clay in this manner are the new C.S.S. building in Lagos, the Shell headquarters (Freeman House) where all the 16 floors except the car parking floors are made of hollow block, and several others.

In spite of the foregoing points, it has been found that local builders use sandcrete blocks and other cement products in preference to competing clay products. The reasons lie partly in the general availability of sandcrete products, and consequently of masons capable of handling them, and partly in their relatively lower cost. The major area of competition between clay products and cement is in their use in walls and floors of houses. Clay products that are used in this manner are mostly solid and perforated bricks, and hollow tiles and blocks. The competing cement products are the 9" (225mm) 6" (150mm) and the 4" (100mm) sandcrete block. The costs of using these products for construction are given in Table 2.

TABLE 2 COST IMPLICATIONS OF BUILDING IN CLAY OR CEMENT

	N.S. (Normal Size) Brick (250 x 120 x 60 mm)	(B18L)250 x 180 x 225 mm (10" x 6.9" x 8.8")	9" cement block 450 x 225 x 225 (18" x 9" x 9")	HB12 300 x 150 x 200mm (12" x 6" x 8")	6" Cement Block 450 x 150 x 225 mm (18" x 6" x 9")
No. per m <sup>2</sup>	52	16	9	16	9
Cost per unit	₦0.11k	₦0.50k	₦0.85k	₦0.45	₦0.70k
Cost per m <sup>2</sup>	₦5.72k	₦8.00k	₦7.65k	₦7.20k	₦6.30k
Length of joints/m <sup>2</sup>	21.12m	8.5m	6.0m	9m	6.0m
Wall thickness	120mm (4.5" approx)	180mm (6.9" approx)	150mm (6" approx)	150mm (6" approx)	150mm (6" approx)
Labour charge — per unit	₦0.20k	₦0.30k	₦0.30k	₦0.30k	₦0.30k
— per m <sup>2</sup>	₦10.40m <sup>2</sup>	₦4.80k	₦2.70k	₦4.80k	₦2.70k
Total cost (bricks & labour)	₦16.12m <sup>2</sup>	₦12.80k	₦10.35k	₦12.00k	₦9.00k

In Enugu Area; Cost of rendering 1m<sup>2</sup> blockwall = ₦3.00  
 Cost of painting 1m<sup>2</sup> blockwall = ₦2.80

#### 4. CLAY PRODUCTS MANUFACTURE IN NIGERIA

The situation is varied. The first modern brick plant was established in 1962 at Oregun village, near Ikeja, Lagos State. Its ownership was entirely private; initially it belonged almost entirely to G. Cappa, a large builder based in Lagos. Partly for that reason, in establishing the factory the owners were very cost conscious. Thus the bricks used in building the first kiln were handmade and burnt in clamps prior to the construction of the brick plant proper. By contrast, many of the succeeding, generally government-owned brick plants, were built with bricks often imported from abroad. A further point of difference is that the plant belonged to a major builder who used the products extensively in executing his contracts. In consequence, the factory made products that were what builders needed. It is worthy of note, that the decking pots made in this plant have been used extensively in decking tall buildings for many years, and that hollow cement blocks were used for the same purpose in the University of Nigeria Teaching Hospital Enugu, but that none of the products of the other brick plants has been so used.

Currently, there are over 20 brick plants in Nigeria. The pioneer plant has operated profitably since its inception. Of the seven plants owned by the Nigerian Mining Corporation, 5 are said to be selling well, while two have problems finding purchasers for their products. However the products of these factories are said to be rather expensive and the plants are not

really profitable. Most of the other plants have closed down or never started production. Surprisingly enough, one of the plants that closed down after operating for a short while is privately owned.

The current situation therefore, is as follows:—

- Most brick plants in Nigeria are operating unprofitably or have been closed down.
- Nigeria manufactures about 4 million tonnes of cement annually and imports 1.50 times amount (see Table 3).
- Much of the cement consumed in Nigeria is used in decking or walling various structures, in direct competition with clay products.
- Other clay products such as soil pipes are simply not made. Their function is satisfied by plastic and asbestos cement pipes, for which the raw materials have to be imported.

Table 3 shows quite clearly that there is a very large potential market for clay products which is currently being satisfied by imports of cement and asbestos cement products.

#### 5. THE USE OF CLAY PRODUCTS IN NIGERIA

It was stated earlier that bricks were a popular building material until cement became generally available. Plants that have been set up to make clay products have generally not been very successful. The brick industry in Europe met the challenge of cement by a variety of ways, some of which may be of interest.

TABLE 3 IMPORTATION OF CEMENT AND ASBESTOS CEMENT PRODUCTS

Year	Cement	Asbestos, Cement Roofing and Ceiling Materials	Asbestos Cement Soil Pipes
1977	4.5 million tonnes ₦168 million	42,240 tonnes ₦10.786 million	3,757 tonnes ₦1.212 million
1978	4.4 million tonnes ₦185 million	25,293 tonnes ₦10.630 million	7,459 tonnes ₦2.954 million
1979	6.1 million tonnes ₦162 million	7,923 tonnes ₦4.036 million	2,735 tonnes ₦1.926 million

There are several obstacles to the widespread used of clay products in construction in Nigeria. These will be discussed under three main headings as follows:—

##### 5.1. Design Considerations

Architects see these products as limited in conception to narrow span and load bearing structures. They do not for example, visualise clay products in the

construction of stadia, auditoria, factories, railway stations, and similar structures. They consider cement to be more versatile. For example bricks are usually linear and cannot be used for non-linear structures unless special shapes are produced. Building in brick is inherently slow, as is building in cement block, hence significant cost savings are difficult to achieve. Brick walls cannot be nailed except through the joints,

and conduits for utility services are difficult to fit in, unless ducts are pre-made. Rather, more patience and skill are required for work in clay than for work in cement. All masons can lay concrete block work, but only a few can work confidently in brick and their rates are high. Nigerian brick products are said to be poorly fired, and some architects would like to see the production of engineering bricks for use in paving and flooring in markets, warehouses, drains etc. The production of roofing tiles is also advocated.

### 5.2 Cost Considerations

The cost comparisons made in Table 2 show clearly that cement blockwork is cheaper than any form of clay blockwork. However while a brick surface requires no rendering and provides excellent external experience with virtually no maintenance, the cost of rendering and painting a cement block wall in the Enugu area is given as ₦3.00/m<sup>2</sup> for rendering, and ₦2.80/m<sup>2</sup> for painting. When these figures are added to ₦10.35 for 9 blockwork, and ₦7.90 for 6 block work, the latter becomes clearly more expensive. Added to this is the need for periodic maintenance/repainting of the concrete block wall.

### 5.3 Skilled Labour Requirements

Nigerian masons can all work in cement with varying degrees of skill. Very few masons however can handle clay products. The greater level of skill required to cope with such work is reflected in the relatively higher labour charges for laying clay products, which range from ₦4.80 to ₦10.40 per square metre, as compared to less than ₦3.00/m<sup>2</sup> for cement blockwork.

## 6. ENCOURAGEMENT OF THE USE OF CLAY PRODUCTS

The most serious criticisms that have been levelled against clay products have been on the grounds of excessive costs and skills needed to use them. Others have included slowness, lack of versatility, linearity etc. In looking at possible ways of removing these objections and hence increasing the use of clay products in local construction, the experience of more advanced countries who have passed through a similar stage might be useful.

### 6.1. The Experience of Foreign Countries

In 1945, brick production in France totalled one million tonnes per year, divided roughly equally between solid and hollow products. Concrete blocks were being produced from low capital plants and were hence receiving official encouragement. The Brick and Tile Manufacturers Federation (F.F.T.B.F.) set up a professional body (SPPFTC) to organise the equipment and technical development of the industry, as it was felt that these were the major areas of weakness.

This body, which later became the Technical Centre for Bricks and Tiles (C.T.T.B.) was financed by a government supported compulsory levy of 0.5% of the turnover of all manufacturers. The work of the centre included developing new bricks and blocks better designed to compete with concrete blocks. The result of its efforts was a production of nearly 3 million tonnes in 1947. A better picture of the impact of its work can be seen in Table 4 below:

TABLE 4. PRODUCTION OF BRICKS, TILES, AND BLOCKS IN FRANCE  
(IN THOUSANDS OF TONNES)

Year	Fired Earth Products					Total	Concrete blocks (Including floor blocks)
	Solid bricks	Hollow bricks	Floor bricks	Tiles	Miscellaneous		
1950	1979	940	224	802	113	4058	505
1951	19541	1125	265	885	111	4327	580
1952	2037	1240	338	936	129	4680	710
1953	1830	1299	388	915	101	4533	1020
1954	1924	1558	477	950	110	5019	1325
1955	2152	1946	533	999	129	5778	2045
1956	2042	2062	550	1008	134	5796	2270
1957	1884	2450	627	1077	132	6170	2800

Two points emerge from Table 4. Total production rose rapidly from 1 million tonnes in 1945 to over 6 million in 1957. Solid brick production remained more or less constant, and the increase in production was almost entirely in the new products which compete directly with cement blocks. Judged from this view point the increase in production of these products from 0.5 million tonnes in 1945 to over 4 million tonnes in 1957 represents considerable success in fighting off the challenge of the cement block industry. The Italian experience<sup>2</sup> is somewhat similar although the lines of development differ. According to Klein<sup>3</sup>, Italy pioneered the use of clay products in factory and site prefabrication of floor beams and wall panels. The system is based on the use of large, very light hollow clay bricks and blocks joined with the minimum amount of prestressed or reinforced concrete. This development started in the early 1920s and spread to other European countries after 1945. As a result of the considerably cost and time savings achievable by the use of these systems, they have almost completely replaced massive reinforced concrete slabs in floors, roofs, and vaults, leaving only the reinforced concrete frame of columns and beams. One of the pioneer developers of this system in Italy, was the firm Enterprise S. Fiorio which was unique in being both a brick maker and a major contractor. The pioneer of the use of clay pots for decking in Nigerian G. Cappa, is also a brick maker and a contractor. The G. Cappa factory at Oregon village near Lagos is, not surprisingly, the only successful factory of its type in Nigeria.

## 6.2 The Nigerian Situation

The situation in Nigeria is similar to that in Europe in the first half of this century, with the exception that the industry is young, uncoordinated, and unsuccessful. The solutions that have been adopted successfully in Europe can be applied here, and will now be discussed in the Nigerian context.

### 6.2.1 Cost Reduction

This can be examined from two main view points. Firstly, the cost of the clay product itself, and secondly the cost of laying. Schotman<sup>4</sup> claims that the cost of constructing a brickworks in Nigeria is twice as high as in the Federal Republic of Germany. This high cost is reflected in the cost of the finished product and serves to reduce the competitiveness of the clay product. In spite of this problem, which can probably not easily be solved for existing brickworks, cost reductions can be achieved by a critical look at the actual production processes themselves. Norton<sup>5</sup> has pointed out that cost reduction can be achieved by a systematic programme of reducing defects, and gave an example of a plant that operated at a loss for several years at a production rate of 89% of capacity. An improved inspection system raised

the level of merchantable ware to 93% and the company then recorded a healthy profit. In Nigeria, inputs of labour and fuel, are generally above European levels, and can profitably be reduced

The second aspect of cost reduction concerns the cost of laying. The relative cost of laying concrete blocks and various clay blocks were shown in Table 2. Studies<sup>6, 7</sup> have shown that the speed of laying of bricks and blocks depends on the size, shape, and weight of the block among other factors. Local brick plants may benefit from the results of such studies and produce and market more easily laid products than hitherto.

### 6.2.2 Technical Developments

The success of the Italian brick industry depended on the use of prefabricated systems by builders who were often brick makers also. In Nigeria the Federal Government, through the Nigerian Mining Corporation is a major brick manufacturer. It is also, through the Federal Capital Development Authority, the Federal Housing Authority, and the Federal Ministry of Works, a major builder. The symbiosis between Cappa the brick maker and Cappa the builder has already pointed the way to what is achievable in Nigeria. This example should be emulated by the Federal agencies mentioned. The technical developments envisaged would include:—

- (i) A critical examination of clay block sizes, shapes and weights and of clay block laying practice with a view to determining the most economical sizes and shapes for use by the construction industry.
- (ii) The adoption of a suitable system of prefabrication for the construction of different types of structures.

The achievement of the aims stated above can only result from collaboration between the FCDA, the N.M.C. and possibly the Nigerian Building and Road Research Institute (NBRRI). Whatever systems and units decided upon can be applied to further housing development in Abuja.

### 6.2.3 Marketing Aspects

The marketing performance of many of the brick companies in Nigeria has been somewhat lacklustre. For years one privately owned plant in the Eastern States produced no facing tiles at all, even though tiles produced in Lagos were transported to the East and sold readily at exorbitant rates. Schotman had pointed out this weakness, but the situation appears not to have changed. In a situation where the buying public is being asked to use a new product, a determined effort should be made to exploit the advanta-

\* Source: *Trans. Brif Ceram. Soc.* vol. 57 P. 472.

ges of this new product. The only effort being made in this direction is in fact not from the industry. An indigenous engineering firm in Ibadan undertakes the design of clay block deckings for private houses. At the appropriate stage, the prestressed beams, previously cast in the company's premises, are delivered and placed in position, and the decking pots grouted. The whole process is completed in a few days. Brick producers would do well to emulate this company, as it is only through such efforts that their products can succeed in competing with cement products.

#### 6.2.4 Development of Skills

As stated before, every mason can work in cement but only a few can handle clay products. The Nigerian Mining Corporation has trained a number of brick layers and is working towards an upliftment of brick laying standards. This should be encouraged.

#### 6.2.5 Policy Issues

The most important area of attention in encouraging the use of brick and clay in construction lies in the area of policy. A bold policy statement to the effect that given percentage of government projects should be built in clay is counter productive and can be disastrous in the long term. It was shown in Table 2 that some clay products are more expensive than others, and much more expensive than cement. It would be more sensible to research the problem thoroughly, and to direct the NMC, FCDA, and NBRRI to ensure the optimum use of clay products in the further development of Abuja. It would probably be necessary also, to bring the clay products manufacturers together in some form of association (say a Brick Manufacturers Association) which would work with these agencies to achieve the stated goals.

Another area of interest is in the use of other clay products such as clay pipes for drainage and sewage. Currently, asbestos cement and U.P.V.C. pipes are used for these purposes. Both products require the importation of all the raw materials employed in their manufacture, while stoneware pipes can be produced entirely from local raw materials. This fact explains their widespread use in Britain, which had no local sources of asbestos, and, until recently, of petroleum products.

### 7. CONCLUSIONS

It is clear, from the preceding pages, that the clay products industry is not contributing adequately to the country's requirements for building materials. This is in spite of the fact that Nigeria imports over 6

million tonnes of cement annually. The blame for this short-coming lies with the industry, with government, and with the construction industry as well. A number of actions need to be taken if the situation is to improve. These actions include the following:—

1. Improvement in production efficiency of the existing brick plants, so as to reduce costs and make more competitive products.
2. Adoption of more imaginative and aggressive marketing policies by the existing brick plants.
3. Increased training of brick layers so as to reduce the labour cost of building in brick.
4. A policy decision that further development at Abuja and of other Federal Government projects should be substantially in clay.
5. Following on (4) above, the FCDA, FHA, NMC, and NBRRI should be directed to produce a programme for the implementation of this directive. This programme will include the development of suitable products and prefabrication systems, and will aim at ensuring that building in clay is competitive in cost with building in cement.
6. The establishment of a Brick Development Association which will bring together all brick and clay construction products manufacturers for the solution of common problems.

The high level of activity in construction, coupled with the high level of importation of cement (over 150% of local capacity) and the Federal Government's statement that the establishment of more cement plants is not contemplated, together provide a good climate for the rapid growth of the heavy clay industry in Nigeria. This growth will not take place unless steps, such as those outlined above, are taken to improve the health and competitiveness of the industry.

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## CLAY PRODUCTS IN THE SHELTER INDUSTRY

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### ABSTRACT

Clay is a widely available building material. For affordable housing, clay and its products are the most favourite materials to use. This is because only very simple skills and technology is required to improve the quality of clay products. This paper highlights how to use clay for building in a resourceful manner. It also shows that clay could be prepared for use both locally and industrially.

### INTRODUCTION

Clay is essentially earth, but characterised by very fine particles, tenacious and impervious. There are several types of clay. In use, clay is either fired or sun-dried and has been used in the provision of shelter for mankind since historical times.

Clay products for housing have been popular because of the availability of clay and lateritic clay deposits almost everywhere. They become convenient for building when they have the right amount of moisture. The clay mix is then cut into blocks which are sun-dried or fired. These would work well in extremely dry climates because they are very strong and durable.

### PREPARING CLAY FOR USE

Clay is usually mixed into a paste, then moulded and air dried. They are subjected to a gently rising temperature, followed by a gradual cooling after satisfactory baking. In industrial kilns, the temperatures may reach up to 950°C and the process of heating-cooling take up to 4 days. Smaller kilns could also be locally built for smaller scale production.

The ordinary sun-dried clay blocks (referred to as Adobe blocks) are left to dry over a period of about 7 days. The fired bricks are much stronger than the sun-dried ones as a result of the very high temperature which causes vitrification of the clay minerals. The local builders improve the quality of their blocks by adding straws or cow-dungs to the mix to improve bonding; this mix is kneaded and left for some days. The blocks are finally cut out from them after re-mixing with water to form a workable paste. This traditional procedure is common in the Northern parts of Nigeria.

To ensure a good performance of the clay, it is advisable to make an on-the-site assessment of its suitability before use. The following are a few of possible quick tests on site:—

#### (a) Visual Test

Physically separate a handful of soil into its sand, and gravel components. The powdery left-over is the silts and clays. Assess the quantity of each to know the soil type or suitability.

#### (b) Dry-Strength Test

This helps to determine how much clay there is in the soil. Three wet pats of the soil are made measuring about 25mm thick and 50 – 100mm wide and these are sun-dried or oven-dried. The dried soil pat is broken and crushed between the thumb and forefinger.

The soil has a HIGH DRY strength if it snaps sharply and if it is difficult to powder. It has MEDIUM DRY strength if it is not too hard to break the pat and if with little effort, it is possible to powder the soil. It has LOW DRY strength if it breaks and powders very easily.

#### (c) Thread Test

Moisten a lump of the soil and roll on a flat surface into a thread. If the thread does not crumble at 1/8" diameter the soil is lumped and kneaded together, and the rolling process repeated. This test gives an idea of how much and type of clay content there is in the soil.

Having carried out a suitability test, decision is easily made as regards:

- the kind of stabilizer to use,
- the strength limitation of soil in use and
- the expected behaviour of the soil in use.

Figure 1 shows particle size classification of soils. The shaded area indicates soils most suitable for stabilization.

### STABILIZATION OF CLAY

Essentially, soil stabilizers would improve the strength of the blocks by improving the bondage of its component particles. They also reduce the water absorbing tendency of soils, especially if the stabilizer is water-repellent. Other effects of soil stabilizers include keeping soils from shrinking or swelling. Examples of stabilizers include

### Sand and Clay:

These are for soil types that do not contain enough of them. This is done by adding sand to a clayey soil and adding clay to a too sandy soil.

### Portland Cement:

This is good for sandy soils. It is applied to the soil, mixed thoroughly before adding any water. The blocks obtained from the mix should be well cured.

### Lime:

It reacts with clay to form a binder. It also improves workability of clayey soils.

Asphalt, straw, fly-ash, sodium silicate, wood ashes, coconut oil etc. are all known soil stabilizers. The exact amount of stabilizer needed for a particular type of soil depends on testing, experience and desired effect.

## CLAY AND THE ARCHITECT:

Clay building components form one group of the tools the architect uses in making his creation come alive. Some buildings are entirely conceived by the architect in bricks; these buildings look clean and beautiful. In other instances, bricks are used to punctuate the facade of buildings either to break monotony or simply to beautify. These surfaces are sometimes only finished off with brick tiles but actually built with sandcrete blocks.

### CLAY WALLS:

In some rural development projects, the architect cannot afford to use fired bricks because of costs or for some other reasons in which case sun-dried clay blocks have to be used. The immediate problems that come to mind are those of maintenance and resistance to the open weather (erosion and attrition). This problem is usually solved by using large roof overhangs to protect the walls as much as possible. The lower part of walls are also protected by galvanised metal sheets in some places (see Fig. 4 a & b).

Due to the rough nature of clay walls, rodents find it very easy not only to climb them but also burrow holes into them. In figure 4c, the groove introduced before the wall, is expected to break the path of rodents and smaller climbing creatures. These clay walls are made in any of the following ways viz:—

- (a) Constructing walls with 'adobe' blocks: These blocks are made from simple moulds without any pressure. However, their strength could be increased by using brick-making machines which allow some pressure to be applied unto the mix in its mould (Fig. 2 a & b). These blocks are then sun-dried and used.

In the industrial production of fired clay bricks, there are numerous types and shapes produced. These fired bricks have provision in their surfaces to ensure a good bonding with the cementing mortar. They are much harder than the sun-dried ones.

- (b) Constructing walls with the clay-mix only. This system of construction is referred to as Pise.

Due to the limitations of wet clay-mix to withstand height, the wall is constructed in stages. Each layer is allowed to dry substantially before laying the next. This is repeated until the desired height is reached (Fig. 3a.)

In figure 3, a device is used for this type of construction. It ensures that the walls are straight and of uniform thickness and also allows for tamping. These walls have been found to be good regulators of the house's micro-climate, especially in rural communities where artificial devices for comfort are not affordable. The heat-lag effect of clay walls ensures a cool interior during hot daytime and a warmer interior during the chilly night. This effect is sharply noticeable in the hot-dry climates.

Also in rural areas, as in Northern Nigeria, where clay is predominantly used in building, the 'azara' clay roof is popular. 'Azara' is the local name for palm stems beams popularly used in construction. The roof is flat and it is made from a layer of the clay-mix on a close arrangement of azara. Sometimes a mat is laid first on top of the azara before the pouring of the clay which is predominantly lateritic. This kind of roof has been found to perform very well in hot-dry regions.

## OTHER CLAY COMPONENTS

Some buildings have their surroundings landscaped and finished off with clay products. These include foot-path tiles, flower pots, kerbs and so on. The combined effect of these results is a pleasant environment. Roof gutters are sometimes made of fired clay. They have the advantage of being resistant to rust. Clay tiles come in handy as roofing material, and they overlap along the slope of the roof.

## CLAY AND STRUCTURAL SYSTEMS:

Other than in the construction of load bearing walls, clay bricks are also used for floor, slabs, columns, lintels and beams.

### Columns and Beams:

The clay bricks are aligned so as to allow the reinforcement to pass through (fig. 2 c & d). After the

bricks have been properly laid, the concrete mix is then poured into the hollows and vibrated appropriately to form columns. They appear very neat and compare favourably with the standard reinforced concrete columns. The same applies to the construction of lintels and beams. They could be cast in situ or even be made as pre-cast units lifted into place. The steel reinforcements are placed before pouring in the concrete mix.

#### Floor Slabs:

Figure 2e shows slab units. These units are placed as shown and the steel reinforcement put into position before pouring in of concrete to give the floor slab. The slabs could also be cantilevered.

This system uses hollow pots laid on a flat formwork. The slab units become permanent void formers in the floor. With this system, there is considerable reduction in the steel and concrete used. Savings is also effected by way of lighter support structure because the floor is much lighter than the conventional concrete floor slabs. The deeper floor construction allows for longer uninterrupted spans. When used as roofing slab, it achieves great thermal insulation. Fig. 2e

#### CONCLUSION:

The very many ways in which clay could be used for building have been discussed. These are in the forms of fired or sun-dried components.

Clay is abundantly available in Nigeria. This implies that it is the most likely material to use in effecting a downfall of cost of buildings. However, the following conditions must first be met viz:—

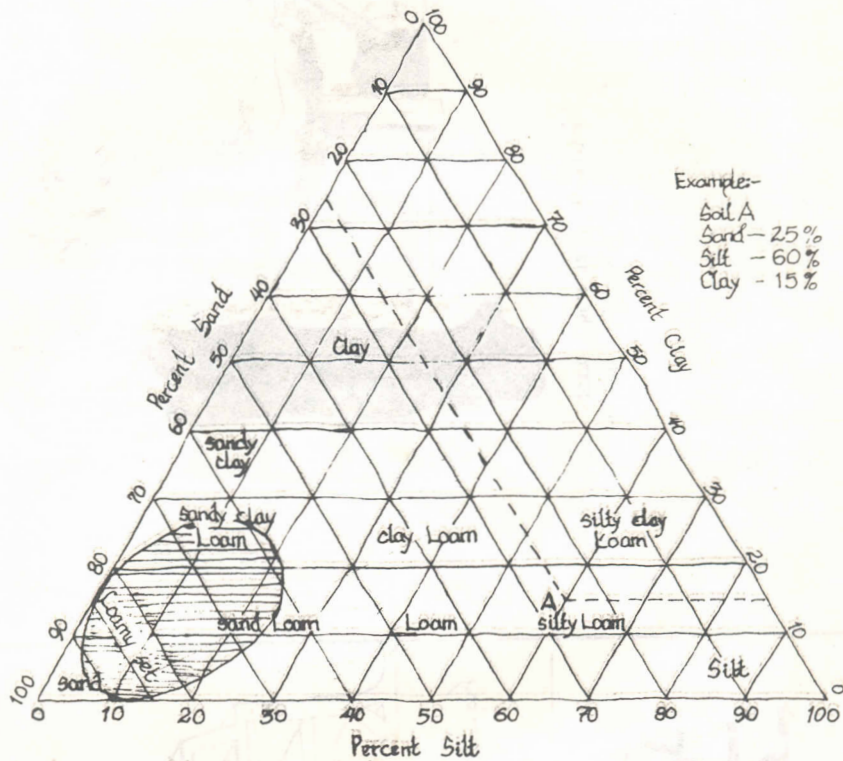
- (a) Educating the builders on the scope of use of the clay mix by way of stabilizing it, firing in a smaller-scale kiln and other ways.
- (b) Embracing simple aids to improve quality of construction e.g. brick making machines, roller device for straight walls (fig. 3b) and so on.
- (c) Encouraging choice of this kind of construction as a better alternative to sandcrete blocks.

In view of the wide possibilities of using clay for buildings and its availability in Nigeria, the final cost of a building will in no doubt be very affordable.

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#### REFERENCES:

- ✓ 1. Spence, R.J.S. and Cook, D.J., Building maintenance in Developing Countries.
2. Handbook for Building Homes of Earth (prepared for Agency for International Development).



Example-  
 Soil A  
 Sand - 25%  
 Silt - 60%  
 Clay - 15%

Fig 1 Chart for particle size classification of soils (shaded area shows soils most suitable for stabilization)

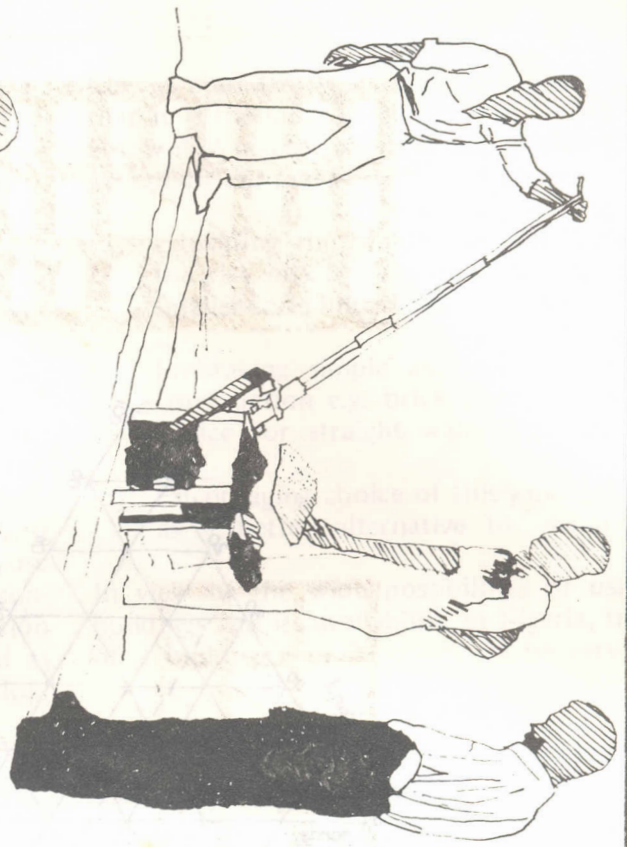


Fig 2a Preparing adobe blocks by hand & machine.

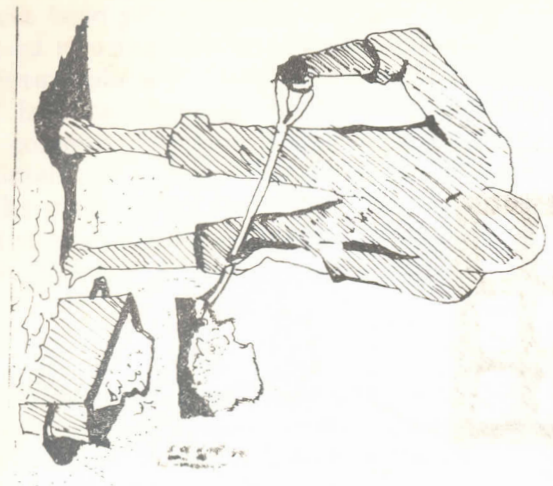


Fig 2b Removing adobe blocks from molds.

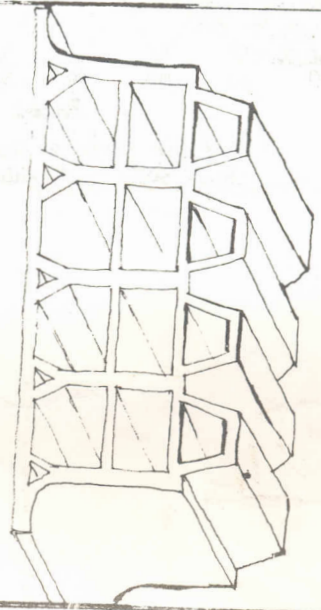


Fig 2c Floor slab unit

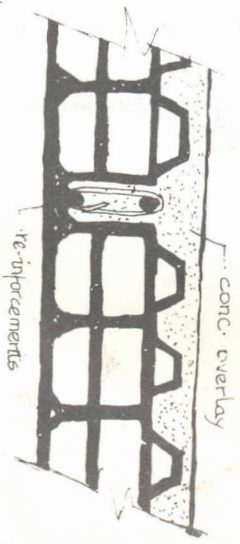


Fig 2d Section through floor slab.

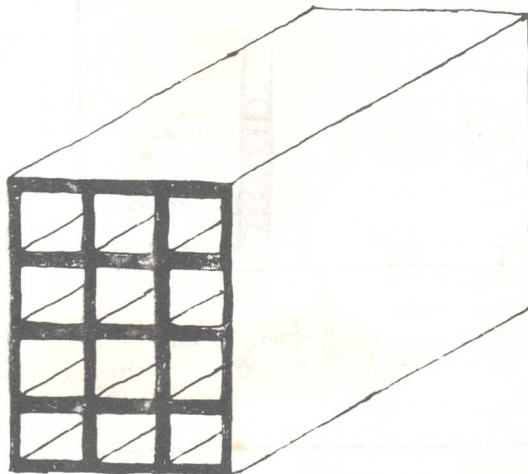
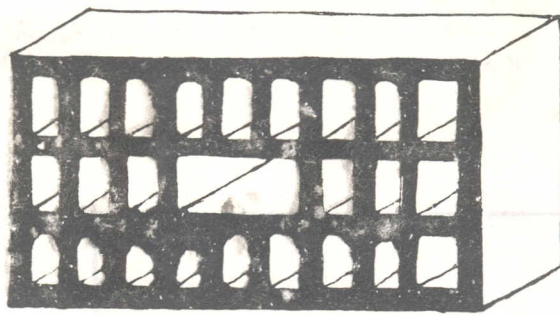


Fig 2(c and d) Burnt clay bricks

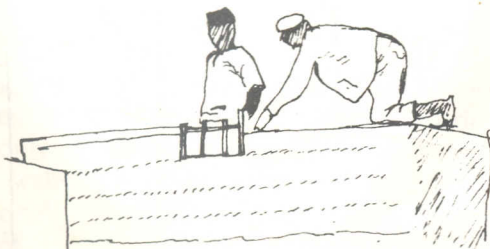


Fig 3a Rammed Clay construction. (Roller device in Fig 3b is used)

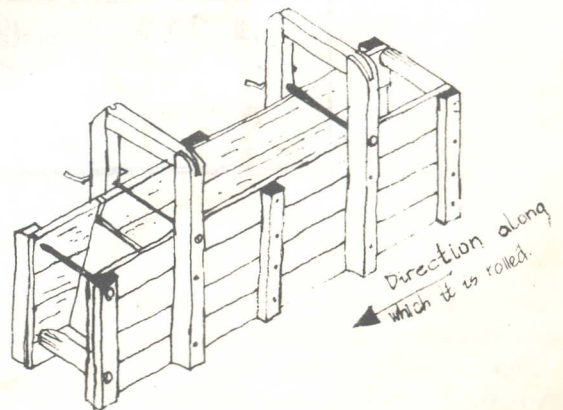


Fig 3b Device for improved rammed clay construction.

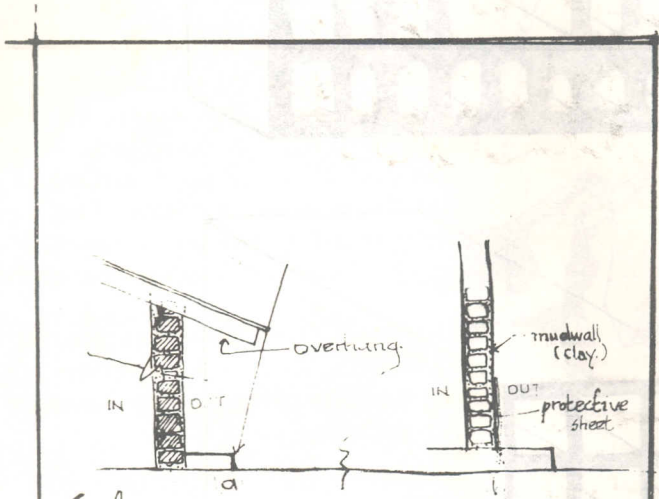


Fig 4 a&b Showing wall protection by overhang and metal sheet.

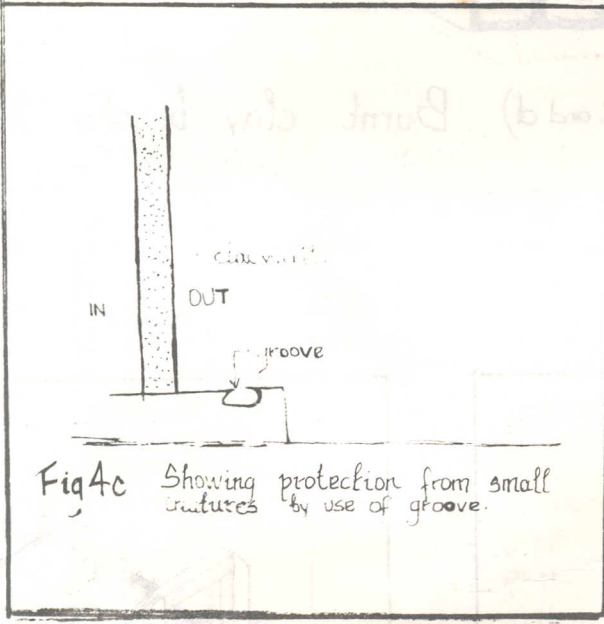


Fig 4c Showing protection from small craters by use of groove.

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## THE AESTHETICS OF BRICK MASONRY IN LAGOS, NIGERIA.

By

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### INTRODUCTION

The aesthetic potential of the bricks produced in Nigeria has only rarely been realised by Nigerian architects. Much of the brickwork is completely disguised by a plaster finish even where the brick is strong enough to withstand the ranges of the weather. Brickwork has also been subjected to superfluous coats of paint reflecting a disregard for the nature of the material. The majority of visible brickwork is restricted to rectilinear patches of infill wall between the structural wall or supports and the windows. This presentation, however, focusses on those architectural designs where the treatment of the brick is central to the architect's aesthetic intent.

### THE ORIGINS OF THE LAGOS BRICK INDUSTRY

The brick industry in Lagos dates back to the mid-nineteenth century. Three separate brickmaking enterprises were begun within ten years. In 1857, a Sardinian identified as Scale produced and sold bricks and tiles<sup>1</sup> mainly to affluent returned slaves. In 1965, another brickyard was established in Iddo by a Baptist missionary named Harden. He needed a source of income when he became cut off from the funding provided by American churches because of the American civil war.<sup>2</sup> A year later, another missionary introduced brickmaking as part of a programme to import technology in order to improve the quality of life of the converts. The Church Mission Society supported a project supervised by F.A. Ashcroft as the Industrial Agent. He had previously taught brick and tilemaking in Sierra Leone. His Lagos factory was established at Ebute Metta and introduced the use of charcoal as an improved fuel.<sup>3</sup> These early examples of imported construction technology occurred at the time the British were establishing their control over Lagos trade and life.

### FACING BRICKS

Although the visible expression of brickwork can be achieved through the use of structural bricks, more commonly in Nigeria, facing bricks embellish cement block walls when an aesthetic effect is desired. Occasionally architects successfully rely on limited areas of facing brickwork to enhance their designs.

Extremely pale facing bricks have highlighted the principal aesthetic focus for the block of flats at 23-50 Adeolu Odeku Street in Victoria Island. Each balcony has been designed as a solid wall which leans out very slightly rising from its base at the floor

of the balcony. This sloping barrier continues below the balcony splaying out slightly to serve as an over-head brise-soleil. The architect's modification in the standard straight balcony brise-soleil form is further underscored by its solid surface in contrast to the normally perforated forms. This aesthetic variation is heightened by the use of facing brick as the finishing for these specially angled parapets.

These brick-faced balconies are set off against the white walls of the living spaces distinguishing this block of flats from its neighbours through the subtle brick detailing.

The decorative potential of facing bricks has been fully developed in the house at 45-35 Ademola Adetokunbo Street on Victoria Island. The architect has embellished the upper storey of the white stucco facade with a relief pattern of pseudo arches rendered in the facing brick. The old world imagery suggested by these arches is reinforced by the use of bricks at the corners recalling the use of larger rusticated stones as quoins at the corners of impressive European stone buildings from the Renaissance onwards. These brick quoins are laid up alternately as stretchers and headers to delicately frame the upper facade

The aesthetic effect of large curtain walls depends mainly on the size and shape of the wall. The end walls on the set of duplexes at 8 Rumsey Road in Ikoyi designed by Ronald Ward and Associates (1983) pulls these tall multifaceted units together. The large expanse of facing brick laid in common bond forms a single dramatic element, punctured only at the base for the side entry and the garage. The facing brick reads as structural brick partly because of the large expanse which appears to support the roof. The detailing also contributes to this impression; the brickwork completely camouflages the ends of the cement blocks and the thinness of the facing bricks by turning the corner of the cement block with one set of bricks.

Just as the large brick lateral facades frame the architectural design of these duplexes, the duplexes themselves are set off against low, red brick walls. Here the composition is broken in contrast to the smooth lateral facades. The hollow bricks used for the walls possess their own inherent complex pattern deriving from the bracing grid set within the bricks and from their scored surfaces. Their arrangement in alternating rows set at 45 degree angles creates

further visual variety. These low brick walls encircle the entire compound and link the duplexes to each other. In combination with the series of large lateral brick facades, they provide the thematic unity for this cluster of duplexes.

Large expanses of brickwork have also been used to unify another type of complex, one involving two related buildings performing different functions. The brick facades embracing the lateral facades of the Arts Theatre are echoed in the end facades of the Arts Block complex designed for the University of Lagos by Design Group (1975). The brickwork on the Arts Theatre is central to the architect's concept. The form of the Arts Theatre expresses its function as a theatre. The brick curtain wall which projects out beyond the structure recreates the shape of the interior space where the tiered seating contrasts with the level, stage platform. The brick curtain wraps around the edges at the front and back of the Theatre to softly close the composition which has been designed basically to be seen from the main dual carriage-way approach or from the administrative complex. The break in the brick facade for the side entry marks the divide between the stage and the tiered audience.

The brickwork is the principal visual link between the two buildings which constitute the Arts Complex, aside from their rather awkward juxtaposition. Contrary to the standard lateral arrangement of bricks, the facing brick in this complex has been laid up vertically with a common stretcher bond. The vertical alignment emphasizes verticality, thereby lending a monumental character of these public buildings. The vertical alignment also facilitates the generation of the smooth curves that dramatize the corners of the theatre. On the ends of the long block, the vertical coursework is interrupted by a thin groove which defines each floor deck. The higher spaces in the classroom wing only allow for four floors in contrast to the office wing which is divided into six floors. These differential heights, reflecting different functions, are visible in the brickwork. Thus, the brickwork in this complex has been consistently handled as minimal decoration which follows the International Style principal that "Form Follows Function"

Mobil Petrol Stations derive their special character from the contrast between the red brick box form for the building and the flat umbrella form sheltering the pumps. Each station is designed as a red brick box which houses the office and the lube bay for car servicing. Prototype designs providing for front and side entry are supplied by the Head Office in New York City. Draftsmen in the Lagos Head Office adapt these prototypes to the site. These structures are built with cement blocks and faced with red bricks up to the level of the lintels placed above the garage openings and the huge glass panel of the office. Above this point, the facade is plastered white and the flat roofline is rimmed with a black

band. A large circular logo in white with a winged horse is set off against the red brick facade between the office entry and the service garage.

In this design, the nature of the brick as a facing brick is frankly expressed. Clearly the bricks support nothing. They do not rise to the roof line nor are they actually under the ends of the lintels. Instead they are stuck onto the cement blocks as is clearly revealed at their visible juncture above the line of the brick. The brick facade stops abruptly and reveals itself to be a mere surface in front of the cement block wall which continues to rise behind it.

From both a practical and an aesthetic perspective, the architect's choice of facing brick for the facade is particularly successful. The station design must function as a trademark for Mobil helping motorists to easily identify it as opposed to the stations of the competitors. In contrast to the other predominately pristine white stations, the Mobil image of a brick box stands out. Moreover, the red brick offers an excellent backdrop to the Mobil logo. The brick facing is also practical in terms of maintenance, having no need for annual painting to maintain its pristine look. The red brick forms the basis of a balanced abstract composition of red, white and black punctuated by the voids of the window, door and garage entry. The simplicity of this red brick composition is appropriate to its dual purpose, the creation of a pleasant petrol station and a lasting trademark.

Entire buildings are sometimes encased in a brick veneer. In his design for the University of Lagos Women's Society Nursery School, David Aradeon selected brick, quarry tiles, and exposed wood to reinforce the warm friendly atmosphere he created to welcome small children to their first exposure to school. The nursery school is designed as clusters of classrooms each conceived to look like a house in order to attenuate the transition from the informal house to the more formal school environment. In keeping with the design concept, the facing bricks are laid up in common bond similar to standard dwellings. The main difference is that the windows are small and low on the walls to keep them in scale with the children. Their small size is also inspired by the traditional, rather than the colonial, approach to fenestration involving minimal openings to keep out the sun's glare and hot air.

The administration cluster revolves around a large breeze-through designed as a stage for performances by the children. The quarry tile floor blends well with the surrounding walls defining the office of the headmistress, the staff/public toilets and the staff room. Larger windows punctuate the brick walls of these rooms intended for use by staff and parents attending to official matters. The bright abstract patterns painted on the walls forming the entry to the breeze through are a welcome novelty. Yet, the

wear and tear they are subjected to by the children underscores the value of the brick as a facing material that preserves a good appearance regardless of the conditions to which it is subjected. In contrast to the painted surfaces, the brick walls around the porch linking each cluster of three classrooms/houses remains in excellent condition even though these areas are on constant use as areas for rehearsals and games especially during the rains.

Common bricks functioning as facing brick have served as the finishing material for the public spaces in a block of flats at the end of Alagbon Close designed by Alan Vaughan-Richards. Common bond brickwork lines the long covered walkway that links the entry/parking with the stairway and lifts. The long, walled walkway creates private outdoor spaces for the families living in the ground floor flats. To embellish his entry space, Alan Vaughan-Richards commissioned an original wrought iron sculpture by Bello and carved doors by Felix Idubor. Coupled with the bush planting along the passageway, this entrance establishes an atmosphere of luxury that belies the small size of the flats and the architect's restricted budget. The walkway is lit and ventilated by an open skylight running along the right hand side, above the plantings which help to absorb some of the rainwater.

The potential monotony of the long narrow walkway is further attenuated by the form of the brick wall. The wall is divided into a series of panels set at an angle, slightly wider at the entry end and narrower at the end near the flats. A line of hollow clay bricks links each successive panel allowing further air circulation. This placement of the panels directs the visitor down the gentle slope and through the carved doors.

The main staircase is also faced with common bond brickwork which is interrupted with a row of glass blocks to light the staircase. This solution is particularly successful because it not only conserves electricity but also lights the stairway during the frequent power failures. Despite twenty-one years of use with minimal maintenance, the brickwork in these circulation areas continues to offer a welcoming appearance.

### BRICK GRILLEWORK

The exploitation of brick grillework to camouflage an awkward elevation and/or to provide a measure of privacy is a fairly common architectural device in Lagos; however, rarely has the grillework contributed so successfully to the design as in the Weide & Co. Building in Iganmu designed by Alan Vaughan-Richards in 1966. Here, the upper floor apartments cantilever out above the office/showroom spaces on the ground floor. The large panels of the public areas alternate with cement blocks painted white. A strong white band articulates the cement slab between the two levels. The private domestic areas are camouflaged

with a screen of eight-sided brick grille elements which spread over the entire upper floor except for the strong white cantilevered balconies for each apartment.

The brick grille encompasses the entire upper floor providing a unified formal facade for this commercial building. Rather than diminishing the public nature of the building with an upper elevation cluttered with domestic windows, the architect has hung the brick grille more than a meter from the actual facade. Thus the red/orange grille dominates the recessed ground floor. The grille work is only interrupted at regular intervals by strong white balconies which cantilever out well past the grille. Their juncture with the grille is articulated by two columns of vertically aligned grillework bricks.

The entry picks up the red brick theme with long paving bricks. The paving bricks provide character for the entry steps and the small terrace to the left of the entry. The long flower bed to the right of the entry is raised up with a brick framed ledge. Above the entry itself, the huge Weide and Co. sign superimposed on the brick grille reads well against the regular pattern of the brick openwork. At the ends of the long low building, the brick openwork is alternated with solid brick vertical panels so that the centre and the edges are in openwork. Again the openwork is framed by vertically aligned octagonal bricks almost creating pseudo-columns because of their convex form. Thus, the entire building is embellished with brick except for the facade of the office/showroom which complements the brick and stands out against the unifying background of brick masonry.

The upper floor is designed to read as a brick grille curtain punctuated by white balconies. Each of the four flats possesses one balcony and one area faced by the grillework. To preserve the formal facade, the flats are arranged so that two white balconies are juxtaposed at the centre of the facade. Consequently, their brick grille panels are towards the edge of the facade. The entry is also adjusted to preserve this facade composition. It is placed immediately to the left of these central balconies below the grille which serves as a backdrop for the large sign identifying the building.

### STANDARD STRUCTURAL BRICKS

The Lagos Boat Club Restaurant and outdoor bar designed by one of the members, W.H. Moore, in the 50's exhibits a very effective use of brick to enhance the atmosphere. The side walls which frame the entirely glazed marine frontage are constructed with vertically stacked structural bricks. The bricks are varnished resulting in subdued, slightly shiny brown tones which retain their character without requiring regular cleaning or painting. Moreover, the brickwork is deeply tooled to create a repeat pattern where each brick is visualized separately and as a unit in both the vertical and the horizontal rows. Since vertical

stacking is a non-structural brick arrangement, unobtrusive columns are introduced as the supports.

On the patio, the brickwork is echoed in the bar. Vertically aligned facing bricks cover the sides of the circular bar. Despite the modification in the alignment, the parallel stacking (horizontal stacking in this case) relates to the parallel stacking of the restaurant brickwork. This outdoor brickwork is unvarnished, perhaps in recognition of the impermanence of the varnish finish when exposed to rain. The natural brickwork maintains its paler finish regardless of the rain and the human wear and tear from clients leaning at the bar.

Ola-Oluwakitan Cottage, now known as Baachus Stero Club, in Southwest Ikoyi presents a dramatic brick structure which undulates in section so that the balcony parapets swoop up and the roof curves down towards the street front facade. Although designed as a private residence, upon the death of the owner it was converted to a night club. The apparently free form is designed to ensure air movement at the level of the residents using the spaces. In addition to being visible from the street, the structural brick is revealed in the interior rooms and in the entry staircase.

The night-club owner has coated the brick with shellac because the brick on the staircase was beginning to turn white from exposure to rain. The driving wind brought the rain through the awkwardly controlled, tall windows. The shellac protects the brick from the rainwater. Its smooth, darker surface also has other advantages. Regular cleaning of dry season dust is easier and it ensures that no snags are made in the dresses of customers who sometimes arrive in large groups crowding the staircases. Moreover, the dark, shiny effect is more appropriate than the natural finish of the brickwork for the dwelling's revised function as a night club.

The dignified character of the chambers and residence of Chief Rotimi Williams in Palm Grove also designed by Alan Vaughan-Richards (1968) owes much to the full exploitation of structural brick cavity walls. The long low, brick facade of the chambers is punctuated by large windows for the offices of juniors. The structural brickwork rises to support a deep grey beam which simultaneously serves as the lintel for these windows thereby generating a clearly articulated facade. The deep red browns of the exposed brickwork of the interior walls contributes to the dignified atmosphere. It also ensures that the narrow linkage corridor linking the offices and library preserves its appearance despite years of heavy use.

The residence which forms the private section of this complex beyond the courtyard benefits from a similar treatment of the structural brick. The focal point of the entire composition is the round brick staircase tower which can well be seen from Ikorodu Road.

Brick blocks have been used to great advantage by David Aradeon in his National Gallery of Crafts and Design (1984). Sited opposite the National Theatre, this small exhibition centre was initially conceived as a temporary building. The original intent notwithstanding, this brick structure possesses a strong character of its own despite its proximity to the grand theatre. The soft colour of the brick relates well to the deep gray, spray cement of the structural frame and to the green aluminium roofing.

Although only as large as most duplexes in Lagos, the gallery has the stature of a public building. The L-shaped plan with the entry located at the juncture of the two arms of the L, creates the impression that the gallery is larger than it is in reality. The building acquires three facade sections for its facade: the end of one arm and the inner side of each arm. The end of the facade arm faces the avenue which encircles the National Theatre. The semi-court generated by the juncture of the two arms serves as a semi-formal entry area. A curving raised walkway swings out from the door to welcome visitors coming from the avenue through the parking lot which separates the gallery from the avenue. The walkway rises above an artificial pond paved with brickwork arranged in the double basketwork pattern.

The non-domestic treatment of the hollow core brick wall also contributes to the public stature of the buildings. The grey concrete of the structural frame is revealed without recourse to special detailing. The brick walls lack the large window opening typical of domestic facades. The inner facades facing the semi-court possess large windows; however, these windows have been arranged as a band directly under the eaves effectively minimizing their visual impact as openings on the facade. The visual impact of the window on the end facing the street has also been effectively diminished, in this case, because of its extremely small scale and proximity to the protruding element carrying the emblem of the National Council for Arts and Culture. In contrast, the windows at the rear and part of the side wall flush with the edge of the compound have been handled more like domestic windows. Unlike the other walls which provide essential wall space for gallery exhibits, these walls are punctuated with windows to provide maximum convenience for the office occupants which they service.

Despite the very poor quality of workmanship on the part of the small scale contractor, the overall effect of the building is pleasing. The cement grout was sloppily applied and allowed to dry all over the facade. Yet this rough finish is visually absorbed as a supplement to the texture of the hollow bricks which are vertically scored. The effect of the warm brick set in the well-proportioned concrete frame predominates.

The University of Lagos "bukaterias" designed in 1985 by Joseph Igwe, a Lecturer in Architecture,

demonstrate the potential for sensitively designed brickwork to create a pleasing atmosphere despite a low budget and minimal maintenance. Igwe has created friendly, airy spaces supported on double brick block walls.

The architectural programme called for a more sanitary substitute for "bukas", sheds serving as minimal cost restaurants operated by individual women cooking over firewood in the open air. Each bukateria is only large enough to seat two rows of four tables, each with benches providing for a total of thirty-two dinners. However, each bukateria seems much more spacious. The high revealed roof contributes to this spatial effect which is heightened by the strong uninterrupted rise of the monopitch roof. The differential between the roof of the dining area and the roof over the kitchen is spanned by a deep beam, a row of simple non-moveable window panes to allow light while keeping out rain and a second, deep structural beam.

Although each dining area is rather narrow, only 3.60 metres wide, the dining areas have been visually linked with row of brickwork pier/dividers. Their proportions and spacing reflect the architect's sensitivity. These uprights rise from a low brick wall which separates adjacent bukaterias. A concrete beam serves as a tie beam. Recessed from the facades of the brickwork pier/dividers, the unadorned concrete beam which is square in section straddles the centres of the columns. The columns themselves consists of two parallel bricks aligned in opposing directions for each successive course. Thus, the brickwork itself draws the spectator's eyes smoothly around each column despite their rectilinear form. Moreover, the spacing between columns creates openings more akin to domestic windows than to openings in a commercial establishment or impersonal student dining hall.

In the interest of economy, the detailing has been reduced to the barest minimum; nevertheless, the interior brickwork draws the eye of the diner away from these deficiencies. The windows are simply rendered as openings filled with a screen set in a wooden frame which has been wedged into the opening. A deep concrete beam slightly narrower than the double brick wall serves as the lintel resting directly on the wall and windows with no moulding or other form of transition. The junction between the wall and the roof is left open with the sloping rafters resting directly on the back of the wall. The purlins are neatly held in place by small regularly spaced wedges of timber. The aluminium roof rests directly on this revealed framework. As the warm air rises, it is able to escape through the .20m (8") opening created by the vertically aligned beam resting on the brickwork and supporting the roof. Rather than dwell on these unfinished joints and surfaces in this very high ceiling, the diner's attention focusses on the detailing of the brickwork with its alternating rhythm. The headers capping the low wall between the divider/columns and serving as sills for

the windows provide additional decorative detailing, albeit minimal, appropriate to the rudimentary programme for the bukaterias. If these bukaterias were adorned with hanging plants, furnished with fine chairs and table-cloths and accented by soft lighting from better quality light fixtures, they could serve equally well as elegant, intimate restaurants.

Paving bricks cover the floor of the interiors and the porches. The decision to settle for unobtrusive paving bricks was based on the budget and a realistic assessment of the priorities of the bukateria concessionaires; it is doubtful that they would expend the time and money required to ensure shiny clean floors. Perhaps quarry tiles would have served the purpose better because of their smooth, nonabsorbent surface. Yet quarry tiles look equally messy if they have not been carefully cleaned. Because of the similarity in the colouring between the brickwork walls and floor, the floor surface is scarcely noticed. Moreover, the dirt and grime are fast becoming an integral part of this floor because of the absorbent nature of their finishing.

### ENDURING AESTHETIC QUALITIES

Several attributes of brick ensure that it is particularly appropriate as a building material for Nigeria. The prevailing inadequate maintenance policies and practices continue to disfigure many good architectural designs. One rainy season suffices to streak and discolour painted surfaces which often remain in that ugly state for years. Several rainy seasons suffice to permanently disfigure revealed concrete surfaces.

The heavy rains in Lagos also result in considerable weathering of brickwork which engenders a process of efflorescence causing a white mold to grow on the brick. Like the weathering of revealed concrete or painted surfaces, these gradual changes are rarely uniform throughout an entire facade. Yet, as in the case of the Unilag Women's Society Nursery School, this colour modification can be absorbed into the overall aesthetic composition. Occasionally an unsightly green mold appears near the base of a building which could have been prevented by adequate damp-proofing.

Moreover, where shellac has been used to render the brick surface impermeable, the gradual uneven weathering of the shellac produces variegated colouring. However, unlike most materials, the natural tones of brickwork allow for variegated colouring without disturbing the eye. For example, the Arts Theatre shellac has eroded considerably creating colour contrasts between the natural brick showing through the shellac free surfaces and the darker brick which still possesses the shellac veneer. Nevertheless, the subtly variegated colours have been assimilated into the brick facade without detracting from the design.

Perhaps most relevant to the Nigerian architectural environment is the potential of some brickwork to present a good appearance despite the poor quality of the bricklaying and overall construction. Not all brickwork has this potential. The smooth facing bricks require careful workmanship and alignment. However, highly textured and/or multicoloured bricks dissipate the effects of a rough surface created by sloppy workmanship. Such is the case with the splattered mortar on the vertically scored brick blocks on the facade of the National Council for Arts and Culture exhibition gallery. The rough, thick mortar joints between the rough structural bricks as seen under the plaster on buildings being demolished in Lagos or on as yet unplastered roughly fired

bricks in the towns between Ikořodu and Ijebu-Ode resemble the brickwork on the interior and exterior of the Maisons Jaoul by Le Corbusier. Such highly textured brick surfaces possess a rustic sophistication appreciated by Le Corbusier and many of his followers, especially for domestic work.

The work of the architects presented here indicates that a great variety of bricks have been incorporated into highly successful architectural designs in Lagos. The enduring aesthetic qualities of these designs despite minimal maintenance are due to the inherent qualities of brick as material. It is hoped that Nigerian architects will exploit, more fully, the aesthetic potential of brickwork.

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2. Ibid., p. 25.
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## STRENGTH AND STRUCTURAL PROPERTIES OF SOME STABILIZED/UNSTABILIZED COMPRESSED KWARA SOILS

by

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### INTRODUCTION

There has been an increasing demand for clay products in Nigerian manufacturing and construction industries. Today, clay is used extensively as a raw material for the production of building bricks, paving bricks and structural tiles, etc in the manufacturing industries. Before a clay can be utilized for the above purposes, it is good engineering practice to ascertain its suitability for the intended use by experimentation. The objective of this paper, therefore, is to determine the strength and structural properties of some Kwara soils including the clay deposits which the local people normally utilize for brick construction, find out the effects of additives like cement, and the effects of compaction at high pressures.

### GEOLOGY OF KWARA STATE

Topographically, Kwara State is a land of contrast. The landform varies from massive rocky height (tors) and boulders inselbergs in Okene, Okehi and Kogi Local Government Areas to domed inselbergs in the Ifelodun and Irepodun areas to undulating plains in Oyi and Borgu Areas (Oyegun, 1983). In contrast to Bendel State where about 90% is underlain by sedimentary rocks and 10% is underlain by the crystalline Basement Complex, about 90% of Kwara State is covered by the Basement Complex of Precambrian to Upper Cambrian, Age. The rest is occupied by sedimentary deposits of cretaceous to quaternary origin. As shown in the Geological Map of Kwara State in Fig. 1, the undifferentiated basement complex stretches from the northern part of the State (Borgu Local Government Area) to the south eastern part (Okene area). It is markedly absent around Pategi — Lafiagi area. Biotite gneiss, banded gneiss and migmatite have been identified in the basement complex. The biotite gneisses are typically fine-grained and strongly foliated. The foliation is marked by alternating dark and light streaks which are arranged in a parallel orientation (Oyawoye,

1964). The dark portion is seen under the microscope to be of the mineral composition of the granite consisting of biotite, plagioclase, feldspar and quartz (Rahaman, 1976). The light-coloured portion is predominantly of quartz and microcline. The undifferentiated meta-sediments consist of both the older meta-sediments and the younger metasediments. The ancient metasedimentary rocks consist of granites, calcisilicate rocks, arkosic quartzites and high grade schists. The younger metasediments consist predominantly of pelitic, calcareous and meta-igneous rocks. These undifferentiated metasediments are found in large patches around areas like Lafiagi, Kabba, Okeode, Oke Onigbin, Omu—Aran and Ilorin (Oyegun, 1983). Many of the phyllites and gold bearing quartzites in Ilorin, the marbles and low grade schists in Kabba may be members of this sequence (Oyawoye, 1965). The older granites have been used to describe a complex of gneissose granites and coarse porphyroblastic granites and granodiorites which occur as batholiths in the basement complex. They are found around northern part of Kabba with small patches around Okuta area.

Quartzites are found around Omu—Aran area with little patches around north of Borgu Local Government Area. They outcrop poorly but tends to form a good topographic feature. The quartzites consist of about 90% of quartz with minor amount of muscovite, sillimanite, staurolite, garnet, hematite, graphite, tourmaline and Zincon (Rahaman, 1976). It is also found around Jebba.

Around the Ilorin area, the rocks of the basement complex have been classified as porphyroblastic honblende — Biotite gneiss, porphyroblastic honblende — honblende gneiss, granite gneiss, banded gneiss, quartzites and pegmatites. Along the river bed, the basement rocks are cut by a number of pegmatites, dykes and veins.

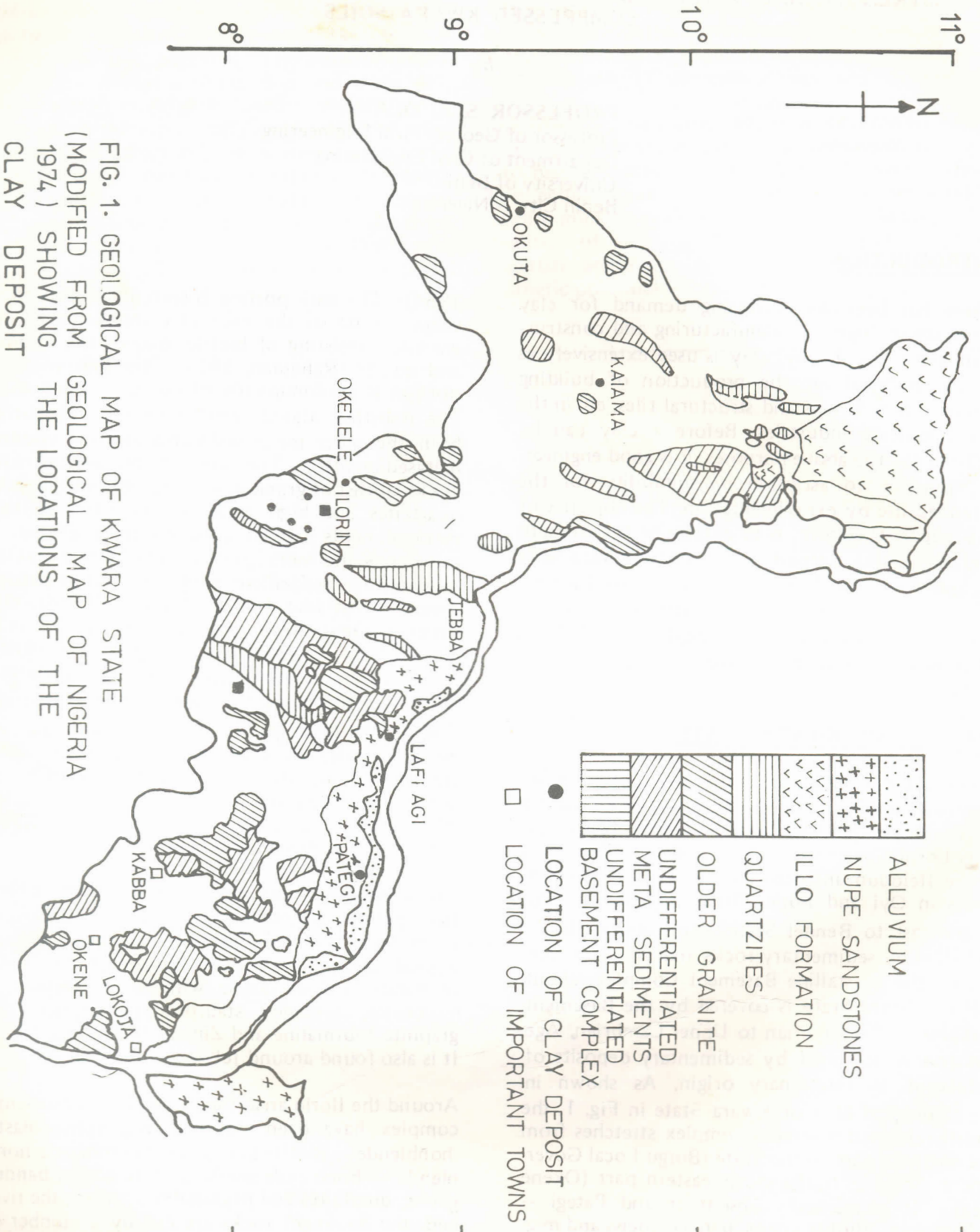


FIG. 1. GEOLOGICAL MAP OF KWARA STATE  
 (MODIFIED FROM GEOLOGICAL MAP OF NIGERIA  
 1974) SHOWING THE LOCATIONS OF THE  
 CLAY DEPOSIT

## SEDIMENTARY ROCKS

The sedimentary deposits of Kwara State is of cretaceous to quaternary in origin. It began in the Campanian and ended in the Maestrichtian age. The sedimentary deposits are made up of Alluvium, Illo formation and Nupe Sandstones (Fig. 1).

**Alluvium:** This is of the quaternary period and is found around the bed of river Niger at Lokoja area. The alluvium deposits range between zero and three meters thick and rarely exceed four meters in thickness. They are predominantly loose sands which may be quite coarse in some localities, small lenses of clay may be intercalated in the sands, especially in flood plains (Durotoye, 1983). Pebbly river gravels are remarkably rare. The alluvium also contains muds and mudstones.

### **The Nupe Sandstone**

The Nupe Sandstone is of the Cretaceous age. It runs diagonally from Kainji lake to Lokoja where it is known as Lokoja sandstone Formation. This may be of upper Maestrichtian age. It consists of pebbly and clayey grits, sandstones, coarse false-bedded sandstones and thin oolitic ironstones. The thickness ranges from about 100 meters to about 270 meters (Reyment, 1965). The basal conglomerate consists of well-rounded quartz pebbles in a matrix of white clay. North of Lokoja, they are numerous outliers of sediment and a thin sheet of basal conglomerate is widely spread. The ooliths consist of concentric shells of impure goethite. The oolitic ironstones of Lokoja does not truncate the bedding planes of the underlying sediments and it is therefore difficult to distinguish between sedimentary oolite and oolitic laterite (Reyment, 1965). Again around Lokoja, the plateau capped by the iron stones cover about 250 square miles (Adeleye, 1974). In Okene area, some rich deposits of calcitic marble and Haematitic banded ironstones have also been reported (Adeleye, 1974).

### **The Illo Formation**

The Illo Formation is pre-Maestrichtian age (Reyment, 1965). It derived its name from the Illo district of the southern part of Sokoto province. It consists of terrestrial grits and pisolitic and nodular clays with a thickness of about 210 meters in place. Silicified wood occurs (Reyment, 1965). It is found mainly in north-most part of Borgu, but markedly absent in the other parts of the State. It has sandstones of fluvial and lacustrine origin and are probably contemporaneous with the Bima Sandstone.

### Location of Clay Deposits in Kwara State

Fig. 1 is the geological map of Kwara State showing the location of the clay deposits. Table 1 gives Local Government Areas, the relevant towns and the description of the site of the deposits. The estimated quantities are given in Table 2. Details of the samples that were utilized are given below.

**Owode—Jimba Clays:** It is located at about 18 km along Ilorin — Omu-Aran road. The clay is found less than 1 kilometer away from the major road. It is intensively used for pottery work within and around the town. The extent of the reserve is yet unknown.

**Kaima Clay:** This is a town in northern part of Kwara State in Borgu Local Government Area. The reserve is at about 200 meters from the roundabout at the core of the town. It occurs at a shallow depth opposite the new post office. It is a greyish clay with white patches, and sand inclusions. It is overlain by a thin lateritic overburden. The actual reserve has not been investigated. It is put to use by local potters.

**Okelele Clay:** This is in the North—Western part of Ilorin township, Ilorin Local Government Area. It lies slightly South—West of Sobi Hills. The clay is a residual deposit formed by insitu weathering of migmatic gneiss. It is a greyish clay with occasional reddish brown stain, it becomes friable, whitish grey and kaolinitic towards the partially decomposed parent rock below. There are large reserves of the mineral with minimum of 2 million tonnes. The clay occurs at shallow depth under thin lateritic overburden. The clay can be mined by open cast method because of the thin lateritic overburden. This reserve could support an industry with a daily production capacity of 30,000 bricks for 74 years assuming a 6—day working week and a 50—week working year (Abatan, 1983). It is intensively used by the local inhabitants for pottery and brick making. It has potentialities of being used for sanitary wares, drainage pipes and pottery material. The site for Oloje clay deposit is close to that of Okelele and slightly south—west of Sobi Hills. The quantity of the deposit is unknown.

## TEST PROCEDURE

The test procedures are as shown in Ola (1985a) as presented in this seminar.

## **GEOTECHNICAL PROPERTIES OF SOME UNSTABILIZED KWARA SOILS**

### **Mineralogy**

Details of X—ray diffraction analysis performed on the Kwara soils are identical to those shown for the Bendel soils in Ola (1985a). The results indicate that all the Kwara soils investigated including Kaima, Pategi, Okelele and Owode—Jimba clay consisted of mainly kaolinite and quartz. The Owode—Jimba clay however also had K — feldspar. The results are consistent with those shown for the Bendel soils. It appears that in the two States soils which have been found adequate for brick (and pottery) making are predominantly kaolinite, quartz with some feldspar.

Table 1: Location of Clay Deposits in Kwara State (Modified from G.S.D.)

Local Govt. Area	Town/Village	Location of Deposit
Asa	Ballah	Located at about 5 km West of Eyekorin, along and around Eyekorin – Ballah road.
	Budoegba	Located around and within the channels of River Jaju.
	Elerinjare	3 km from Idofian on Ilorin–Ajasse road.
	Onire–Kolofo	5 km along Ilorin – Igbetti road.
	Owode–Jimba	18 km along Ilorin – Omu–Aran road.
Borgu	Kaiama	Opposite new Post Office at about 200m from garage along Kaiama – Kainji road.
Edu	Pategi	About 500 m from the centre of the town.
Ifelodun	Igbaja	About 200 meters north of Igbaja town.
	Oke–Oyan	Located 36 km north of Omu–Aran
	Share	4 km from Iyana, Iyana is 6.1 km from Ilorin.
Ilorin	Okelele	North–Western part of Ilorin.
	Oloje	Slightly south–west of Sobi Hills close to Okelele.
Irepodun	Ojan–Otin	5.5 km South–east of Oro.
Kogi	Mimi	About 2.4 km from Lokoja by the bank of Mimi river.

Table 2: Quantities of Clay Deposits in Kwara State

Town/Village	Quantity	Source
Ballah	Unknown	Federal Ministry of Mines and Power G.S.D. (Ilorin).
Budoegba	About 100 sq meters in lateral extent.	
Onire—Kolofo	Area extent of about 1.5 sq. km.	
Kaiama	Unknown	
Pategi	1000 tonnes	
Igbaja	About 6 km in lateral extent, Thickness varies.	
Oke—Oyan	approx. lateral extent of 350 meters.	
Share	2.9 sq. km; 7 – 10 million tonnes.	
Okelele	2 million tonnes	
Oloje	Unknown	
Ijan—Otin	Unknown	
Mimi	1.5 million tonnes.	
Owode—Jimba	Unknown	
Elerinjare	Unknown	

The physical properties of the soils are shown in Table 3. The dimensions of the mould utilized for all the test are as follows: 228.6 x 114.3 x 76.2mm (9<sup>1</sup>/<sub>8</sub> x 4.5<sup>1</sup>/<sub>8</sub> x 3<sup>1</sup>/<sub>8</sub>). The specimens were moulded at their different dry densities and optimum moisture contents at the various compactive pressures. Sample results of static compaction at the various compactive pressures are shown in Figures 2 to 4. The summary for the soils is shown in Table 4. The drop test is used to determine the starting moisture content for the various compactive efforts. In the drop test, a handful of moistened soils is squeezed into a ball and then dropped from a height of 0.91m (3ft.) on to a hard ground. The soil is assumed to have the right amount of moisture if the ball breaks into smaller pieces but does not break up completely (Okie, 1971).

### Unconfined Compression Tests

Fig. 5 shows the compressive strength plotted against the cement content at a compaction pressure of 5MN/m<sup>2</sup>. The results give approximately a linear relationship between strength and cement content for the three soils. At higher cement contents, each of the three soils shows strength increases. Similar trends were recorded for some Bendel soils (Ola 1985a). At the compactive effort of 5MN/m<sup>2</sup> utilized in Fig. 5, all the soil bricks (in both stabilized and unstabilized states) attained strengths which exceeded the minimum strength of 2.8MN/m<sup>2</sup> recommended in BS 2028 for precast concrete.

Fig. 6 is the graph of compressive strength versus compaction pressure for the unstabilized soils while Fig. 7 is for 5% cement stabilised soils. From Fig. 6, it is observed that there is a general increase in compressive strength with increase in compactive pressure for the three soils considered. The rate of increase in compressive strength with compaction pressure increase has initial high values but at higher compaction pressures insignificant increase in compressive strengths are obtained. For example, for a compaction pressure of 1MN/m<sup>2</sup> to 2MN/m<sup>2</sup> increases in compressive strength of 62.5% to 132% were obtained while for a compaction pressure of 5MN/m<sup>2</sup> to 6MN/m<sup>2</sup> increases in compressive strength of only 2.9% to 5.4% were obtained. Thus at high compaction pressures of 5 to 6MN/m<sup>2</sup>, the compressive strength increases at a decreasing rate. Similar results are shown in Fig. 7 for cement stabilized soils. Also, similar trends were recorded on some Bendel soils (Ola 1985a) and on some Kumasi soils (Lunt, 1980).

From all the work so far presented, it is obvious that compaction pressure plays a major role on the compressive strength of the soil bricks. It is equally obvious that relatively insignificant gains in compressive strength are obtained at higher com-

paction pressures greater than 6MN/m<sup>2</sup>. Therefore, for the purpose of moulding bricks at high pressures, a compaction pressure of 6MN/m<sup>2</sup> is recommended because of the law of diminishing returns.

### Water Absorption Test

Fig. 8 gives the water absorption test results after 24-hour complete immersion, while the Initial Rate of Absorption (IRA) values are plotted in Fig. 9. These results show that the Kaiama soil absorbs the least amount of water and the IRA value for all the soils lie between 25 and 35 for 0% cement and 15 and 20 for 5% cement.

### Durability Test

The percentage loss in weight and the percentage volume change are shown in Figs. 10 and 11 respectively. These values decrease with increasing cement content.

### OTHER PROPERTIES

Other relevant properties are shown in Table 3. The liquid limit ranges between 50 and 66, plasticity index between 25 and 45, and the linear shrinkage between 10 and 16. All these values indicate that the soil has significant swelling and shrinkage characteristics. The specific gravity lies between 2.65 and 2.70, coefficient of linear expansion approximately about  $5 \times 10^{-5}$  and coefficient of thermal conductivity about 1.5W/mK (Watt per metre degree). The results of the coefficient of linear expansion was similar to the values obtained for some Bendel soils ( $3 \times 10^{-5}$ ), Ola (1983). This however compares with the value of  $5 \times 10^{-6}$  obtained by Mehra and Uppal (1950) for some Indian soils. While Watson (1964) obtained the values of  $1 \times 10^{-5}$  for some British bricks, more investigation is continuing.

One of the important requirements of a material for building construction is that it should allow as little heat to pass through it as possible. This is all the more important in tropical countries where the thickness of the wall has sometimes to be increased to reduce the passage of heat. From the results there was no appreciable difference in the conductivity of the Kwara soils, when compacted to the optimum moisture content. The values increase slightly when 4% cement was added. The conductivity of the compacted soils increased slightly as the cement content increased. Thus, from the insulation point of view, less cement should be preferred provided other structural properties are not materially affected. This is yet another point to recommend the compressed blocks, as it has been shown that the use of certain stabilized com-

Table 3: Summary of the physical properties of some Kwara Clays

Tests	Owode Jimba Clay	Okelele	Pategi	Kaiama	Oloje
Liquid Limit (%)	65.8	64	60	56	53
Plastic Limit (%)	25	30.1	17	26.7	26
Plasticity Index (%)	40.8	33.9	43	29.3	27
Linear Shrinkage (%)	16.1	13.9	12.3	11.7	10.4
Specific gravity	2.67	2.69	2.68	2.68	
Coefficient of Linear expansion		$4.9 \times 10^{-5}$		$5.2 \times 10^{-5}$	$6.6 \times 10^{-5}$
*Thermal Conductivity W/mK at 1 MN/m <sup>2</sup>					
0% cement		1.4		1.46	1.36
4% cement		1.5		1.56	1.37
Maximum dry density (standard Proctor) kg/m <sup>3</sup>	1675	1610	172	1795	
Optimum moisture content (Standard Proctor) (%)	19.6	16.2	18.8	16.4	15.6
Mineral Constituents	Kaolinite, Quartz and K-felspar	Kaolinite, Quartz	Kaolinite, Quartz	Kaolinite, Quartz	

\*Calculated from Andersland and Anderson (1978).

Table 4:

**SUMMARY OF COMPACTION TESTS**

Sample Source	Optimum Moisture Content (Wopt½)			
	Drop Test		Standard proctor	Modified PROCTOR
	Unstabilized Soil	Stablized Soil		
Oloje	12.33	13.92	15.60	13.40
Okelele	13.51	14.13	15.20	—
Kaiama	14.60	15.93	—	—

Table 4a. Optimum moisture content values using drop test, standard proctor and modified proctor.

Percentage cement (%)	For 1MN/m <sup>2</sup> Compaction Pressure		For 6MN/m <sup>2</sup> Compaction Pressure	
	Maximum dry density kg/m <sup>3</sup>	Optimum Moisture Content (%)	Maximum dry density (kg/m <sup>3</sup> )	Optimum moisture Content (%)
0	1.68x10 <sup>3</sup>	14.40	1.92x10 <sup>3</sup>	12.60
4	1.685x10 <sup>3</sup>	14.80	1.94x10 <sup>3</sup>	13.40
15	1.82 x 10 <sup>3</sup>	15.20	1.997x 10 <sup>3</sup>	13.60

Table 4b. Static compaction test results for Oloje Soil.

Percentage cement (%)	For 1MN/m <sup>2</sup> Compaction Pressure		For 6MN/m <sup>2</sup> Compaction Pressure	
	Maximum dry density (kg/m <sup>3</sup> )	Optimum moisture content (%)	Maximum dry density (kg/m <sup>3</sup> )	Optimum moisture content %
0	1.697x10 <sup>3</sup>	14.25	1.94 x 10 <sup>3</sup>	12.40
4	1.750x10 <sup>3</sup>	14.55	1.98x10 <sup>3</sup>	14.39
15	1.87 x 10 <sup>3</sup>	15.10	2.02x10 <sup>3</sup>	14.85

Table 4c. Static compaction test results for Okelele Soil.

Percentage cement (%)	For 1MN/m <sup>2</sup> Compaction Pressure		For 6MN/m <sup>2</sup> Compaction Pressure	
	Optimum moisture content %	Maximum dry density (Kg/m <sup>3</sup> )	Optimum moisture content %	Maximum dry density (Kg/m <sup>3</sup> )
0	14.54	1.730x10 <sup>3</sup>	14.15	1.76 x 10 <sup>3</sup>
4	15.55	1.781x10 <sup>3</sup>	15.10	1.821x10 <sup>3</sup>
5	16.35	1.81 x 10 <sup>3</sup>	15.90	1.88 x 10 <sup>3</sup>

Table 4d. Static Compaction test results for Kaiama Soil.

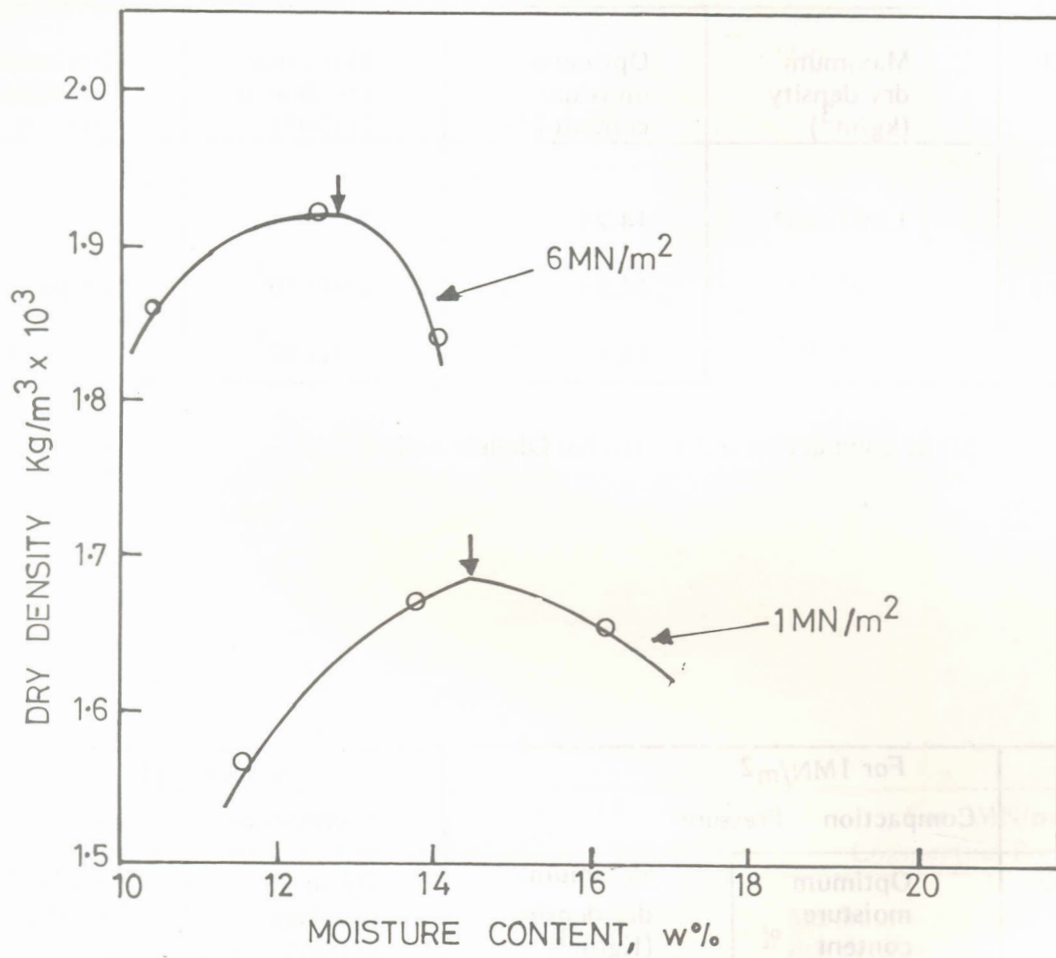


FIG. 2. STATIC COMPACTION CURVES FOR UNSTABILIZED OLOJE SOIL

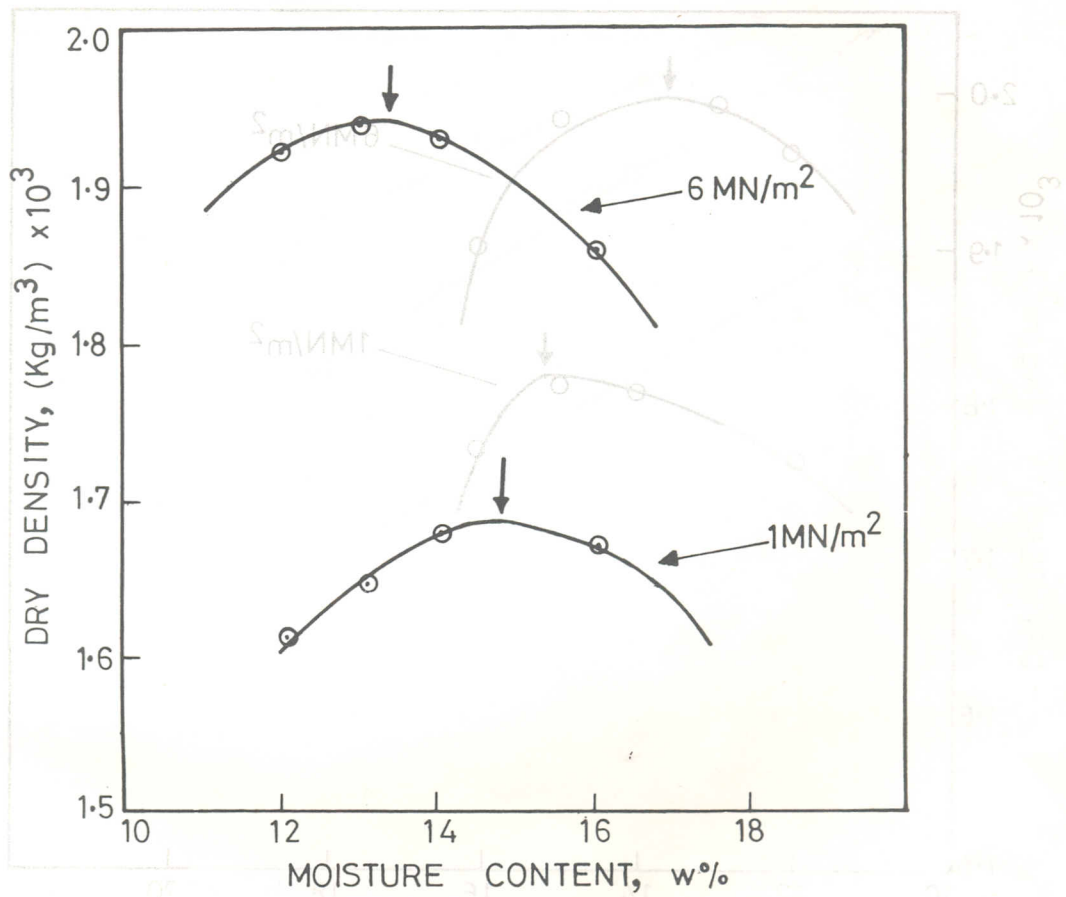


FIG. 3. STATIC COMPACTION CURVES FOR OLOJE SOIL STABILIZED WITH 4% CEMENT

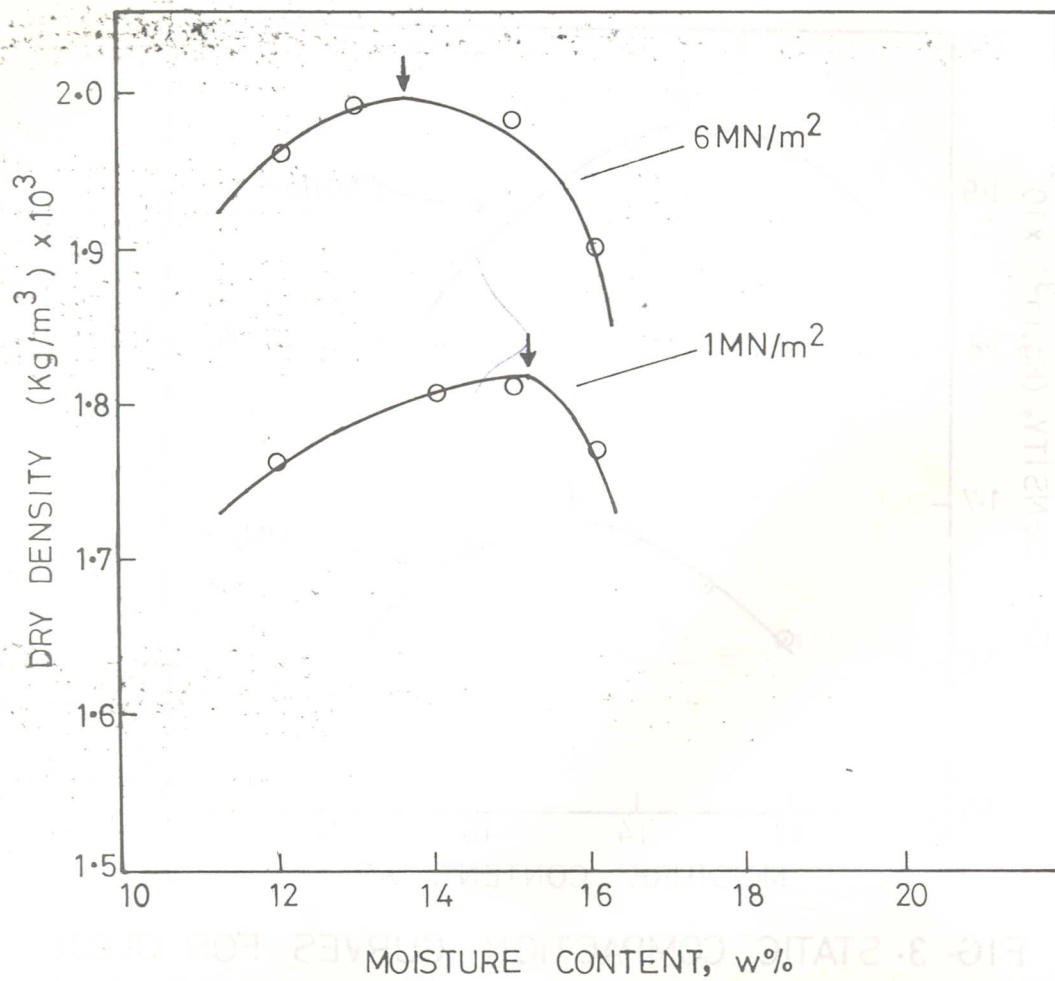


FIG. 4. STATIC COMPACTION CURVES FOR OLOJE SOIL STABILIZED WITH 15% CEMENT

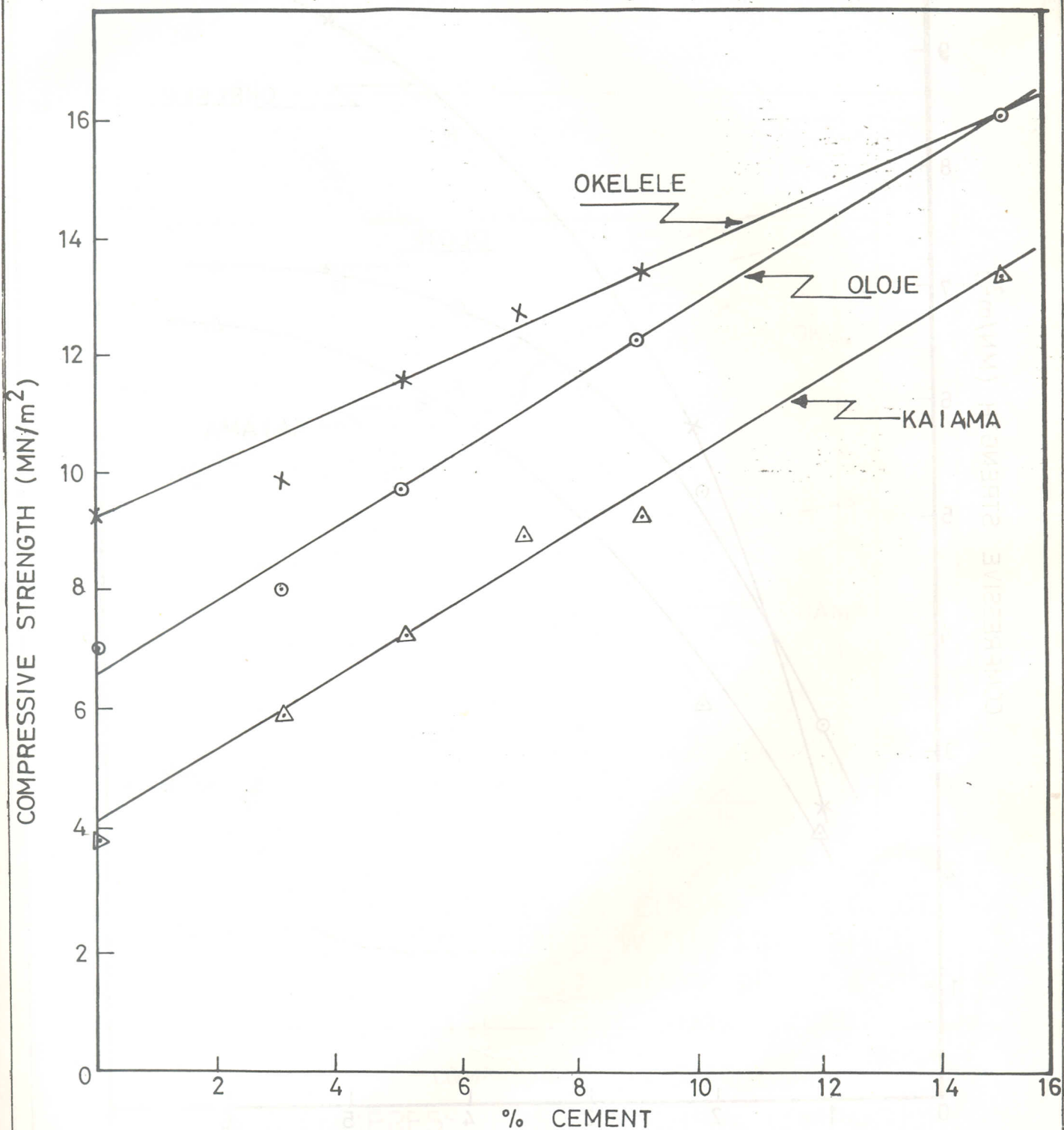


FIG. 5. COMPRESSIVE STRENGTH Vs % CEMENT  
5 MN/m<sup>2</sup> COMPACTION PRESSURE

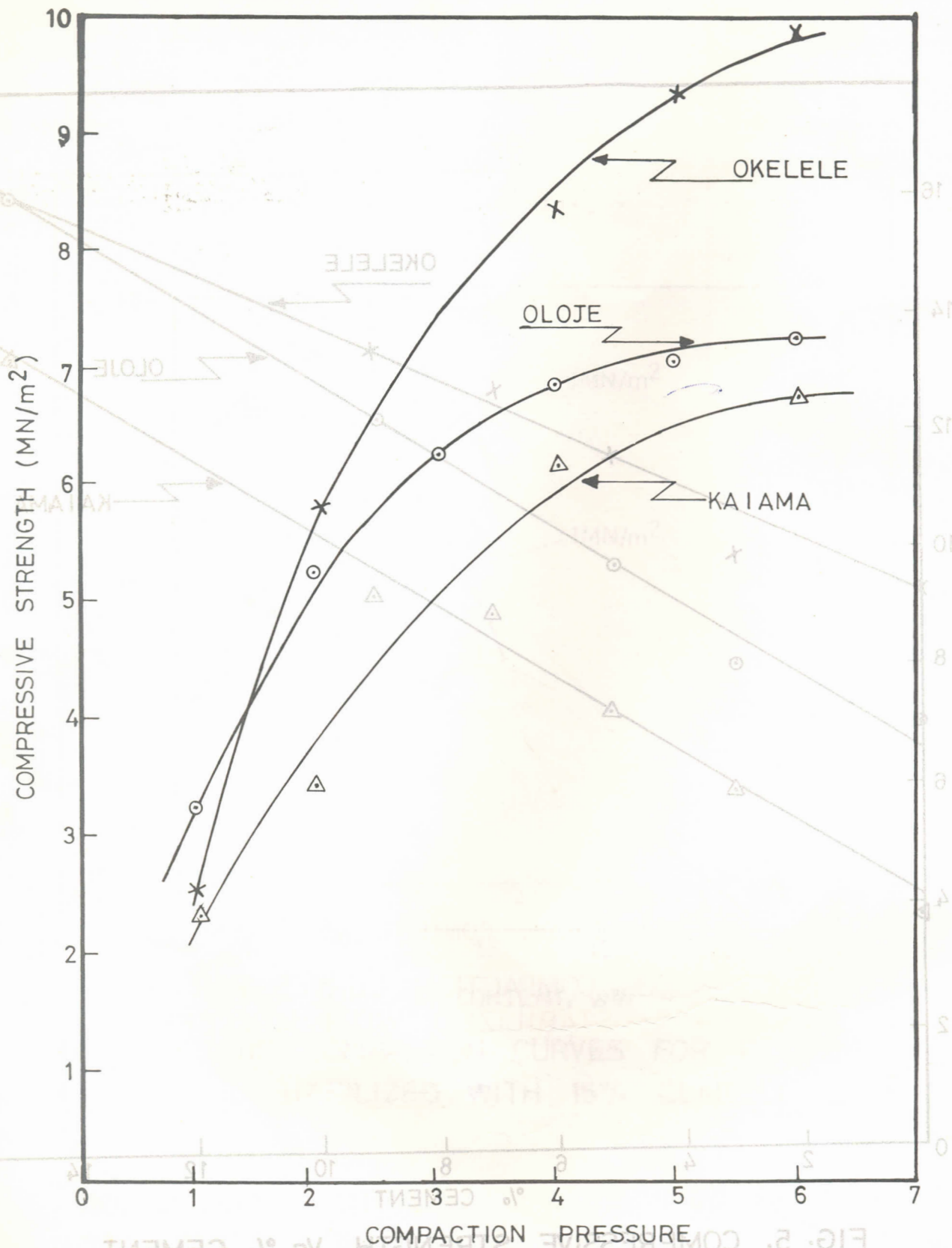


FIG. 6. COMPRESSIVE STRENGTH VS COMPACTION FOR THE UNSTABILIZED SOILS

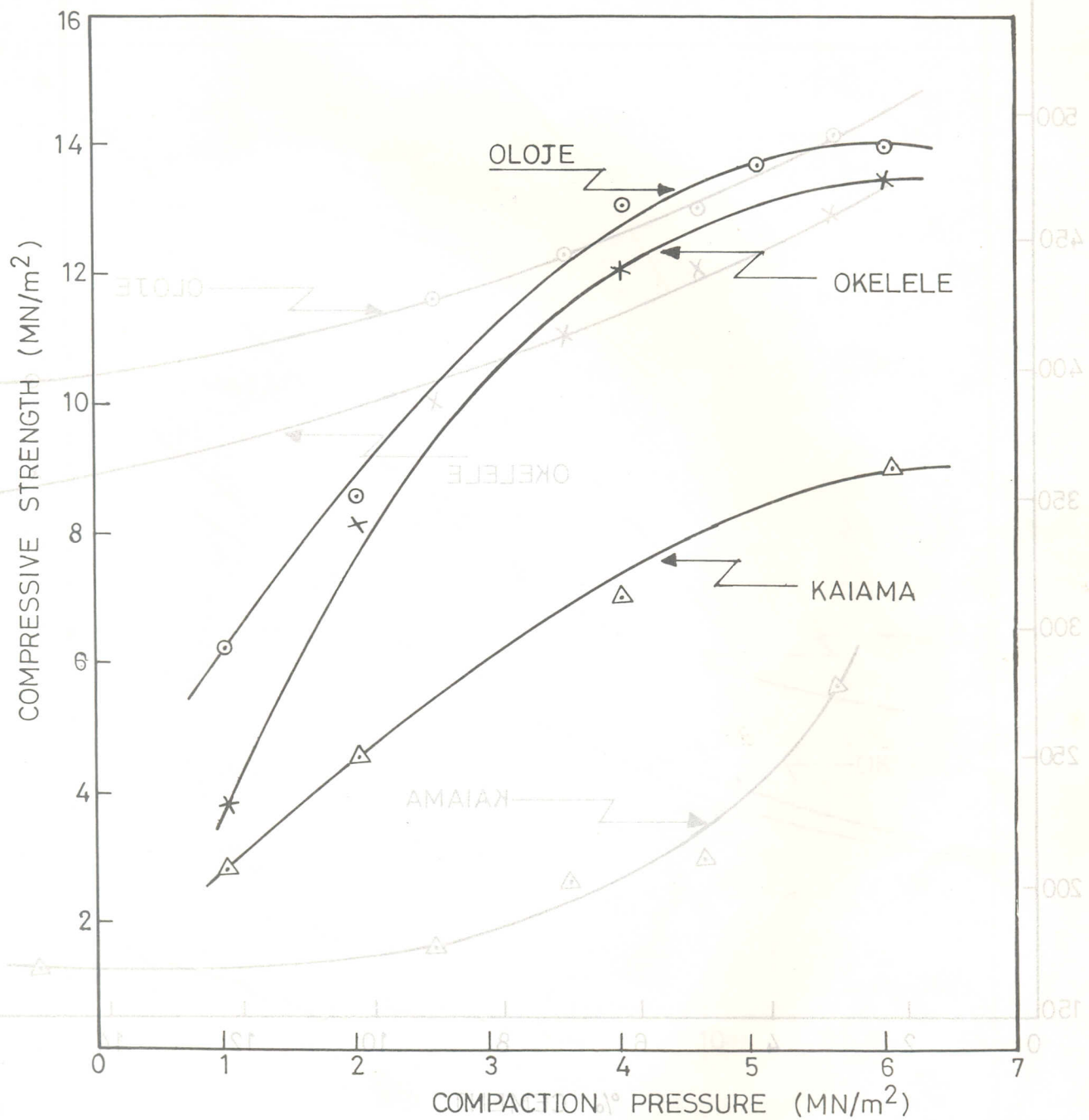


FIG. 7. COMPRESSIVE STRENGTH Vs COMPACTION PRESSURE FOR 5% CEMENT STABILIZATION

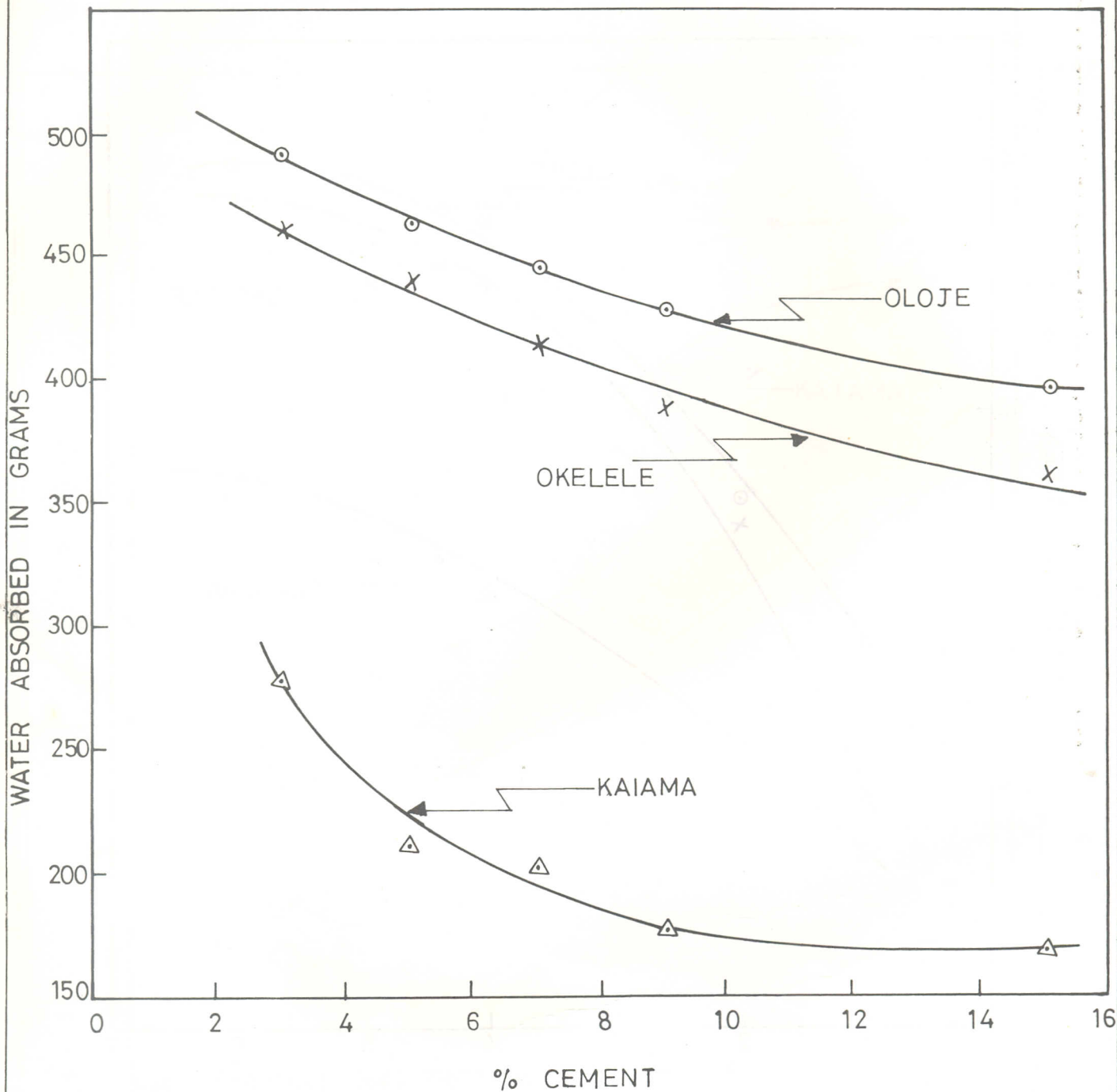


FIG. 8. WATER ABSORBED Vs CEMENT  
(24-HOURS COMPLETE IMMERSION TEST)

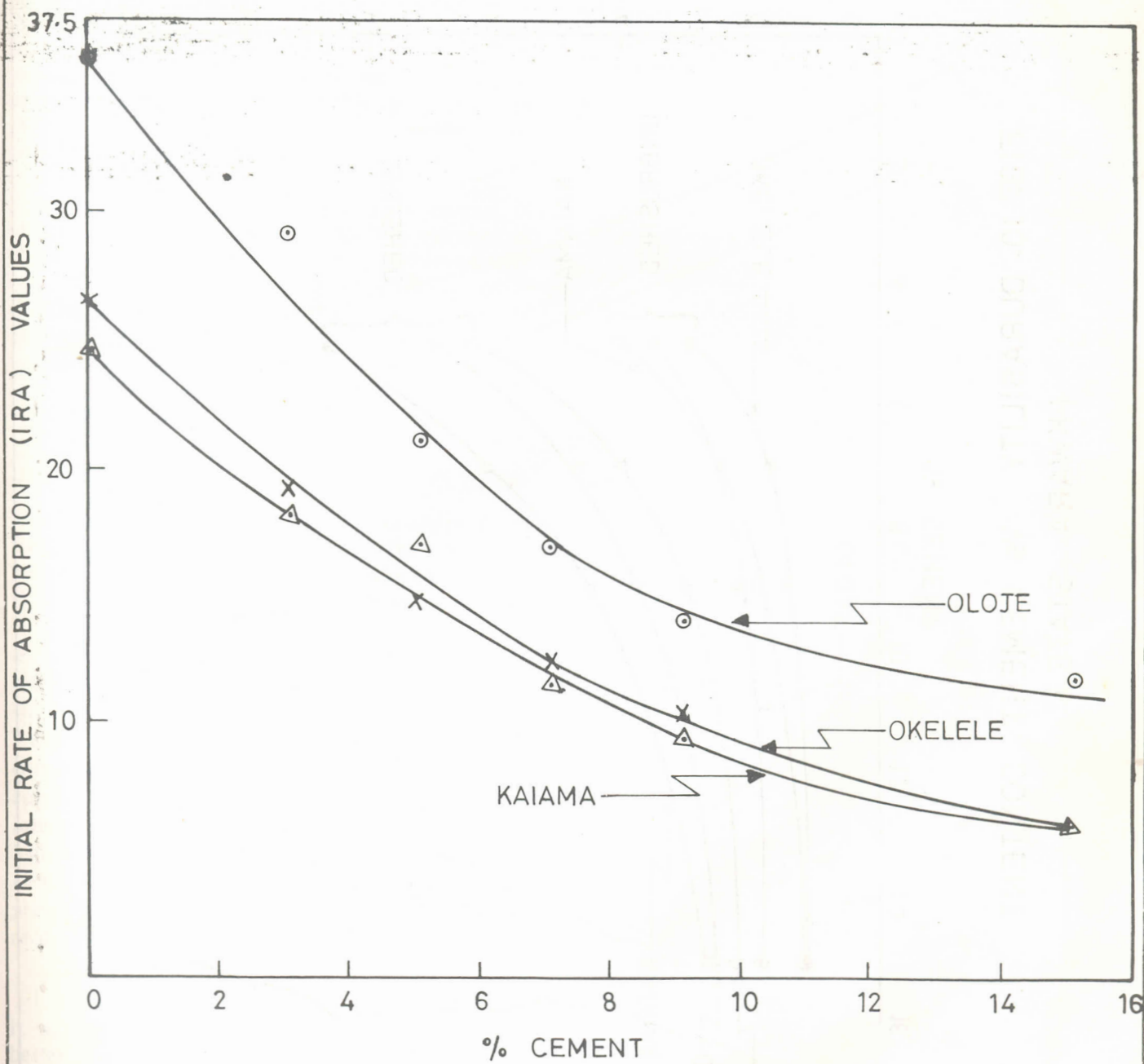


FIG. 9. IRA VALUES Vs % CEMENT

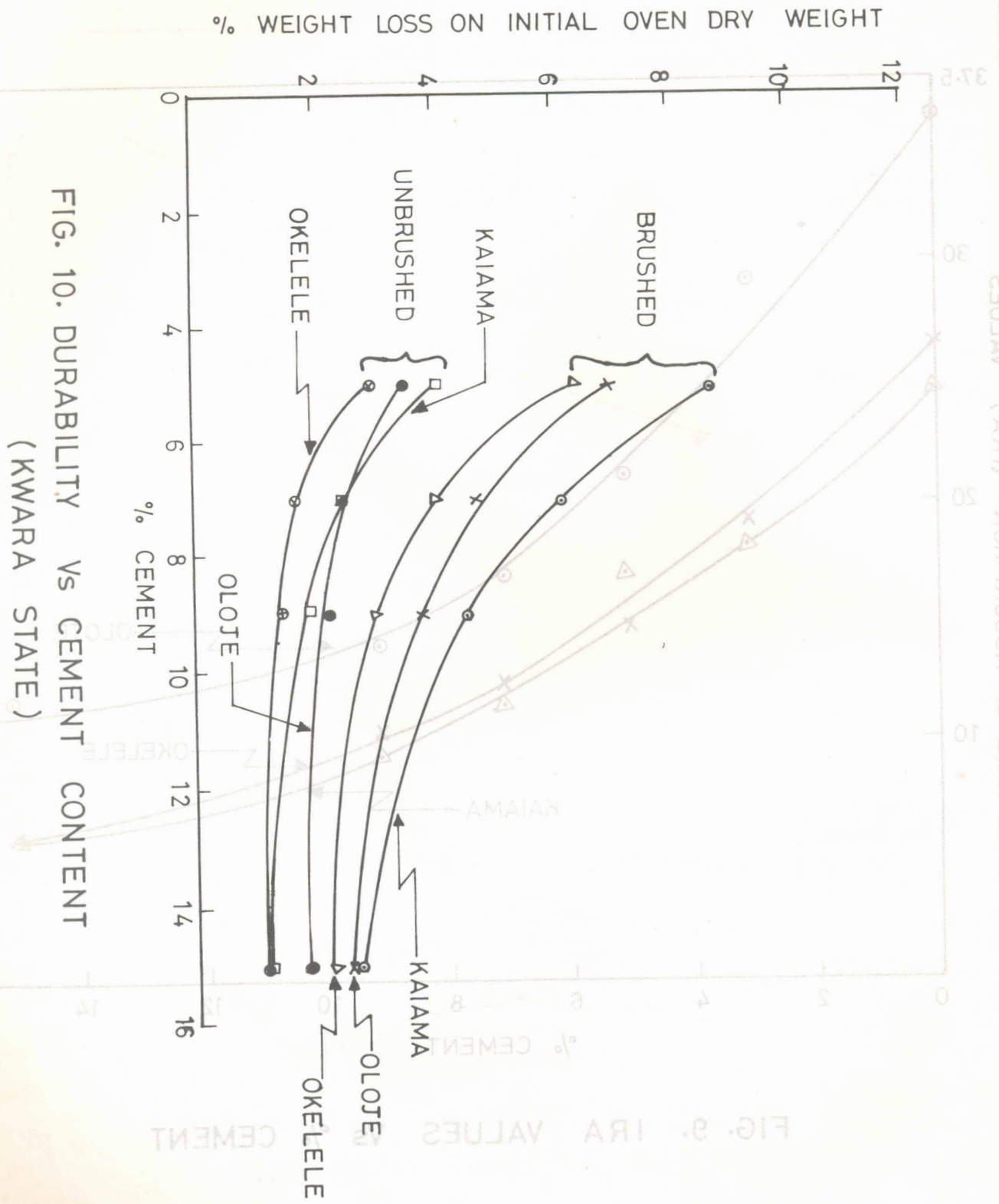


FIG. 10. DURABILITY VS CEMENT CONTENT (KWARA STATE)

pressed bricks in engineering construction can be justified not only because the structural qualities like compression strength, etc. are suitable but also because of their better thermal insulation properties.

Another very important requirement is the sound insulation value. Through any barrier, the transmission of sound is determined almost entirely by its weight per unit area. The brick wall, because of its weight, gives a fairly good sound-reduction values. A party wall according to Wilkinson (1961) should provide an average sound reduction of about 55 decibels. In view of this compressed stabilized soils (because of their higher densities) should have good sound-reduction values.

Rosenak (1957) claimed that a daily output of about 2,000 soil bricks or half the number of blocks of larger dimensions can be achieved with most machines. He, along with many other workers in the area believe that if an addition of cement much in excess of 5% is required for successful stabilization, the method will usually be found to be too expensive compared with say, ordinary brickwork.

### CONCLUSION

The Kwara soils, like the Bendel soils are predominantly kaolinite with some quartz. The behaviours are very similar to those of the Bendel soils. There is a general increase in compressive strength with

increase in compactive pressure. At a compactive effort of 5MN/m<sup>2</sup> all the soil bricks attained strengths which exceeded the minimum strength of 2.8MN/m<sup>2</sup> recommended in BS 2028 for precast concrete. From all the work so far done, it is conclusive that compaction pressure plays a major role on the compressive strength are obtained at higher compaction pressures greater than 6MN/m<sup>2</sup>. Hence for the purpose of moulding bricks at high pressure, a compaction pressure of 6MN/m<sup>2</sup> is recommended.

It was also found that less cement is required for better thermal insulation properties while compressed stabilized soils generally have good sound-reduction values. For trial tests, 5% cement stabilized soils at compaction pressure of 6MN/m<sup>2</sup> moulded at the optimum moisture content should be utilized as the starting point for field trial.

### ACKNOWLEDGEMENT

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## ENGINEERING PROPERTIES AND BEHAVIOURS OF STABILIZED/UNSTABILIZED COMPRESSED BENDEL SOILS

by

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### ABSTRACT

*Bendel soil is widely used for building purposes but it is generally not a very durable material hence many additives have been used to improve its resistance to the weather. Of these, portland cement and lime are the most important.*

*In this report, the geology of the area under study is discussed, the geotechnical properties of the soils without any stabilization are determined by experimentation. The effects of compaction at high pressures on the compressive and tensile strengths, durability, water absorption capacity and other engineering properties are studied at various percentages of stabilizing agents.*

### INTRODUCTION

The objective of this paper is to determine the engineering properties of many Bendel soils including the clay deposits which the local people normally utilize for brick construction; find out the effects of additives like lime and cement, and the effects of compaction at high pressures.

### GEOLOGY OF BENDEL STATE

About 90% of Bendel State is underlain by sedimentary rocks. The remaining 10% of the land areas, restricted to the northern part of the state is underlain by the crystalline Basement Complex (See Fig. 1). Most of the sites under study can be found either in Ameki, Ogwashi, Asaba or Benin formation.

### THE SEDIMENTS

#### Ameki Formation

The Ameki Formation was formalized by Reymont (1965) after it has variously been referred to as Bende – Ameki group. The Ameki Formation which is of the Upper Eocene age overlies the Imo Formation and consists of green-grey clayey sandstone and sandy claystone with a thickness of approximately 84 meter. The thickness may reach as much as 1,400 metres in some places. It is divisible into two lithologic units, lower and upper Ameki. The upper beds contain coarse cross-bedded sandstones, bands of fine, grey-green sandstone and sandy clay and the lower beds consist of fine to coarse sandstones and intercalations of calcareous shale and thin shelly limestones. Below 595.1 m (1951 ft.) there is a distinct lithologic change with the appearance of the greyish-

green Imo Shales. The sediments of Ameki Formation were found to be poorly fossiliferous compared to Imo Formation; (Kogbe et al 1976; Reymont 1965). Agbede is an important town situated on this formation.

#### Ogwashi-Asaba Formation

The boundary between the Ameki Formation and the overlying Ogwashi-Asaba Formation may be difficult to establish. This formation was formerly known as the "Lignite Series" and "Lignite Group". Lithology consists of an alternation of lignite seams, sands and clays. Some of these seams may be up to 6m thick. An age of Oligocene to Miocene has been suggested because of its stratigraphic position (Reymont, 1965). The presence of coal seams in the formation make it suitable for palynological investigation (Kogbe et al 1975).

The Ishan Plateau and towns like Okpanam, Asaba, Ibusa, Umunede are situated on this formation.

#### Benin Formation

The Benin Formation of Miocene-Pleistocene age overlies the Ogwashi-Asaba Formation. The former consists of yellow and white sands sometimes containing crossbedding. Iron stained gritty beds, clays and sandy clay lenses may occur in the formation. (It is over 90% sandstone with shale intercalations.) The Benin Formation is partly marine, partly deltaic, partly estuarine, and partly lagoonal and fluviolacustrine in origin; (Reymont 1965). In terms of surface land areal coverage, the Benin Formation constitutes the largest single formation of the sedimentary group in Bendel State. Various structural units (point bars, channel fills, natural levees, backswamp deposits, oxbow fills) are identifiable within the formation, indicating the variability of the shallow water depositional medium.

It underlies Benin City, Ehor, Agbor, and good outcrops occur along the Benin-Agbor road and in the valley of Ikpoba river in Benin City.

The Benin formation is overlain in the delta area and in the valleys of the larger rivers by Mangrove Swamp Deposits and Alluvium consisting of inter-layered sand, silt, clay and plant debris. The sands are generally well sorted and vary from fine to coarse-grained or pebble size. Cross stratification

may be present. The clayey silt and silty clays are dark grey to black and contain decaying organic matter. These deposits are of Holocene age, and underlie towns like Warri, Sapele and the coastal areas of the State.

### LOCATION AND QUANTITY OF CLAY DEPOSITS IN BENDEL STATE.

The first consideration in any mining operation is the determination of the raw materials. The location of the various clay deposits in Bendel State is thus given in Table 2a while Table 2b gives the location, the type of clay, the estimated quantity and the use to which the deposits are being put by the local inhabitants.

Out of all these clay deposits, 4 samples have been selected for the initial study. These soils are from Igbanke in Orhionmwon Local Government Area, Ubulu-Uku from Aniocha Local Government Area, Usen from Ovia Local Government Area and from the site of the new College of Medical Sciences at Ugbowo.

The Usen soil was collected from a town about 60 kilometres north-west of Benin in Ovia Local Government Area of Bendel State. The deposit is situated in the Arhenwen stream river bed along Ilewa camp road, which is in a village about 30 metres below the ground surface. Augering or borehole was not found necessary. Samples were simply collected from the location after removing the exposed dry layers. At natural moisture content, the sample is (coal) black and stiff. It was this colour that initially aroused our curiosity and attracted our attention to the clay. It must be noted however that the black colour does not make it attractive as a building material hence the inhabitants of the town do not generally use this clay for building purposes.

The Igbanke soil was collected in the bed of Iyoma stream in the midst of a thick bush which is about 25cm below the ground surface. Most of the houses at Igbanke are mud houses built with bricks made from the clay deposit. The clay is also used for pottery.

Ubulu-Uku, the location of Ubulu-Uku soil is a town about 20 km from Agbor. The sample was collected in the bed of Iyi-Ago stream which is about 10m to 15m below the ground surface. The clay is mainly used for pottery, but in some cases, it is also used for construction of houses.

### TEST PROCEDURE

Generally, tests were performed in accordance with ASTM specifications although a few modifications were made because of the nature of the soils. To determine the Atterberg limits, the samples were mixed with distilled water up to the plastic limit for about five minutes and left overnight for 24 hours, then mixed for another five minutes before testing.

For grain-size distribution, the samples were air-

dried then wet-sieved through a No. 200BS sieve with a No. 52 sieve placed on top for protection, then oven-dried at 60°C. In the hydrometer tests, sodium hexametaphosphate was used as dispersant.

The mixing procedure prior to compaction was as recommended by the Portland Cement Association (1959) for soil-cement. The soils were air-dried, pulverized, and divided into batches before each batch was thoroughly mixed with the stabilizer to uniform colour. Water was then added as rapidly as practicable before compaction. The wet-dry test was also conducted according to the recommendation of the Portland Cement Association (1959) for soil cement.

The following tests were conducted on each of the different groups of soil under investigation:

#### (a) Compressive Strength

The samples were cured by storing them for seven days in a room where the temperature was uniform. After curing, the specimens were tested in compression at a rate of 1.72MN/m<sup>2</sup>/min (250lb./sq. in/m.n.) or at a rate of strain of about 1.27mm/min (0.05 in/min). The moisture content of the specimen was determined after testing, using the fragments, and the dry soil-cement density checked by weighing and calculation. The average values of compressive strength, dry soil-cement density and moisture content were reported for each batch of four (five or ten) specimens.

#### (b) Water Absorption

##### (i) 3mm immersion

The specimens were placed on suitable carriers weighed and placed on a perforated plate in a second metal tank in which water was maintained at a level of 3mm above the bottom of the specimen. The weight of water absorbed (in gm) by the brick in 1 minute was determined by weighing. Since bricks are of varying dimensions, the value thus obtained was corrected mathematically to give IRA (Initial Rate of Absorption) in terms of a standard bedding surface area of contact, taken as 193.55 sq. cm. (30 sq. in). Therefore, the IRA of a brick is expressed as the number of grams of water absorbed in 1 minute on a 193.55 sq. cm. (30 sq. inch.) area.

Similarly, the weight of water absorbed (in gm) was then determined at intervals of 1, 3, 7, 14 and 28 days by finding the increase in weight of the specimens.

##### (ii) Complete immersion

Two/(five)\* bricks were dried to constant weight (after curing for 7 days) at 100°C (230°F) and then after cooling to room temperature, they were immersed completely in

water at room temperature for 24 hours. The bricks were then removed from water, the surface water was wiped off with a damp cloth and the specimens were weighed, to find the weight absorbed.

#### (c) Durability Test

For the wetting and drying test, after 7 days curing in a damp atmosphere, the specimens were immersed in water for 5 hours, after which the No. 1 specimen was weighed and measured, and both specimens were placed in an oven at 160°F (71°C) for 42 hours. On removal, both specimens were weighed, the No. 1 specimen was measured, and the No. 2 specimen brushed firmly all over with a nylon (stiff wire) brush and weighed again. This was repeated until the specimens had been through twelve cycles of wetting and drying. They were then dried to constant weight at 100°C (230°F) and weighed.

#### (d) Thermal Expansion Test

After curing the sample in the usual way for 7 days, the samples were dried to constant weight at 110°C in the oven; the sizes i.e. length, breadth and thickness were then accurately measured at least by means of callipers). For each side at least an average of 3 measurements were taken. The sample was then cooled to room temperature and the average measurements were also taken.

#### (e) Uni-axial Tension Test

For the direct tension tests, equipments similar to those of Bofinger (1970) were designed and utilized. Also in order to achieve high compaction pressures special moulds similar to those of Lunt (1980) were built and utilized. The dimension of the mould as constructed by us is 228.6 x 114.3 x 76.2mm (9" x 4.5" x 3").

Each of the soil specimens were moulded at their different Maximum Dry Densities (MDD) and Optimum Moisture Contents (O.M.C.) The specimens, were then finally removed, and a thin film of wax which had been heated to melting point was smeared around the surface of the specimens to reduce the loss of the moisture content of the specimens. They were then cured in a moisture controlled environment for one week (7 days) before being tested.

After 7 days, the samples were tested, using the universal hydraulic testing machine. Initially, the thin film of wax was first of all scrapped carefully from the surfaces of the samples. The samples were then held at both ends by the adapted metal plates, and then clamped to ensure fixity at the ends. Although the clamping and the friction between the surfaces of the specimens and the metal plates gave enough gripping to the samples, care was taken during the tests to prevent any slippage of

the samples from the gripping metal plates.

The clamped samples were then loaded at a constant stressing rate until failure occurred. The load corresponding to failure was then recorded. The rate of loading was approximately 57.4 kN/m<sup>2</sup>/min. For most of the tests, the percentages of cement utilized were 0, 3, 5, 7, 9, 15.

### GEOTECHNICAL PROPERTIES OF SOME UNSTABILIZED BENDEL SOILS

#### Mineralogy

The particle size distribution curves for the Bendel soils used in the investigation as a result of wet sieving is shown in Fig. 2. Ubulu-Uku soil consists of more than 80% clay while the other three soils have clay fraction of 30% to 40%. The physical properties of all the soils are shown in Table 3. These results also confirm the high clay fraction of Ubulu-Uku with very high liquid limit, high linear shrinkage and high free swell.

Fig. 3 shows the X-ray diffraction analysis on the fraction of Igbanke soil passing No. 200 B.S sieve. The result for Ubulu-Uku soil is shown in Fig. 4.

For both soils, the compositions are about 40 per cent kaolinite and 60 per cent quartz. The results for the Usen soil is shown in Fig. 5a to Fig. 5c. The soil is predominantly kaolinite with some feldspar. The presence of kaolinite was confirmed by the presence of 7.13A° peak in the ADPO, which disappears after heat treatment. The presence of quartz was confirmed by the 4.23A° reflection and by the narrow characteristic peak at 3.33A°. The presence of feldspar was suggested by the strong reflection at 3.18A°.

### COMPRESSIBILITY AND STRENGTH

Figure 6 shows the oedometer test results with Igbanke soil placed at liquid limit. Analysis of this gives a compression index (Cc) of 0.24. Results for Igbanke soil placed at standard proctor is shown in Fig. 7 and gives a Cc of 0.20; while that for Ubulu-Uku soil also at standard proctor is Cc of 0.21. These results show all the soils to be relatively compressible. It is interesting to note that this result is similar to the results obtained from the Sokoto soft clay shale. (Cc = 0.23); Ola (1983).

Table 4 gives a summary of the strength characteristics of the unstabilized soil. The Ubulu-Uku soil with highest clay content gives the highest unconfined compression strength at 245.6 kN/m<sup>2</sup>. The results of the Triaxial tests for Usen of C (24 kN/m<sup>2</sup>) and  $\phi$  of (26°) compares favourably with the triaxial tests on a lateritic clay from Zaria with identical mineralogy (predominantly kaolinite) and corresponding plasticity index (PI: 47%). This Zaria lateritic clay gave C of 24 kN/m<sup>2</sup> and  $\phi$  of 26.5°; Ola (1978), Ola (1983).

Other properties of the unstabilized soils are shown in Table 3. The compaction test results at standard proctor, West African compaction and Modified proctor are also indicated. The density of the

Ubulu-Uku soil is relatively low at  $1451.3\text{kg/m}^3$  ( $90.60\text{pcf}$ ) for the standard proctor and the optimum moisture content is relatively high at  $26.2\%$

## TESTS ON SOIL STABILIZED COMPRESSED BRICKS

Most of the behaviour of cement stabilized soils depend on the mechanism of stabilization. These mechanisms have been discussed by Moh (1962) and Ola (1975).

### Unconfined Compression Tests

There are many machines available for making soil stabilized compressed bricks. Some are manually operated presses while others are power-driven presses. A few of the important ones are the Cinva-Ram from Bogota Colombia, Tek-Block from Kumasi Ghana, Landcrete and Ellson from Johannesburg South Africa, Latorex from Vedback Denmark and Supertor from Sao Paulo Brazil. Details of each machine and the addresses of the manufacturers can be obtained in Lunt (1980).

The machine utilized for these tests was the manually operated supertor Model PM3 which has a three brick mould and produces three bricks simultaneously each of size  $230 \times 110 \times 50\text{mm}$  ( $9.1'' \times 4.3'' \times 2''$ ). This machine was provided for the research by the N.B.R.R.I. (Nigerian Building and Road Research Institute). The hydraulically powered supertor with 5HP electric motor has an output of about 20,000 bricks per 8 hour day.

Fig. 9 shows the variation of compressive strength with various cement contents for both Ubulu-Uku and Igbanke soils using the Supertor machine after 7 days curing, while Figs. 10 to 12 show the effect of compactive effort on the compressive strength for 0%, 5% and 9% cement respectively. The inference from the four diagrams is that the compaction pressure of the Supertor machine is about  $1.0\text{MN/m}^2$ . In each case, there is a consistent increase in strength with increase in compaction pressures from 1 to  $6\text{MN/m}^2$ . These improvements in strength for Igbanke soils are from  $1.30\text{MN/m}^2$  to  $3.25\text{MN/m}^2$ ;  $1.65\text{MN/m}^2$  to  $5.2\text{MN/m}^2$ ;  $2.0\text{MN/m}^2$  to  $5.8\text{MN/m}^2$  for 0, 5, 9 per cent cement respectively while for Ubulu-Uku soils observed values are  $0.55\text{MN/m}^2$  to  $2.5\text{MN/m}^2$ ;  $2.0\text{MN/m}^2$  to  $5.7\text{MN/m}^2$ ;  $2.6\text{MN/m}^2$  to  $6.65\text{MN/m}^2$  for 0, 5, 9 per cent cement respectively. These are significant increases; what is also apparent is the fact that the effect of compaction far outweighs that of cement content. Both soils evaluated in this investigation when compacted at  $6\text{MN/m}^2$  gave strengths which exceed the requirement for a one storey structure with light roofing where a strength of only about  $206.8\text{KN/m}^2$  is required; Lyon Associates (1971). These strengths also exceeded the minimum recommended design value of  $1.4\text{MN/m}^2$ ; Ola (1983). In addition, the soil blocks compacted at these higher pressures also exceed

the minimum strength of  $2.8\text{MN/m}^3$  (except unstabilized Ubulu-Uku soil with strength of  $2.5\text{MN/m}^2$ ) which is specified in BS 2028 for precast concrete blocks.

Results from other investigators, Lunt (1980) indicate that the most economic optimum compaction might not be too far from  $8\text{MN/m}^2$  as insignificant gains were recorded for much higher pressures. For a Fumasua soil for instance, he recorded 143% strength increase from 2 to  $4\text{MN/m}^2$  compaction while he only recorded 11% strength increase from 8 to  $16\text{MN/m}^2$  compaction. Similar results for Usen and College of Medical Sciences Benin soils are plotted in Fig. 10.

### Durability

Table 5 and Fig. 13 show the durability results as recorded by the standard tests. The Supertor bricks were used for all the tests. The durability tests (wetting and drying test on compacted soil cement mixtures) gives the weather resistant properties of the soil-cement block. The recommended limit for minimum durability is not more than 5 per cent loss of weight after 12 cycles of wetting and drying for permanent building developments and for urban areas with more than 508mm of annual rainfall (Fitzmaurice, 1958). For the two soils indicated in Table 5, it appears as if 7% cement would be required to satisfy the durability requirement. The durability tests have not yet been performed on the above soils at high compact pressures of  $6\text{MN/m}^2$ .

### Water Absorption

Fig. 14 and Fig. 15 give the water absorbed by the College of Medical Sciences soil in Benin, for about a month and up to 15% cement. Fig. 16 shows the results of 24-hour complete immersion test for two Benin soils taken from the College of Medical Sciences site and the Institute of Child Health site both at Ugbowo. It is important to note that Figs. 14 to 16 were related to the oven dried samples hence the high water absorbed. Figure 17 indicates the absorption properties of Ubulu-Uku and Igbanke soils after 1 minute immersion while Fig. 18 corrects Fig. 17 mathematically to give the Initial Rate of Absorption in terms of a standard bedding surface area of contact taken as  $193.55\text{sq. cm}$ . ( $30\text{sq. in}$ ). Fig. 19 is a replot of Fig. 15 as per cent of oven-dry weight. For the complete immersion test for 24 hours, the Indian test for absorption of water restricts the water absorption to 20% in case of class 1 bricks, 22% in the case of 2 brick and 25% in the case of class 3 bricks; Victor (1963).

### Tensile Strength Tests

Fig. 20 shows that the tensile strength increases with the compactive effort. For each of the compactive efforts, the Ubulu-Uku clay exhibited highest values of tensile strength, while the College of Medical Sciences soil exhibited the lowest values for all the compactive effects. The high tensile

strength of Ubulu-Uku clay correlates with its high plasticity. However, the tensile strength of Igbanke soil is higher than that for the College of Medical Sciences because the grain size of the later has about 25% more sand than that of Igbanke (Fig. 2) and consequently imparts the more brittle properties to the soil. Also, the tensile strength of the sandy College of Medical Sciences soil increases slightly with the compacting pressure when compared with the highly clayey Ubulu-Uku soil with the clay content of about 80% (Fig. 2).

Thus, it appears that for sandy soils, compaction pressures greater than  $8 \text{ MN/m}^2$  will not improve the tensile strength significantly. Fig. 20 indicates that at a particular compaction pressure ( $0.4 \text{ MN/m}^2$ ) the tensile strength of all the soil is zero or relatively insignificant.

## CONCLUSION

The geotechnical properties of at least 4 widely occurring soils have been studied in relation to their use as building bricks. In general, it is found that Ubulu-Uku soil may be too plastic for brick making, the other 3 soils were found to be adequate for making stabilized compressed bricks.

Increases in compactive efforts increases both the compressive strength as well as the tensile strengths.

Higher tensile strength were also obtained with clays of high plasticity. For all the soils tested, insignificant tensile strengths were obtained at compactive pressures of  $0.4 \text{ MN/m}^2$  or below. Consequently, in no case should the compaction pressure employed be less than  $0.4 \text{ MN/m}^2$ .

Indeed, for the most economic benefit and diminishing returns compactive pressures of about  $6 \text{ MN/m}^2$  to  $8 \text{ MN/m}^2$  are recommended. Addition of 5% to 7% cement will improve the durability characteristics of the bricks effectively.

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**Table 1**

**The Stratigraphic succession (modified from kogbe et al 1975)**

Age		Formation	Lithology	Thickness (approx)
Quaternary	Miocene-Pleistocene	Benin (youngest)	Alternation of coarse sands with clays and shales	200 meters
Tertiary	Oligo-Miocene	Ogwash-Asaba	Clays with lignite	300 meters
	Eocene	Ameki	Grey clayey Sandstone and sandy claystone	84 meters
	Paleocene	Imc Shale	Laminated clayey shales	314 meters
Upper Cretaceous	Maestrichtian	Nsukka Ajali (oldest)	Shales with Coal and sandstone beds	233 meters

Table 2a

✓

Location of Various clay deposits in Bendel State (after Awoleye 1982)

*	Local Gov't Area	Town	Location of Deposit
1.	ANIOCHA	Ukwunze	Omeofu Ekeocha bush, Omioka stream bush, Nofia Stream bush, Omi Omobo bush.
		Ubulu-Uku	Iyi Ago and Iyi Obi clay
		Ibussa Mbiri	Obashi River Area Iyi Ugo stream area.
2.	IKA	Oza-Nagogo	Igwuigwugwu bush, Ewebi bush, Iduleha bush
3.	ETSAKO	Imiakaebu	Oghodogbo and Isokwi bush, Ogosombi, Ogiliga, Ukobi and Ijoghodo clay.
		Ibhioba	Uwo - Ibi clay
		Iyereku Udame	Ovia bush Osomogodo bush
4.	AKOKO-EDO	Ojah	Opoto bush, Ugudumi stream, Bashaiye quarters, Ipala stream.
5.	OWAN	Afuze	Ajavu bush.
6.	WESTERN BENIN	Usen	Itawe camp road Arhenwen stream, Eleware camp
		Evburarhue	Evburarhue water side
7.	EASTERN BENIN	Uzalla	Ezeke bush
		Igbantor Igbanke	Iyioma stream Iyi Ukwu; Gidi Iyi Mgbidi
		ite	Ibo river bank
8.	ISHAN	Orekhuan	Edea stream bush.
		Emu	
		Eko Ibadin	Ela stream bush
		Amah	Oshie - Otiti bush
		Ewu Ibore	Kilometre 102 Benin to Auchi Road

Some of the Local Government Areas have changed. Ubulu-Uku is in Aniocha Local Government area. Usen is in Ovia Local Government area. Igbanke is in Orhiommwon Local Government Area.

Table 2b.

## Location and quantity estimation of various clay deposits in Bendel State (after Awoleye 1982)

AREA	LOCATION (TOWN/ VILLAGE)	TYPE	QUANTITY	REMARKS
1. BENIN	Iguoriakhi (North)	Normal sec. clay	212,000m <sup>3</sup>	High over-burden
	Iguoriakhi (South)	Normal sec. clay	255,000m <sup>3</sup>	High over-burden
	Ikpoba Ossiomo	Normal sec. Kaolin	small 14,000m <sup>3</sup>	High over-burden Inaccessible
	Ukwunzu (11km north of Isele-Uku) Siluko	Swamp clay Swamp clay	39.18 x 1020kg. 43,000m <sup>3</sup>	Unworkable Unworkable
2. WARRI- UGHELLI	Kiagbodo	Swamp clay	5664m <sup>3</sup>	Pottery clay
	Agbassah	Swamp clay	4228m <sup>3</sup>	Pottery clay
	Ekiugbo	Swamp clay	21,240m <sup>3</sup>	Pottery clay
	Ujode	Swamp clay	7,000m <sup>3</sup>	Pottery clay
	Iwremare	Swamp clay		Pottery clay
	Effruntor	Swamp clay	small	Pottery clay
	Ughewghe	Swamp clay	small	Pottery clay
	Otedo	Swamp clay	small	Pottery clay
	Ebor	Swamp clay	small	Pottery and brick clay
	Uruove	Swamp clay	8496m <sup>3</sup>	Pottery & Brick clay
	Oleh	Swamp clay	7080m <sup>3</sup>	Pottery & Brick clay
	Emede	Swamp clay	small	Pottery & Brick clay
	Igbide	Swamp clay	small	Pottery & Brick clay
Enwe	Swamp clay	14,160m <sup>3</sup>	Pottery & Brick clay	
3. SAPELE	Koko	Normal sec clay	7080m <sup>3</sup>	Unworkable

sec. = secondary.

**Table 3:**

**Physical Properties of some Bendel Soils**

	Igbanke Soil	Ubulu-Uku Soil	College of Medical Science	Usen
Liquid Limit	50.0	95.0	70.0	31.5
Plastic Limit	16.3	23.1	22.4	12.5
Plasticity Index	33.7	72.9	47.60	19.0
Linear shrinkage	12.1	20.0	17.1	9.3
Specific Gravity	2.59	2.65	2.50	
Free Swell (%)	53.	88.3		5.0
Swell % (Geonor)	50.	97.3		
Standard proctor ) density (kg/m <sup>3</sup> ) )	1682.0 ( 105.0pcf)	1451.3 ( 90.60pcf)	1726.0 ( 107.8pcf)	1806.0 ( 112.8pcf)
Optimum moisture content %	17.20	26.2	17.2	18.1
West African compaction ) density (kg/m <sup>3</sup> ) )	1758.0 ( 109.75pcf)	1541.0 ( 96.2pcf)	1794.0 ( 112.0pcf)	
Optimum moisture content %	16.0	24.60	15.8	
Modified Proctor ) density (kg/m <sup>3</sup> ) )	1862.1 ( 116.25pcf)	1633.9 ( 102.0pcf)	1850.1 ( 115.5pcf)	
Optimum moisture content %	13.6	21.7	14.5	
*Permeability K cm/sec	4.0x10 <sup>-4</sup>	8.0x10 <sup>-6</sup>	1.8x10 <sup>-5</sup>	
Coefficient of Linear expansion (x)			2.0x10 <sup>-5</sup>	3.5x10 <sup>-5</sup>

\* Standard proctor saturated

Table 4a:

## Strength properties of some unstabilized Bendel Soils (Standard Proctor)

	Igbanke Soil	Ubulu-Uku Soil	College of Medical Sciences	Institute of Child Health	Usen
Unconfined Compression Test(KN/m <sup>2</sup> )	50.75	245.5			73.6
Tensile strength KN/m <sup>2</sup>					
(a) Standard Proctor	92.0	121.7	66.6		
(b) West African Compaction	155.0	216.7	106.8		
(c) Modified Proctor	281.3	433.4	134.3		

Table 4b

## Simple Direct Shear test for USEN soil

	Liquid Limit	Standard Proctor
Effective peak cohesion $C_p$ (KN/m <sup>2</sup> )	8	24.7
Effective peak angle of shearing resistance $\phi_p$	26°	26°
Residual cohesion $C_r$ (KN/m <sup>2</sup> )	0	0
Residual angle of shearing resistance $\phi_r$ (degrees)	27°	26°

Table 4c. Consolidated Undrained CU, Consolidated Drained (CD) Triaxial Tests for USEN Soil

		CU	CD
Triaxial effective cohesion	C (KN/m <sup>2</sup> )	24	20
Triaxial angle of shearing resistance	$\phi$	26°	24°

Table 5

## Durability Test



	% Cement	College of Medical Sciences	Institute of Child Health
Weight Loss %	5	6.9	6.0
	7	4.1	3.1
	9	2.8	2.2
	15	1.5	1.3
Volume Change %	5	9.5	0.9
	7	2.7	0.9
	9	2.9	0
	15	4.9	0

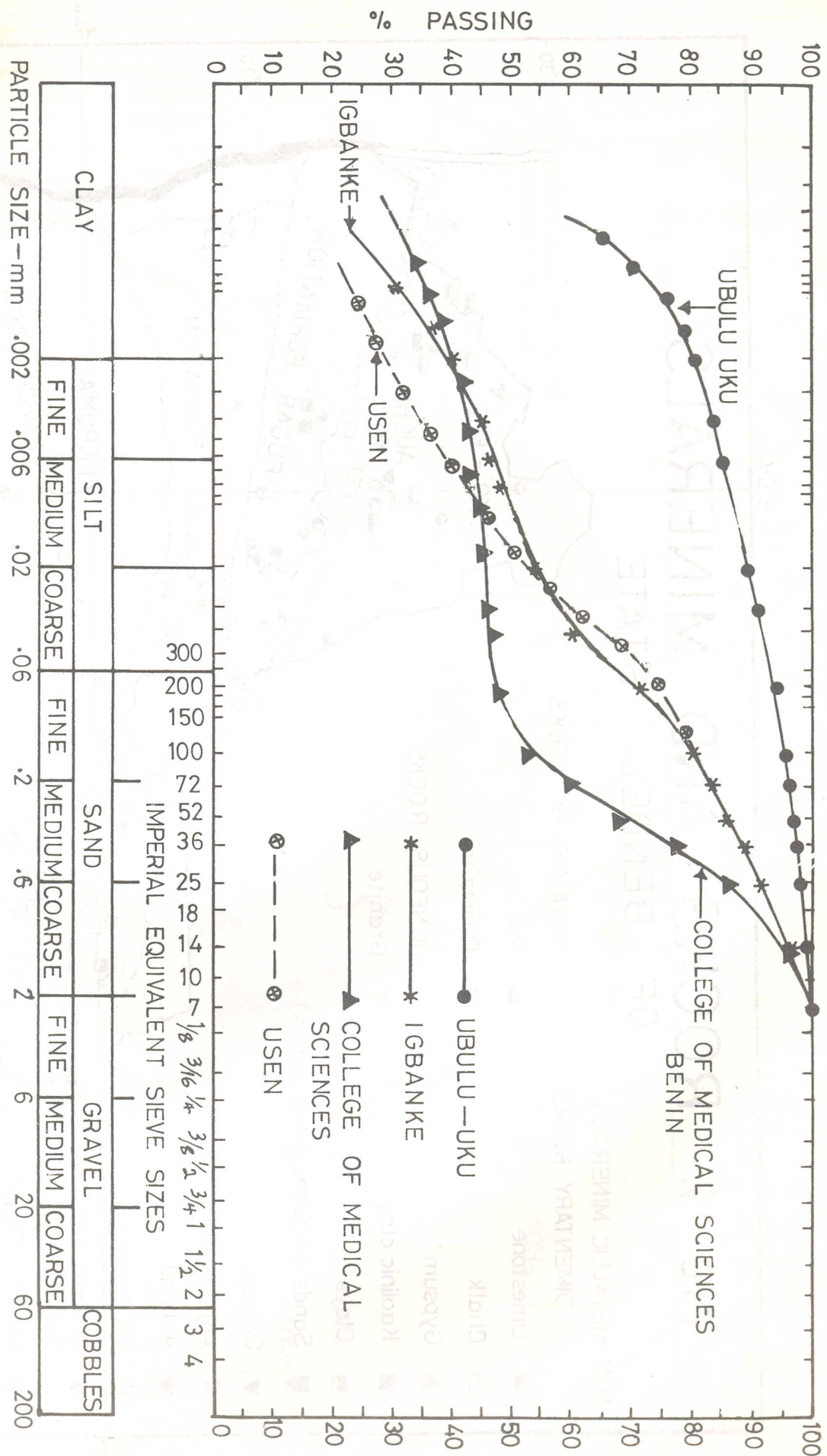


FIG. 2. PARTICLE SIZE DISTRIBUTION CURVES

# FIG. 1. ROCKS AND MINERALS OF BENDEL STATE

6°8'4"

NON METALLIC MINERALS  
 SEDIMENTARY ROCKS

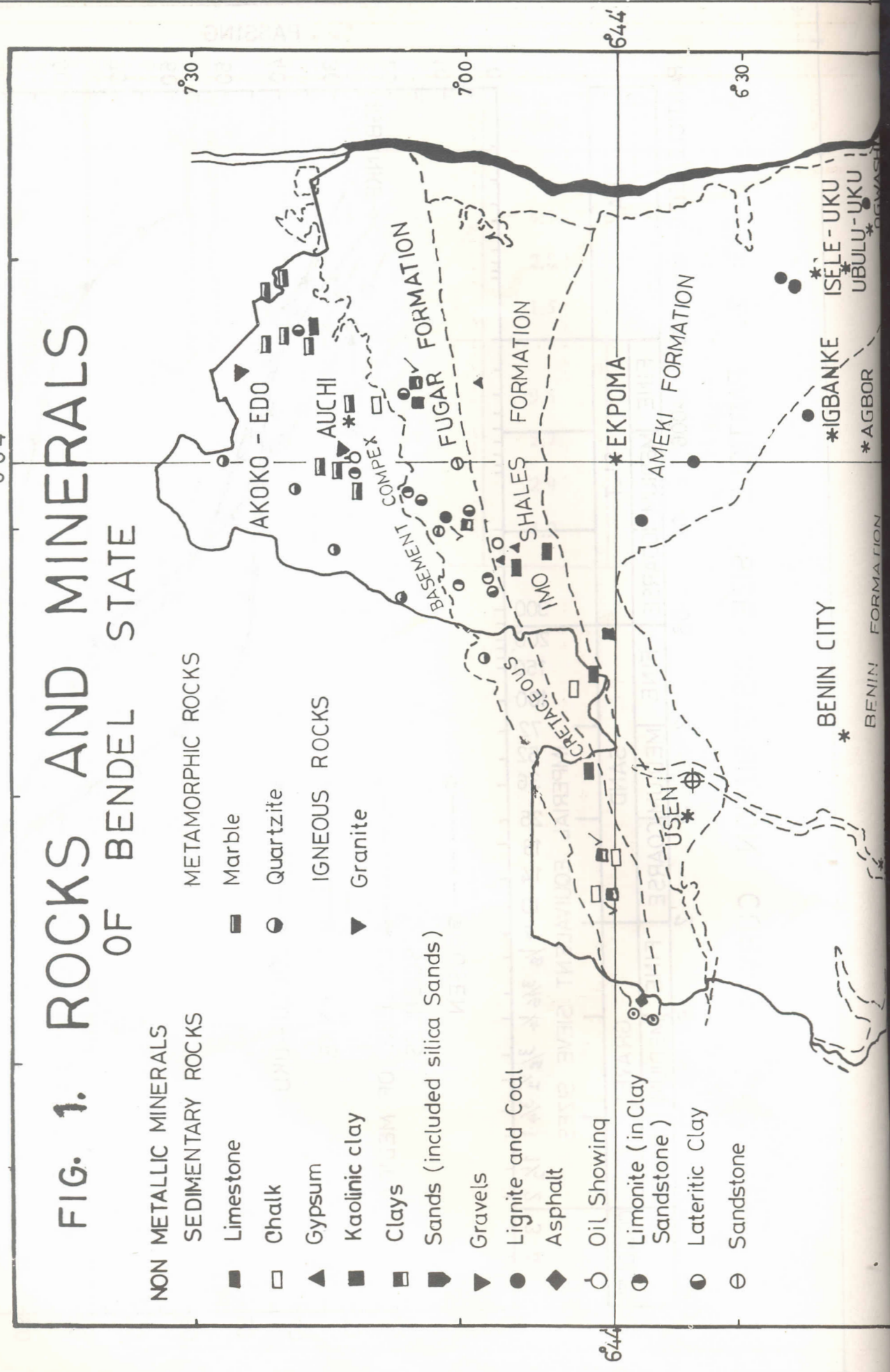
- Limestone
- Chalk
- ▲ Gypsum
- Kaolinic clay
- ▬ Clays
- ▬ Sands (included silica Sands)
- ▼ Gravels
- Lignite and Coal
- ◆ Asphalt
- Oil Showing
- Limonite (in Clay Sandstone)
- Lateritic Clay
- Sandstone

METAMORPHIC ROCKS

- Marble
- Quartzite

IGNEOUS ROCKS

- ▼ Granite



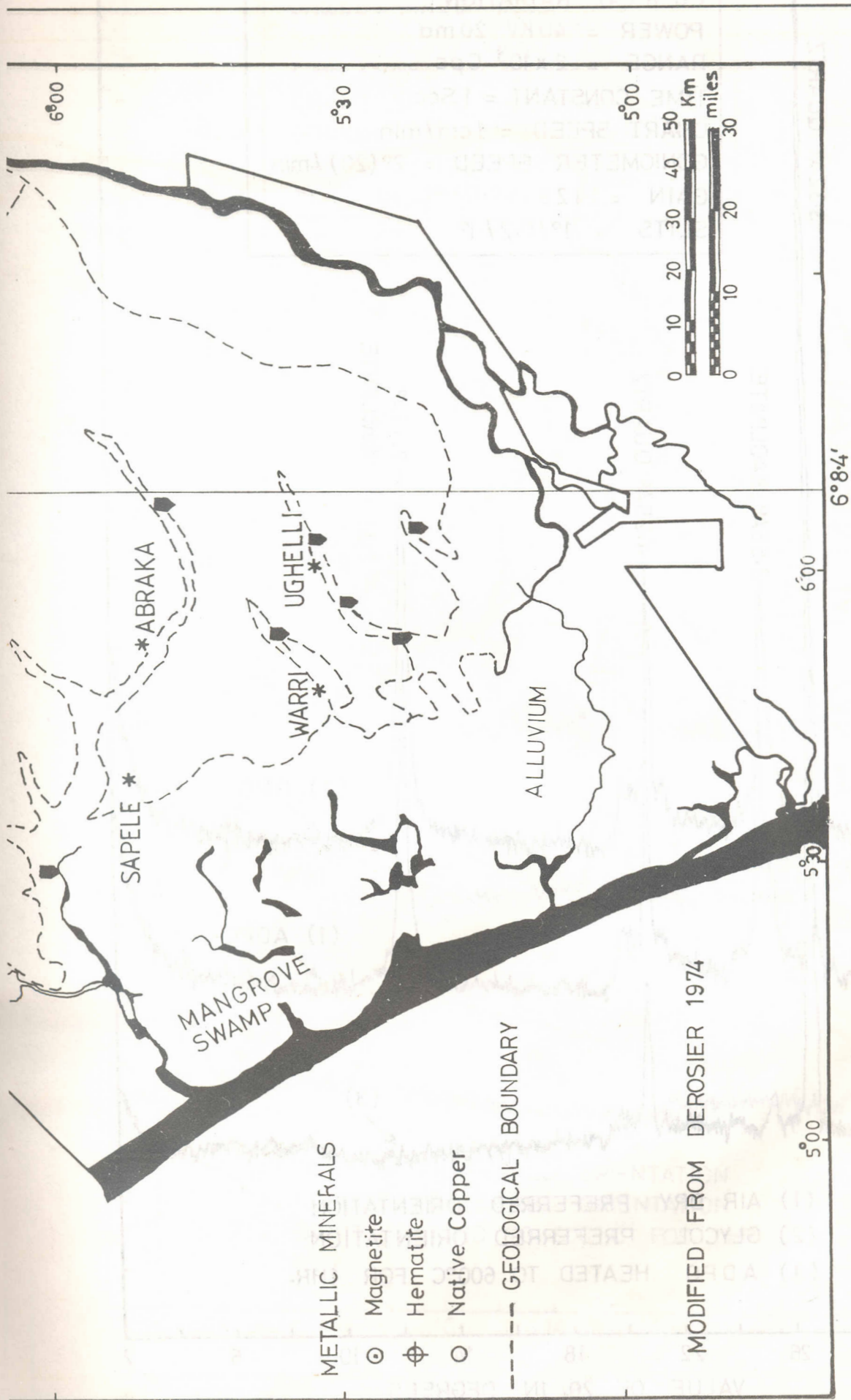
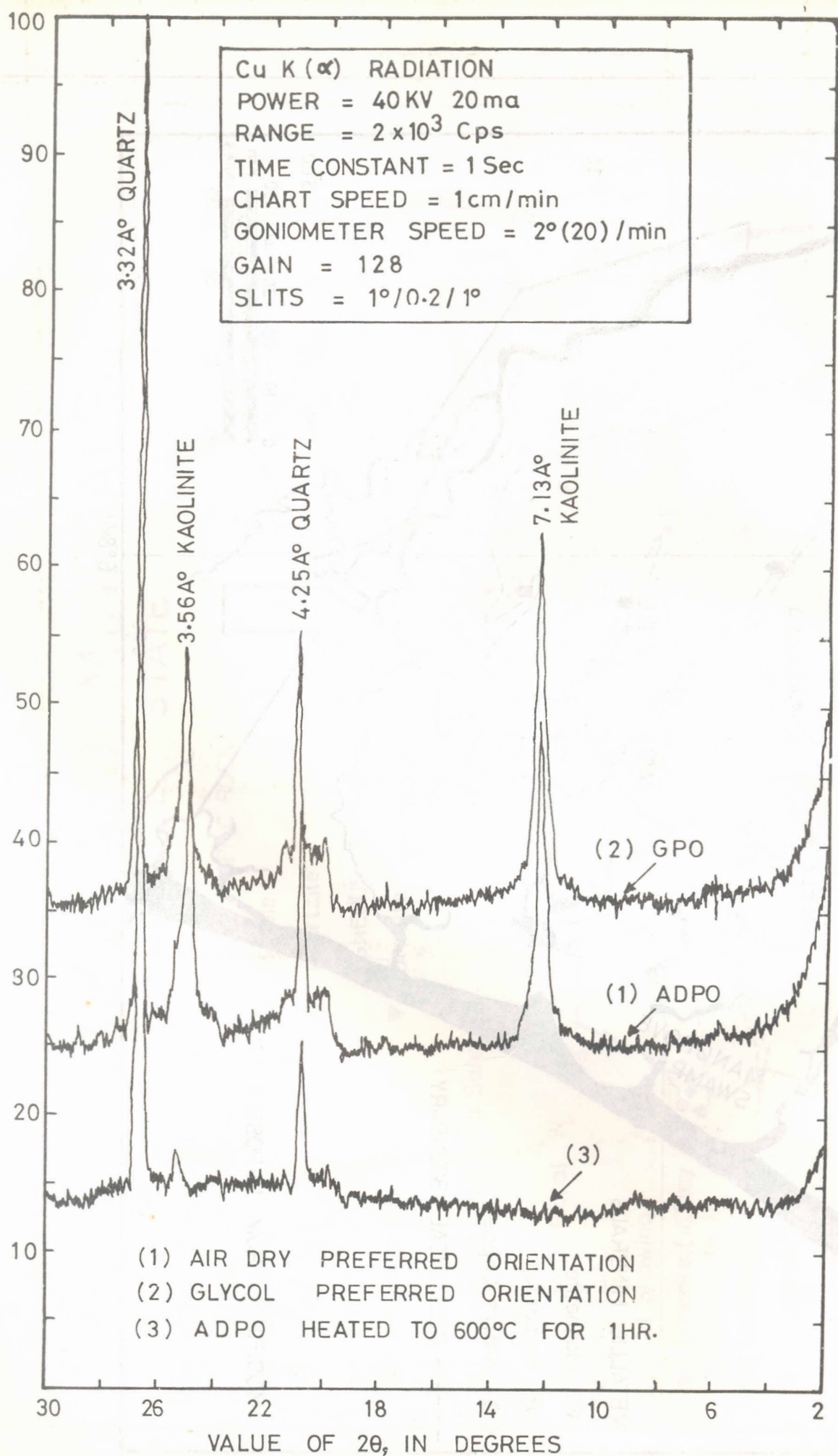


FIG. 3. X RAY DIFFRACTION TRACES



**FIG. 3. X RAY DIFFRACTION TRACES**  
**(< No 200) SIEVE IGBANKE SOIL**

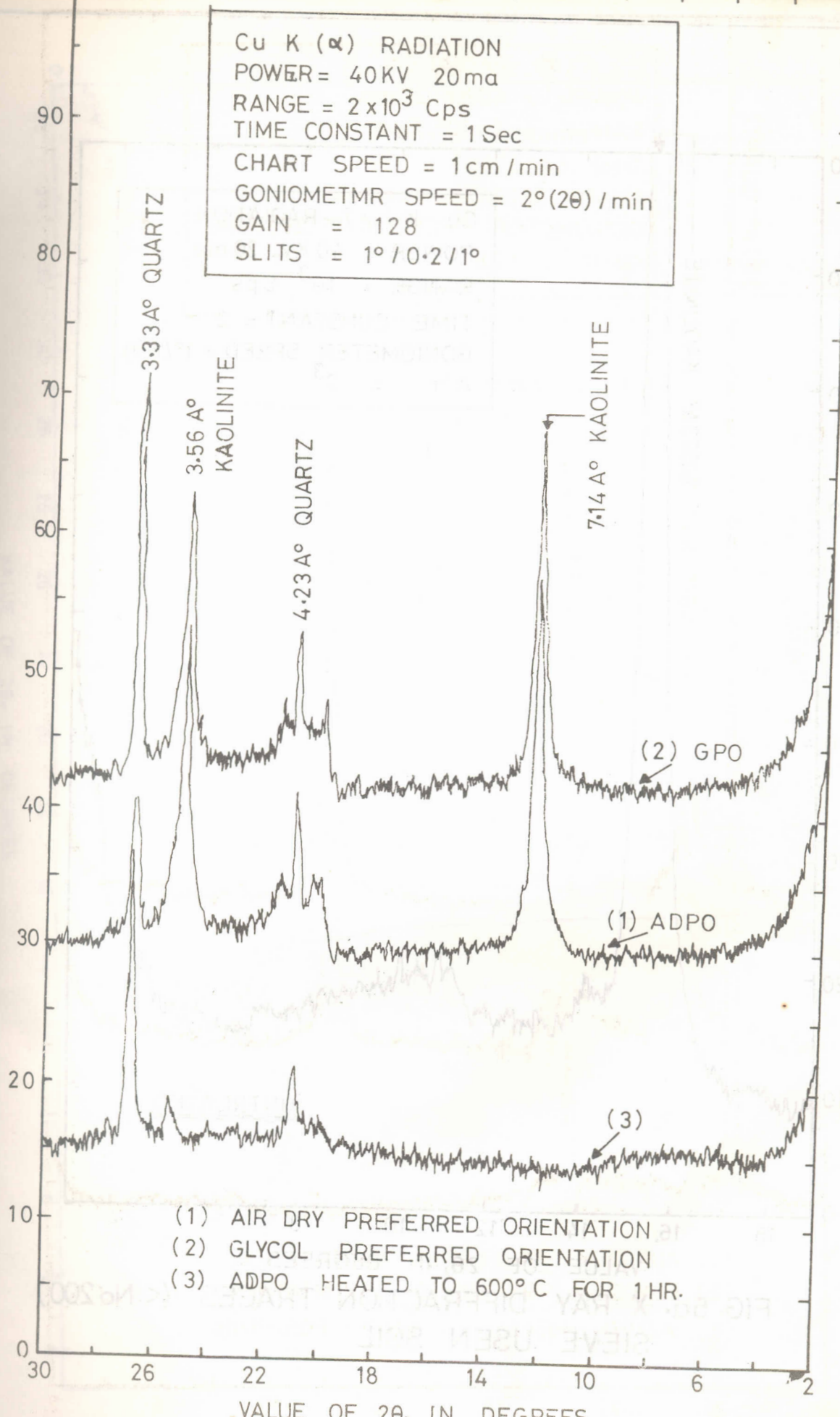


FIG. 4. X RAY DIFFRACTION TRACES (< No 200) SIEVE UBULU-UKU

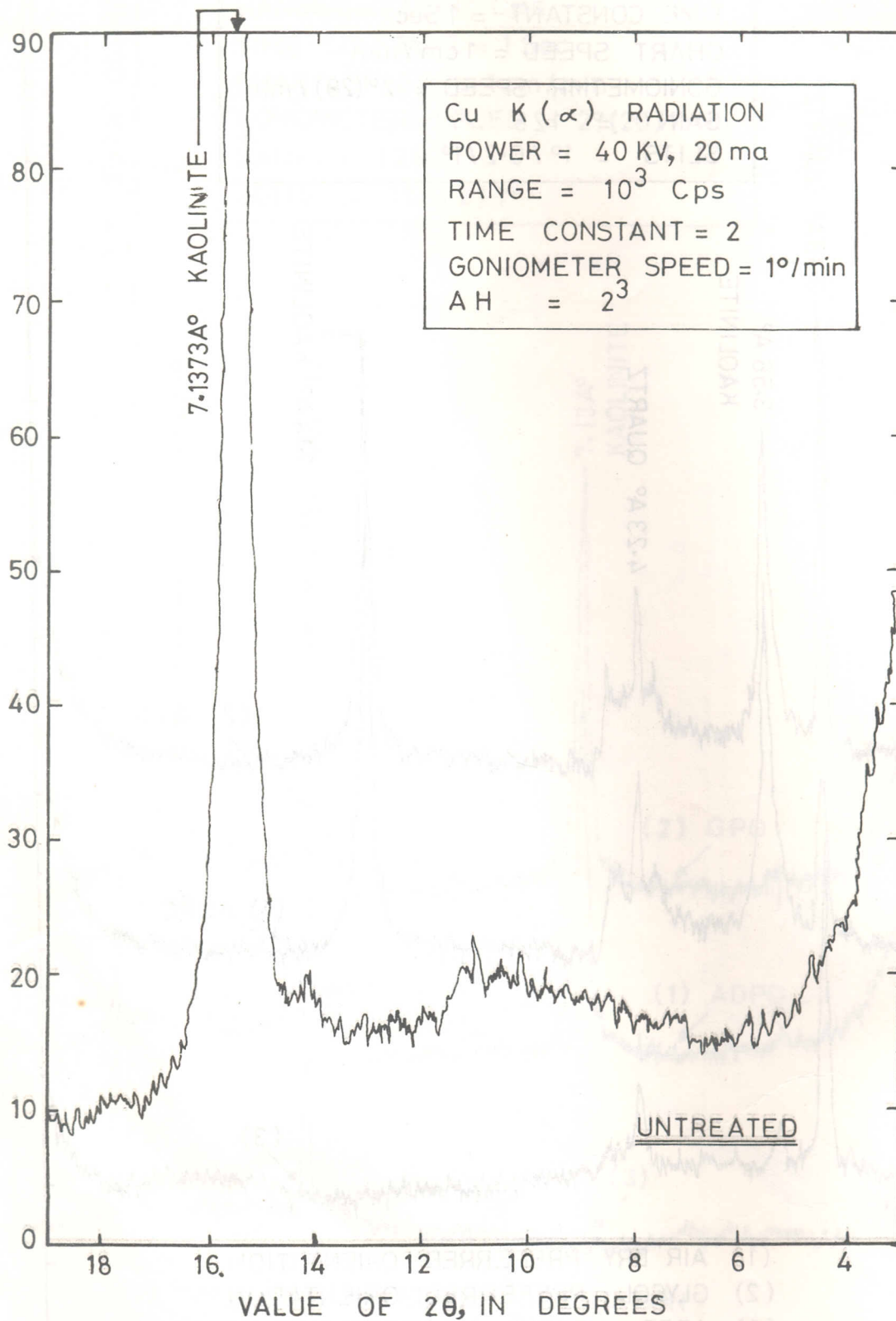


FIG. 5a. X RAY DIFFRACTION TRACES (< No 200)  
 SIEVE USED SOIL

FIG. 5b. X RAY DIFFRACTION TRACES ( < No 200 ) SIEVE USEN SOIL

VALUE OF  $2\theta$ , IN DEGREES

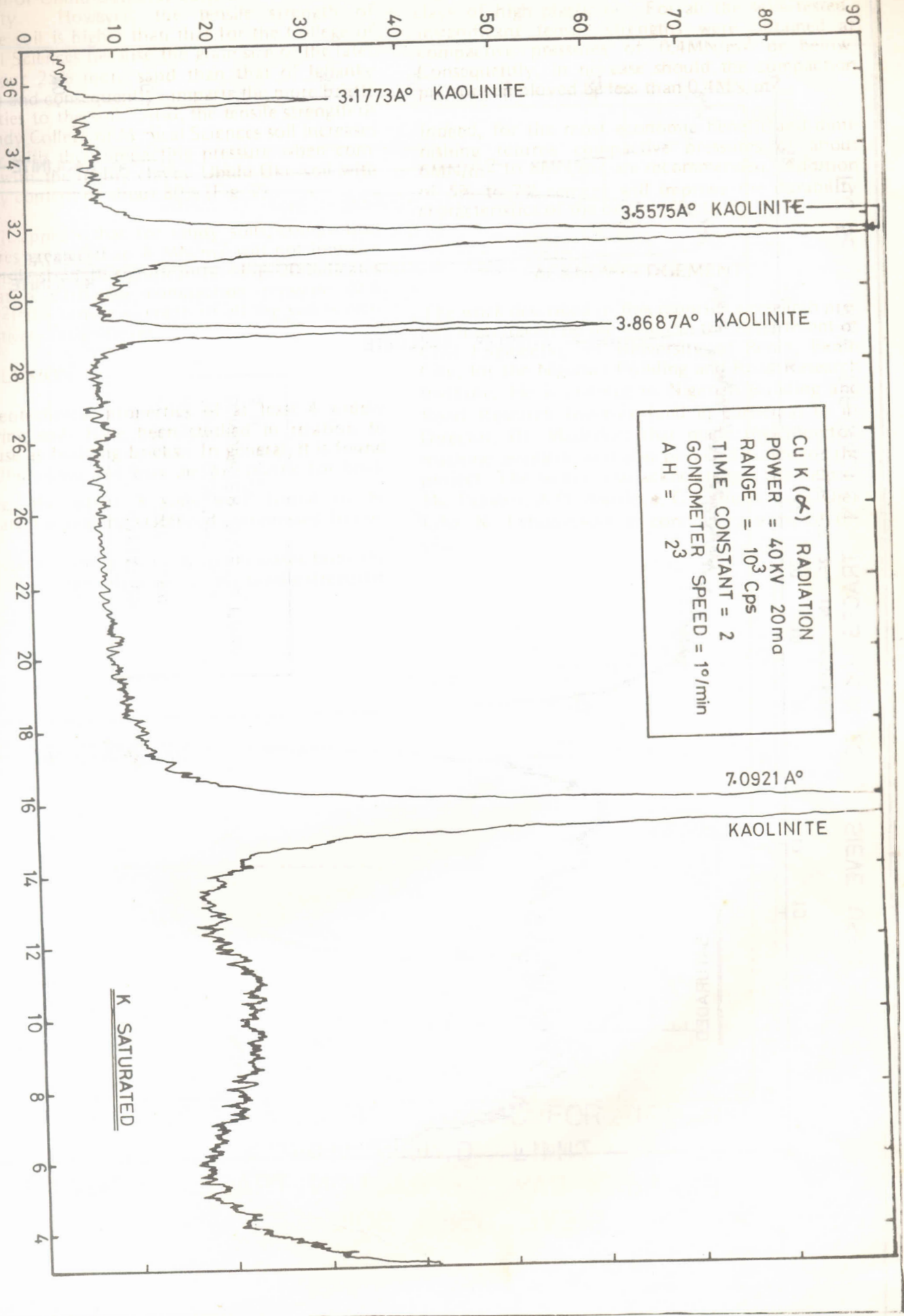
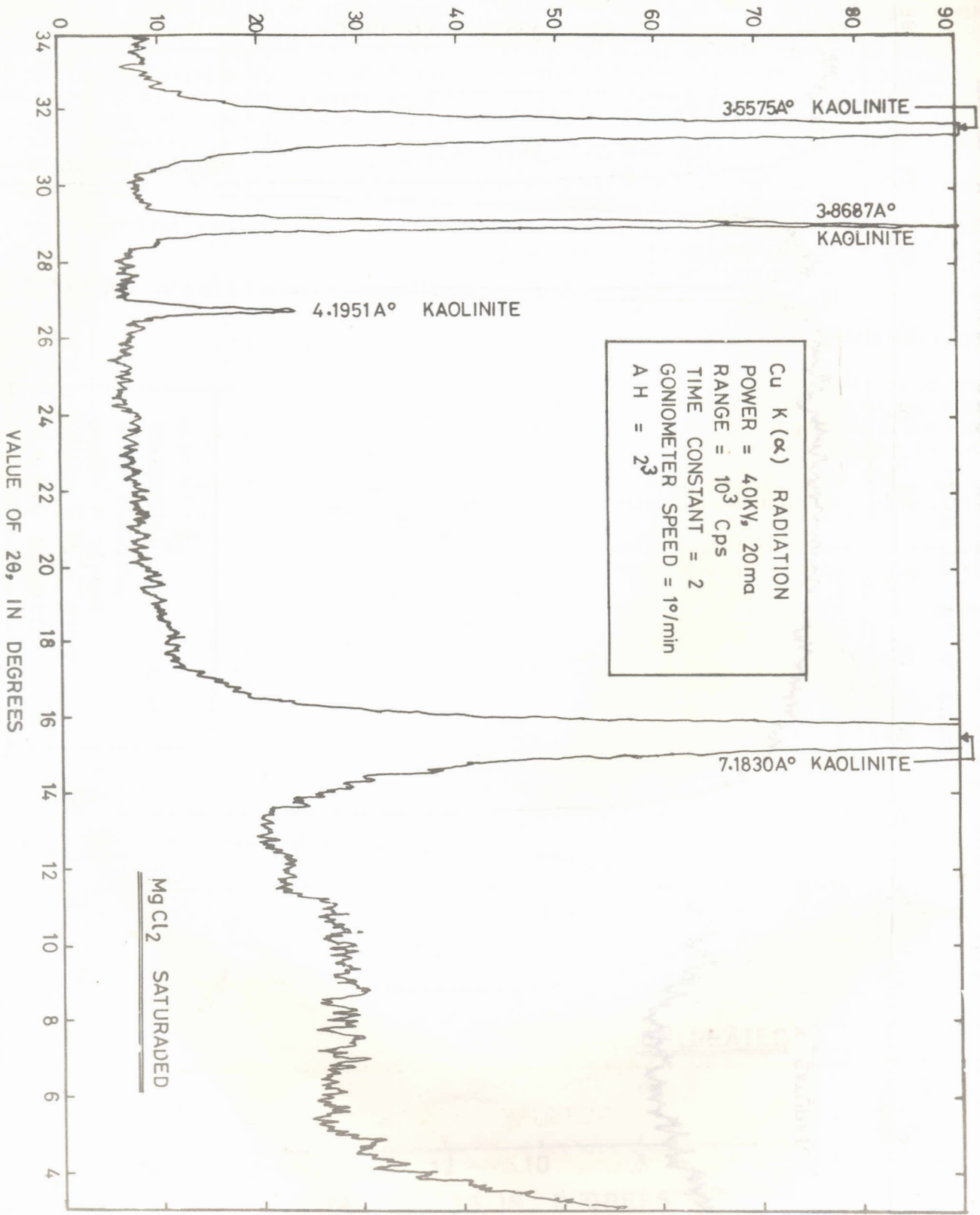


FIG 5c X RAY DIFFRACTION TRACES (< No 200 ) SIEVE USEN SOIL



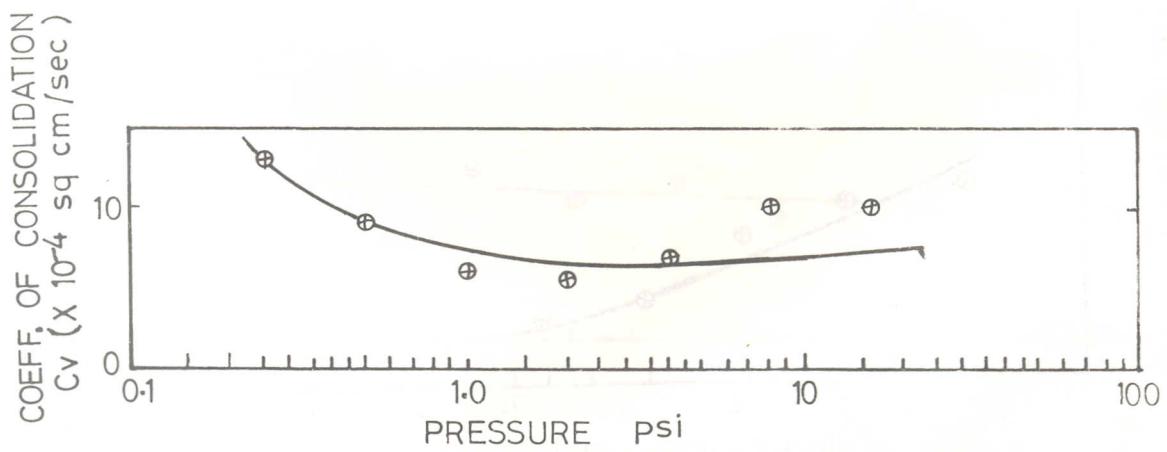
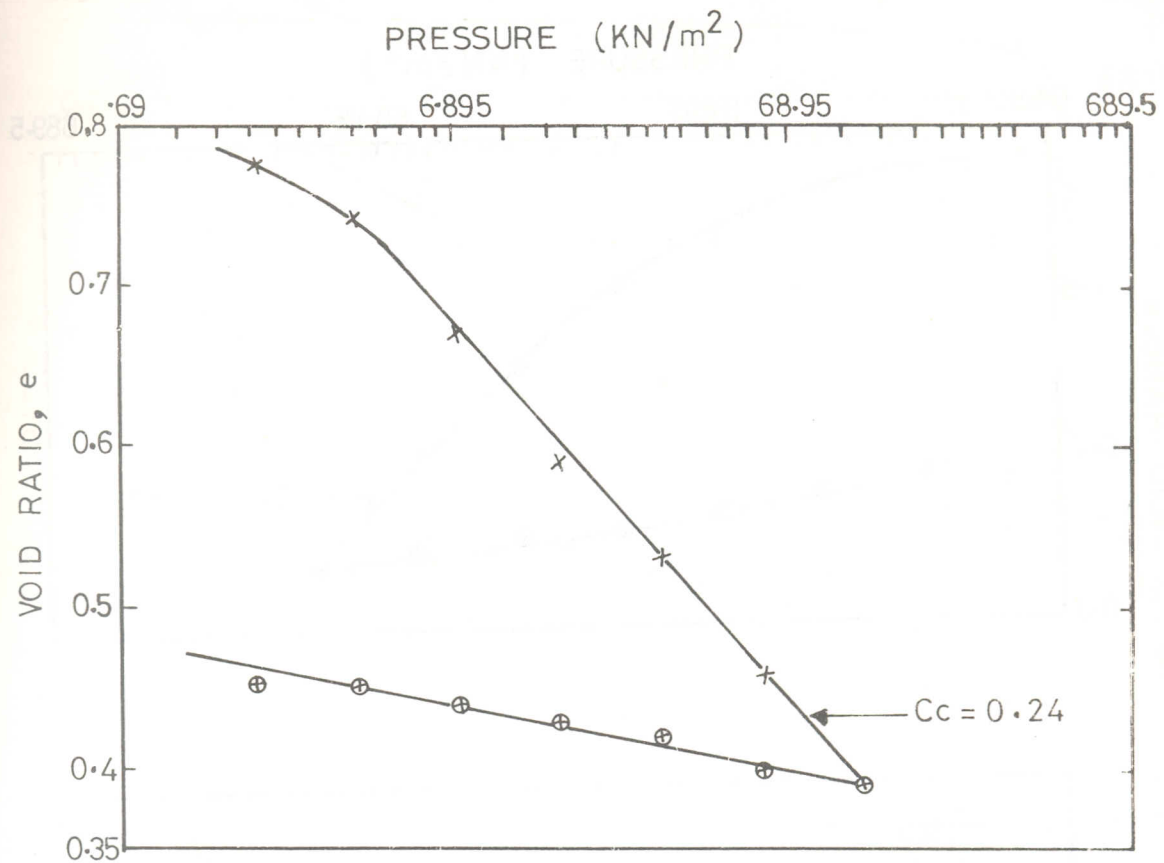


FIG. 6. CONSOLIDATION TESTS FOR IGBANKE SOIL AT LIQUID LIMIT

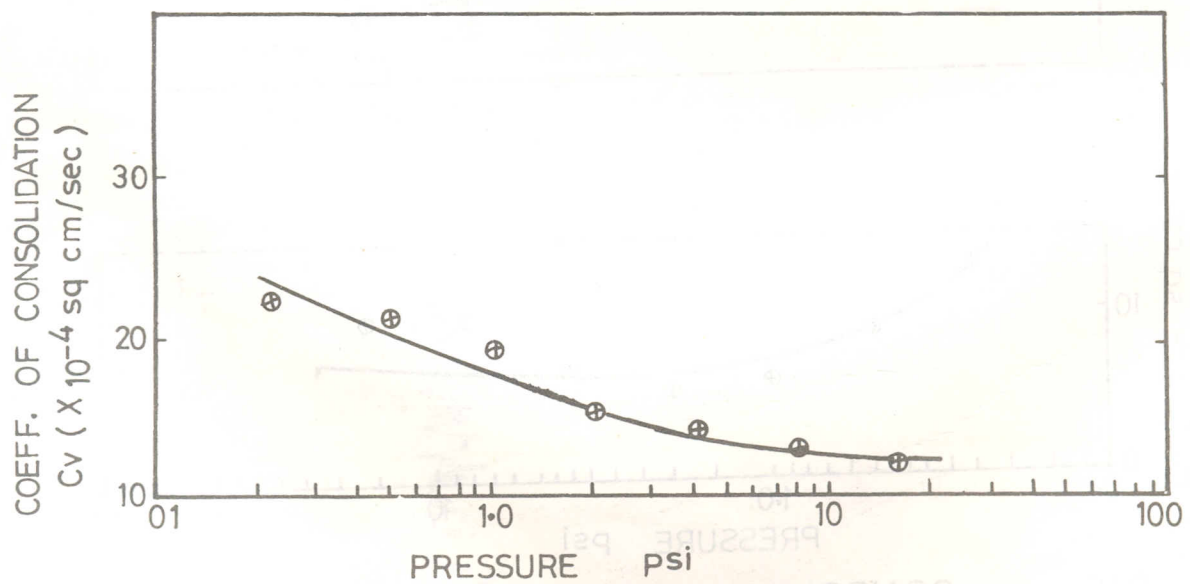
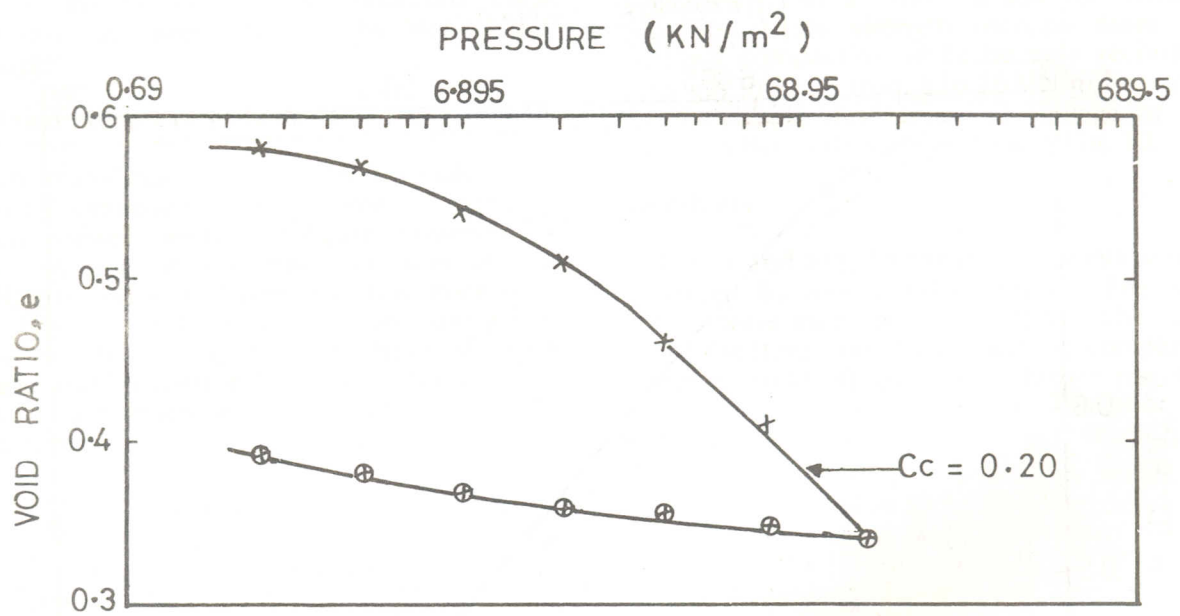


FIG. 7. CONSOLIDATION TESTS FOR IGBANKE SOIL AT STANDARD PROCTOR

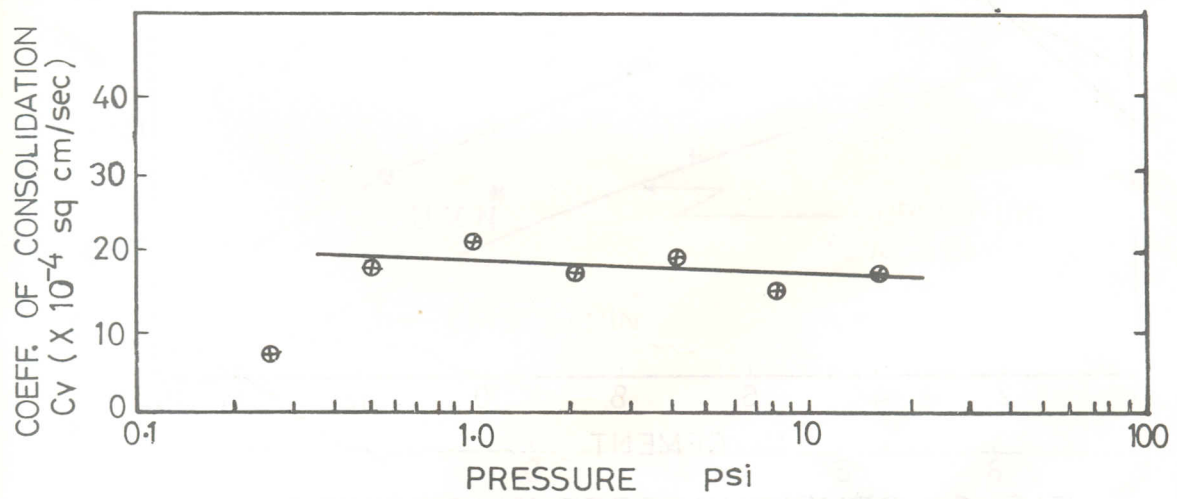
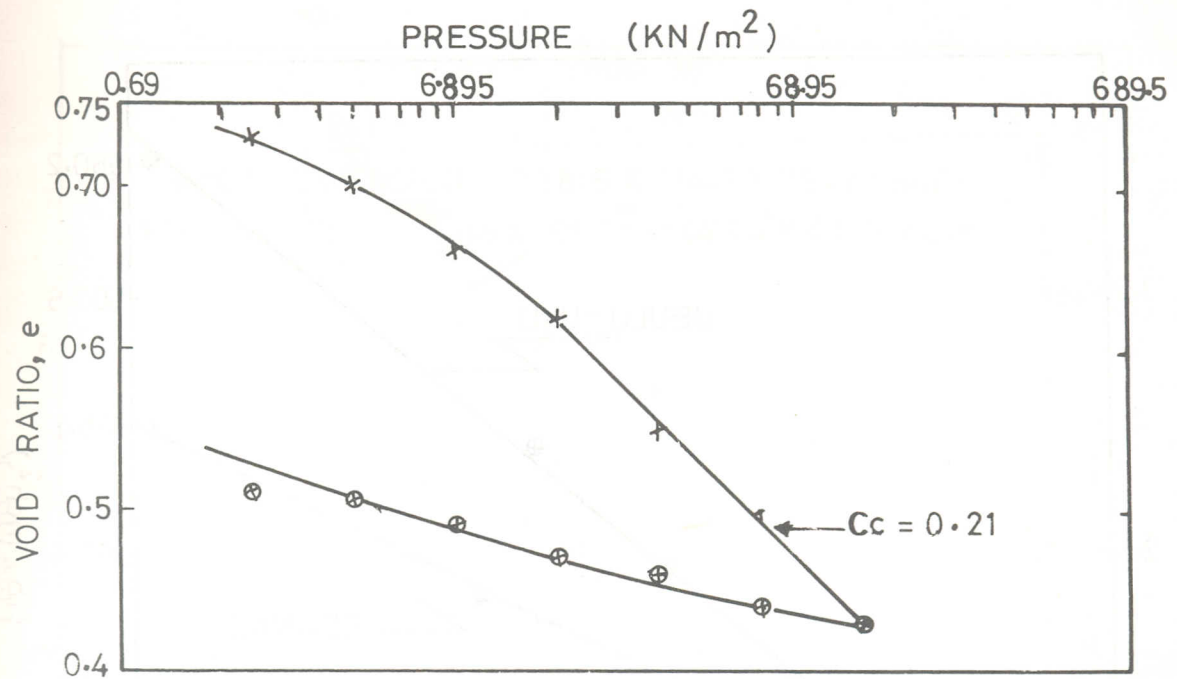


FIG. 8. CONSOLIDATION TESTS FOR UBULU-UKU SOIL AT STANDARD PROCTOR

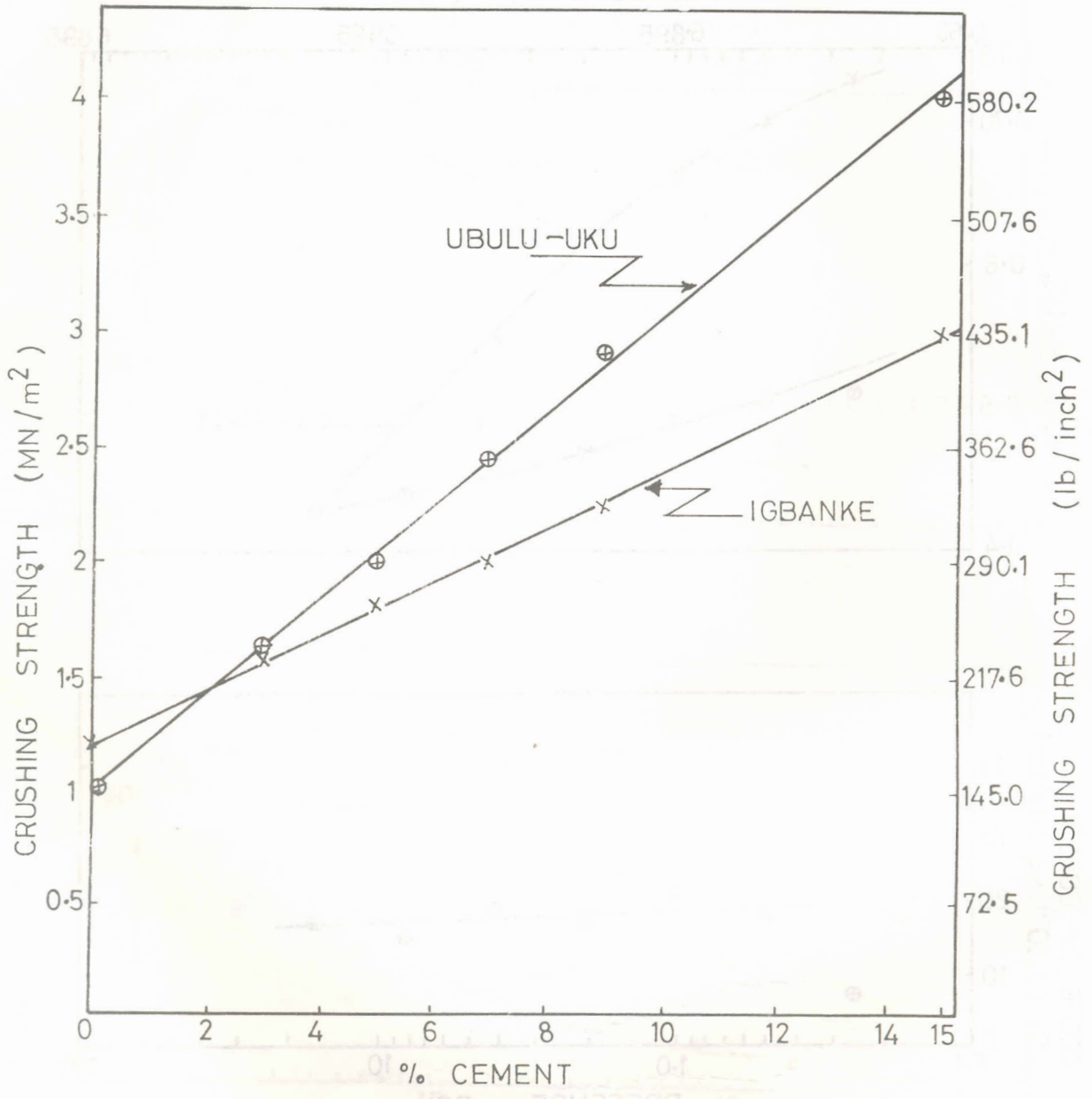


FIG 9 CRUSHING STRENGTH Vs % CEMENT (SUPERTOR BRICKS)

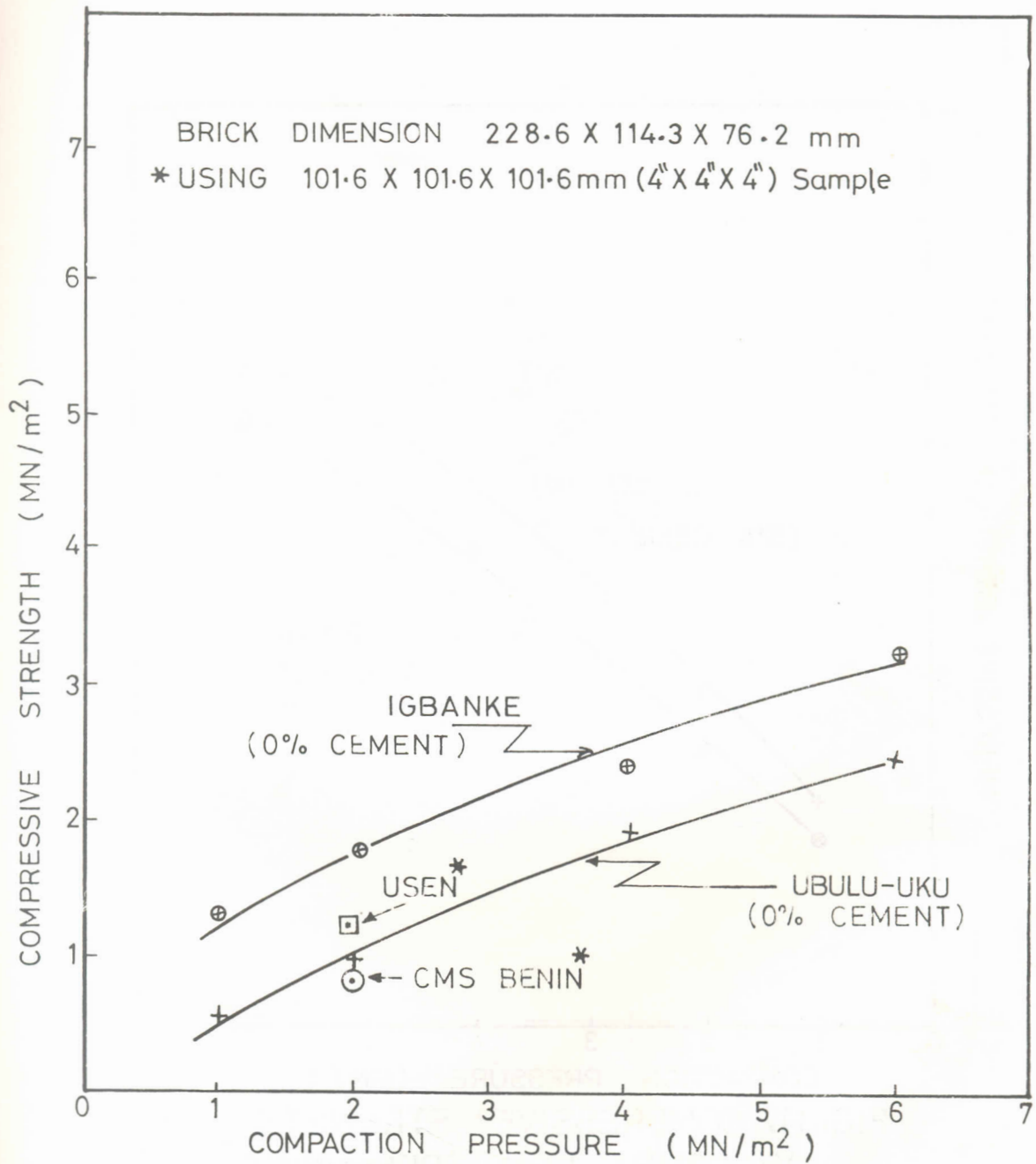


FIG. 10. COMPRESSIVE STRENGTH Vs  
 COMPACTION PRESSURE

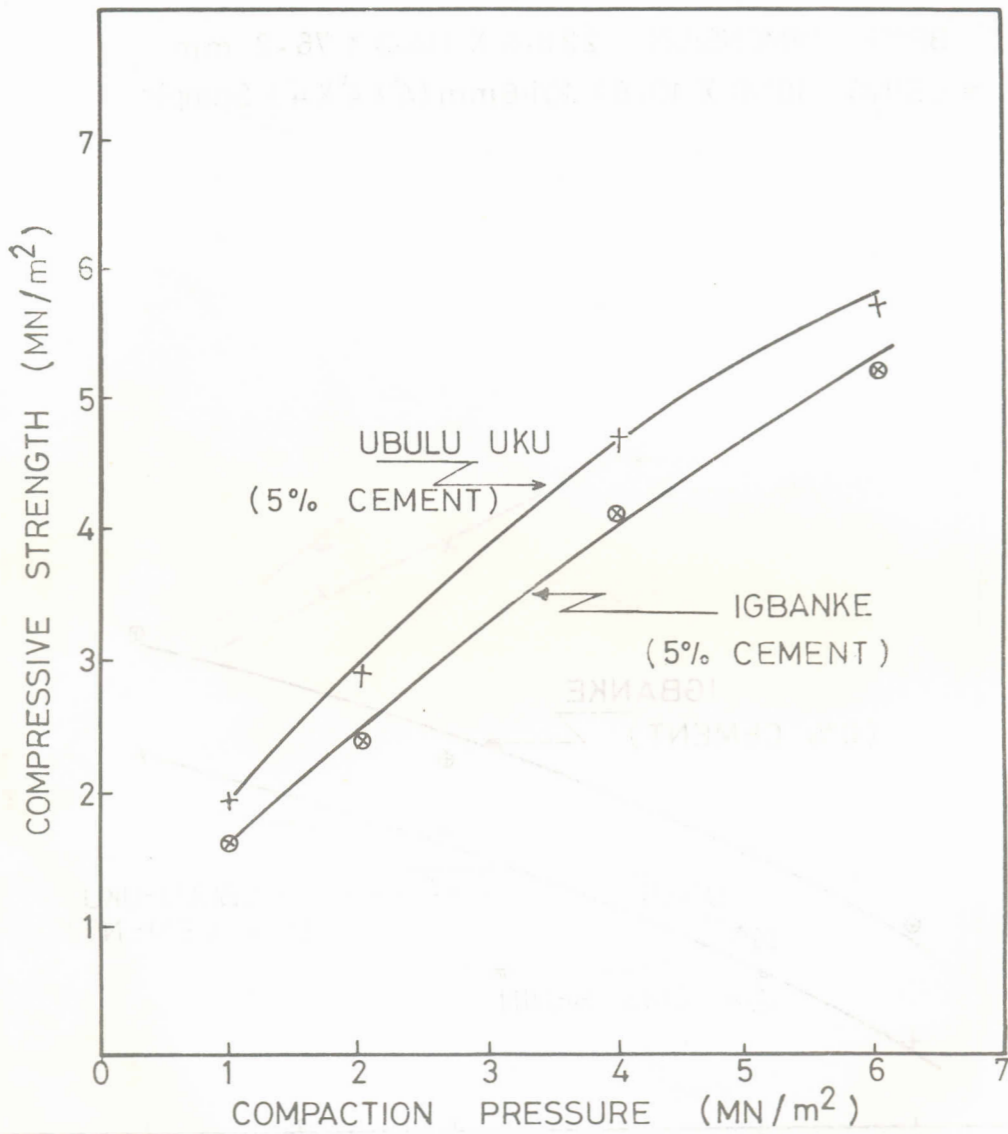


FIG. 11. COMPRESSIVE STRENGTH Vs COMPACTION PRESSURE

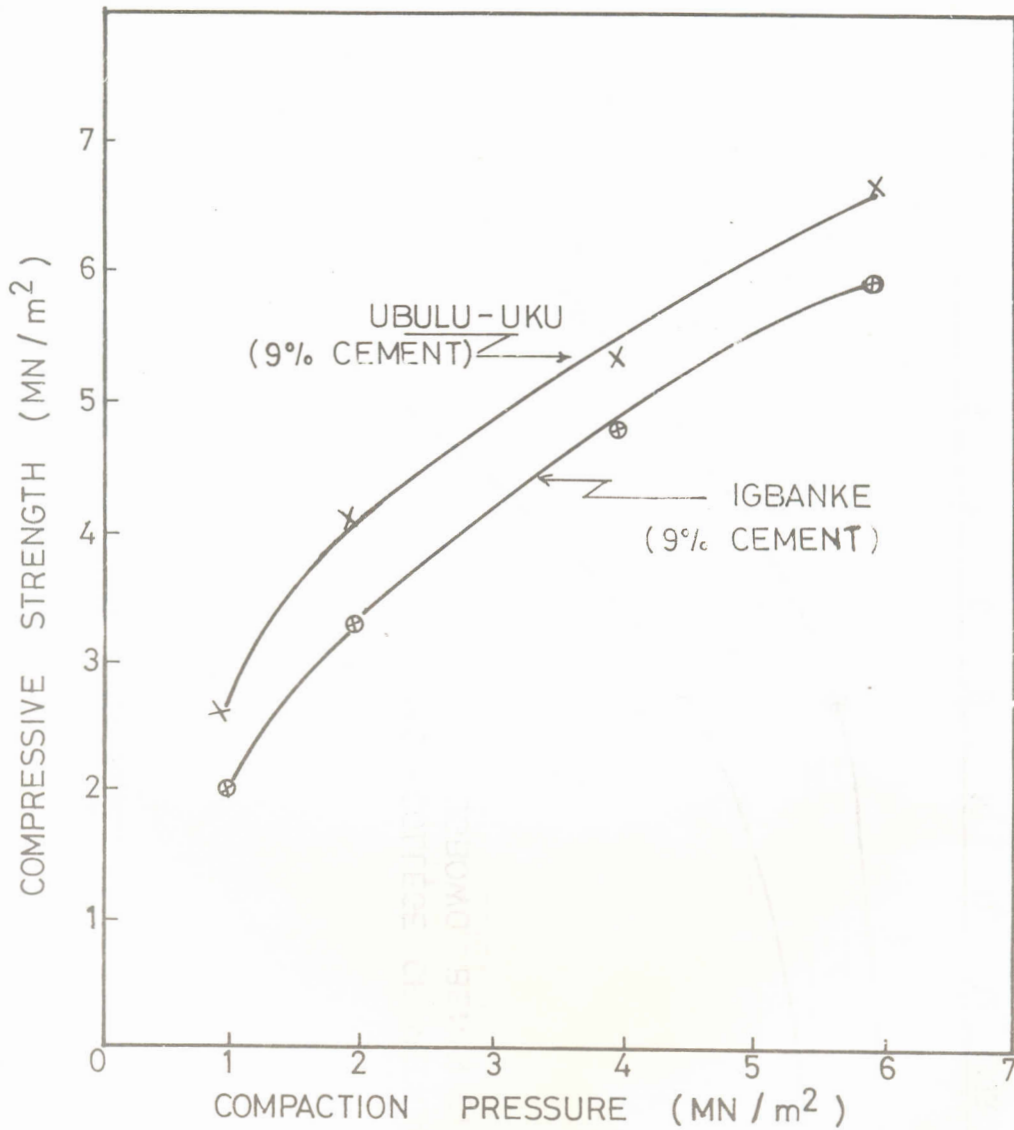
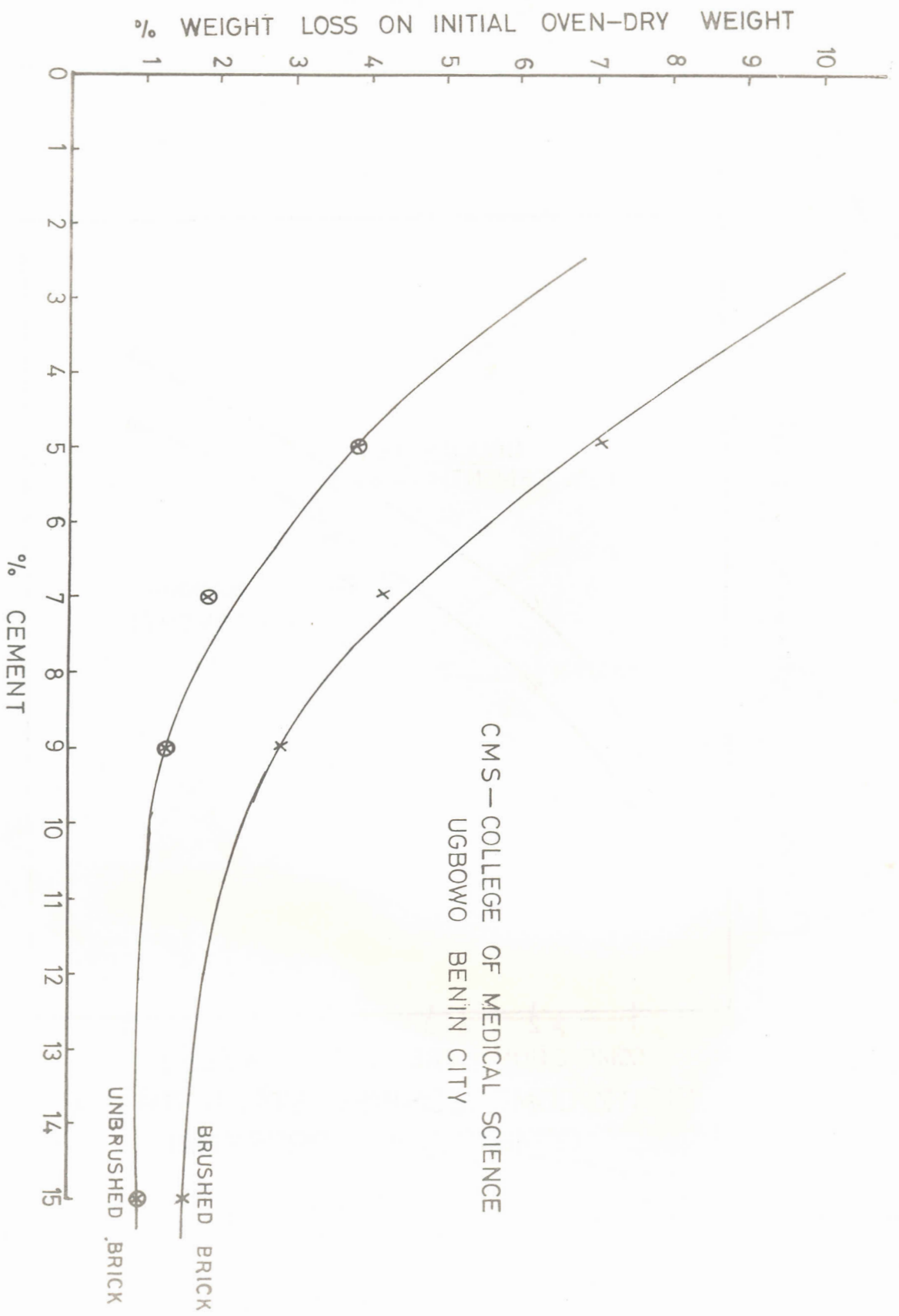


FIG.12. COMPRESSIVE STRENGTH Vs  
COMPACTON PRESSURE

FIG.13. DURABILITY VS CEMENT CONTENT CMS SOIL



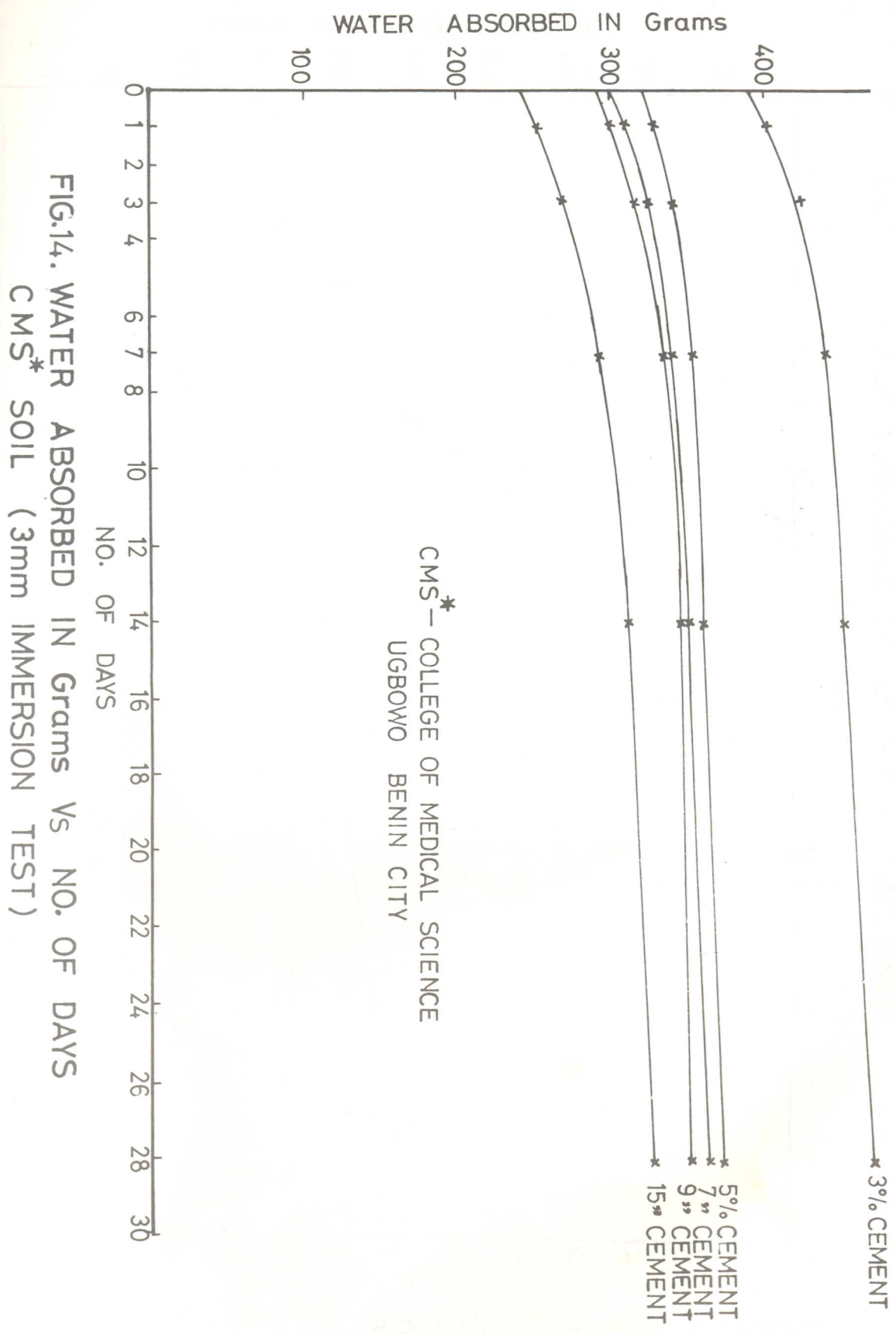


FIG.14. WATER ABSORBED IN Grams VS NO. OF DAYS  
 CMS\* SOIL (3mm IMMERSION TEST)

CMS\* COLLEGE OF MEDICAL SCIENCE  
 UGBOWO BENIN CITY

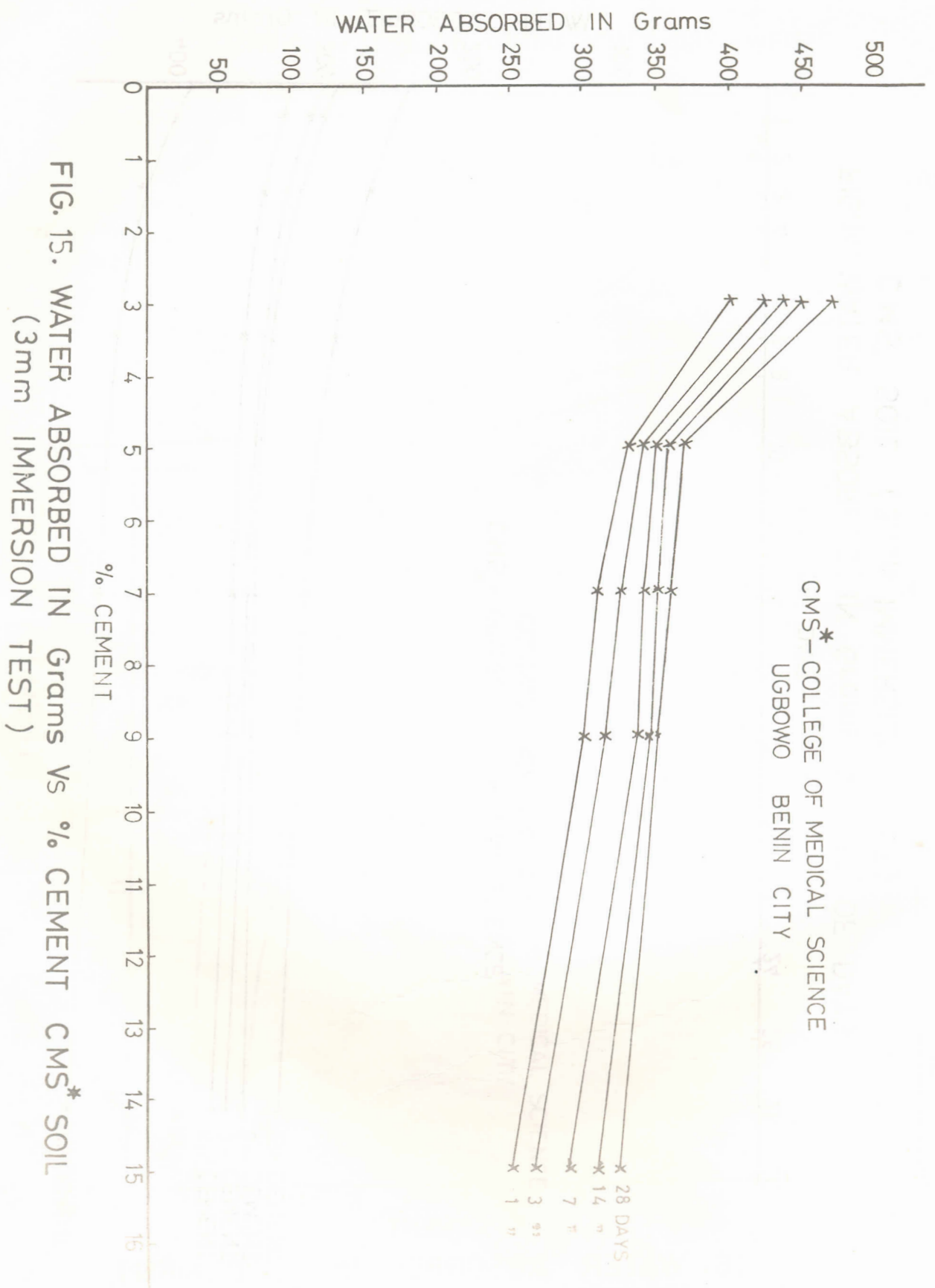


FIG. 15. WATER ABSORBED IN Grams Vs % CEMENT CMS\* SOIL  
(3mm IMMERSION TEST)

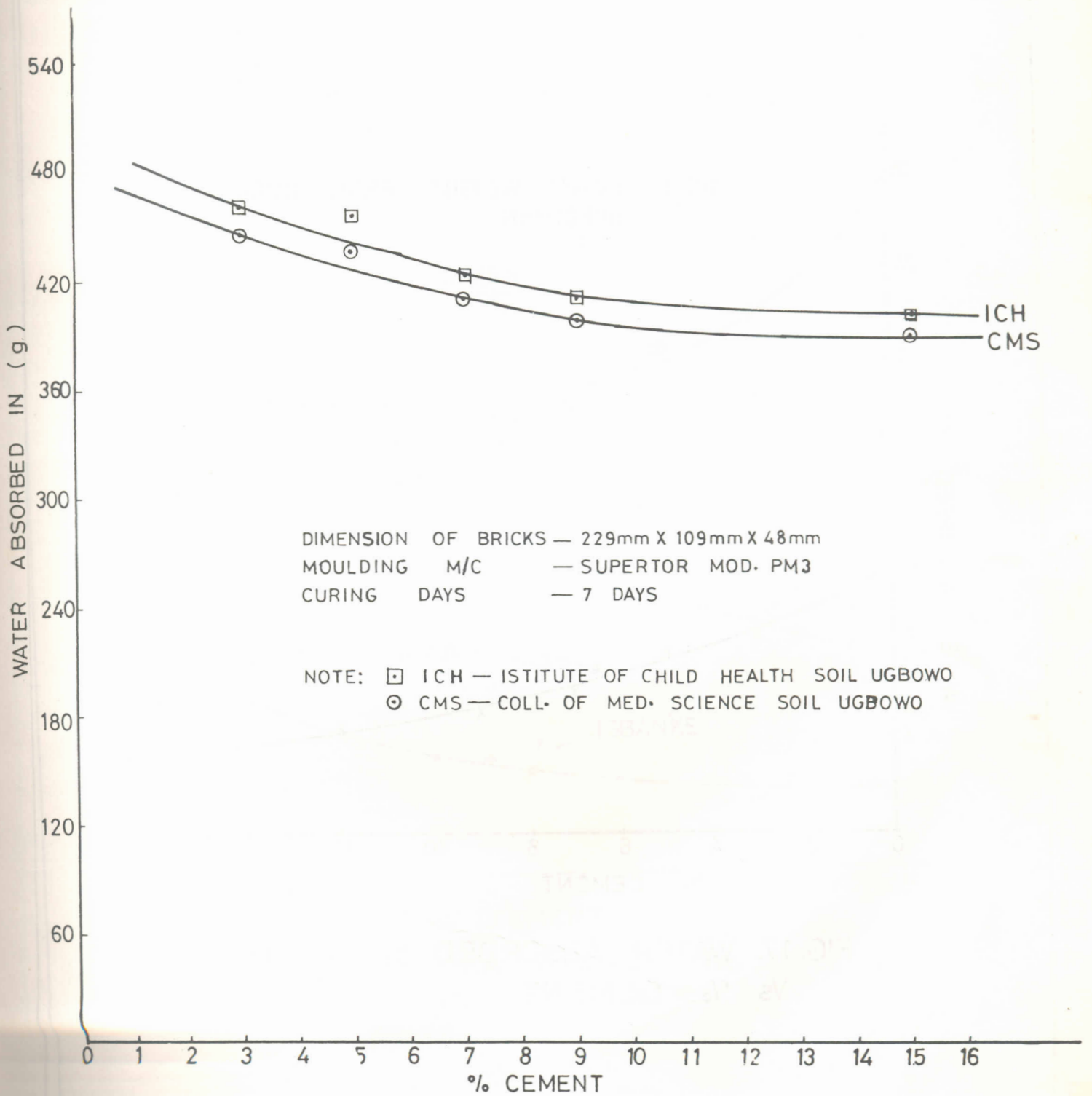


FIG.16. WATER ABSORBED VS % CEMENT  
 (24-HOU. COMPLETE IMMERSION TEST)

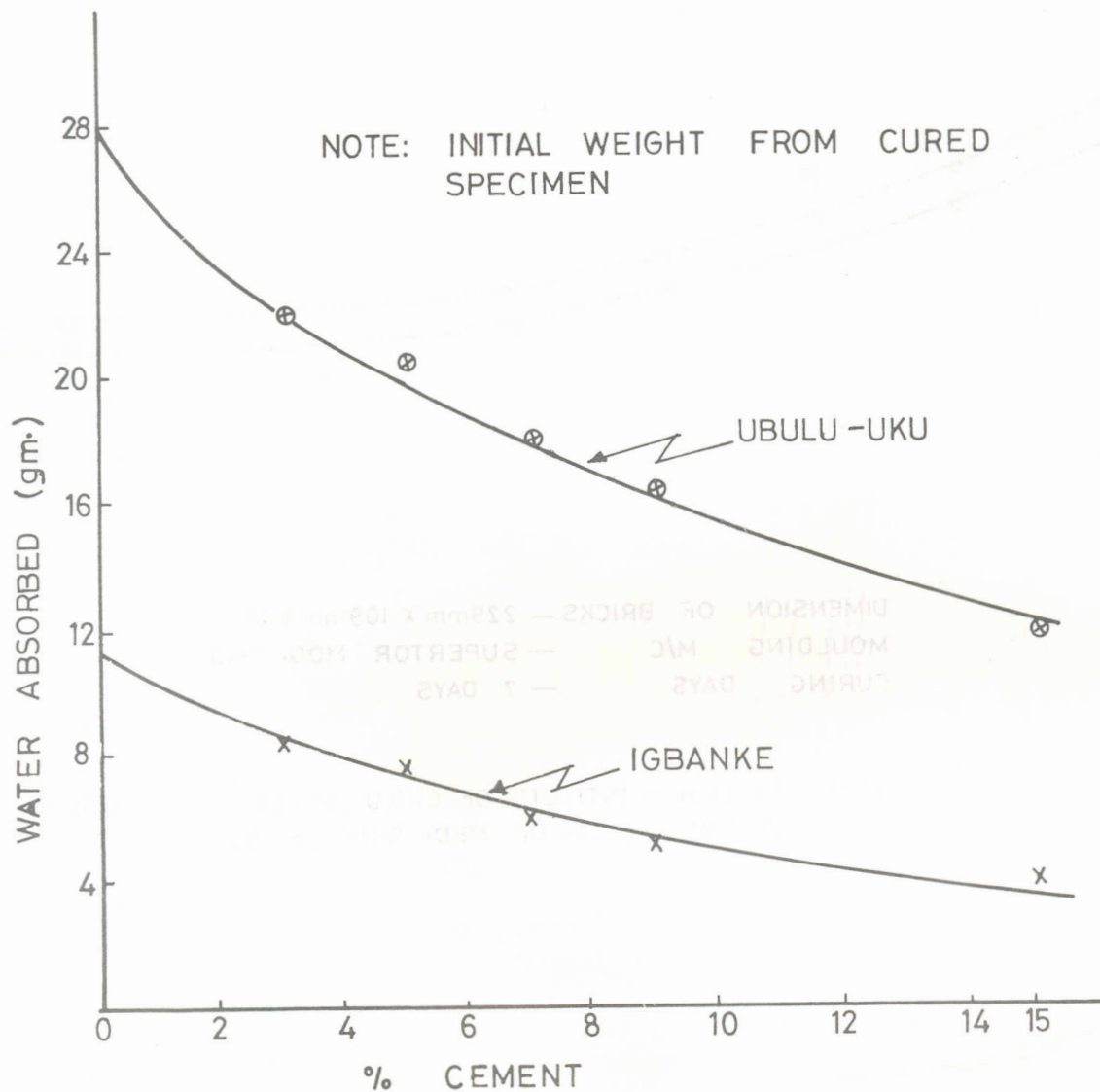


FIG. 17. WATER ABSORBED IN A MINUTE Vs % CEMENT

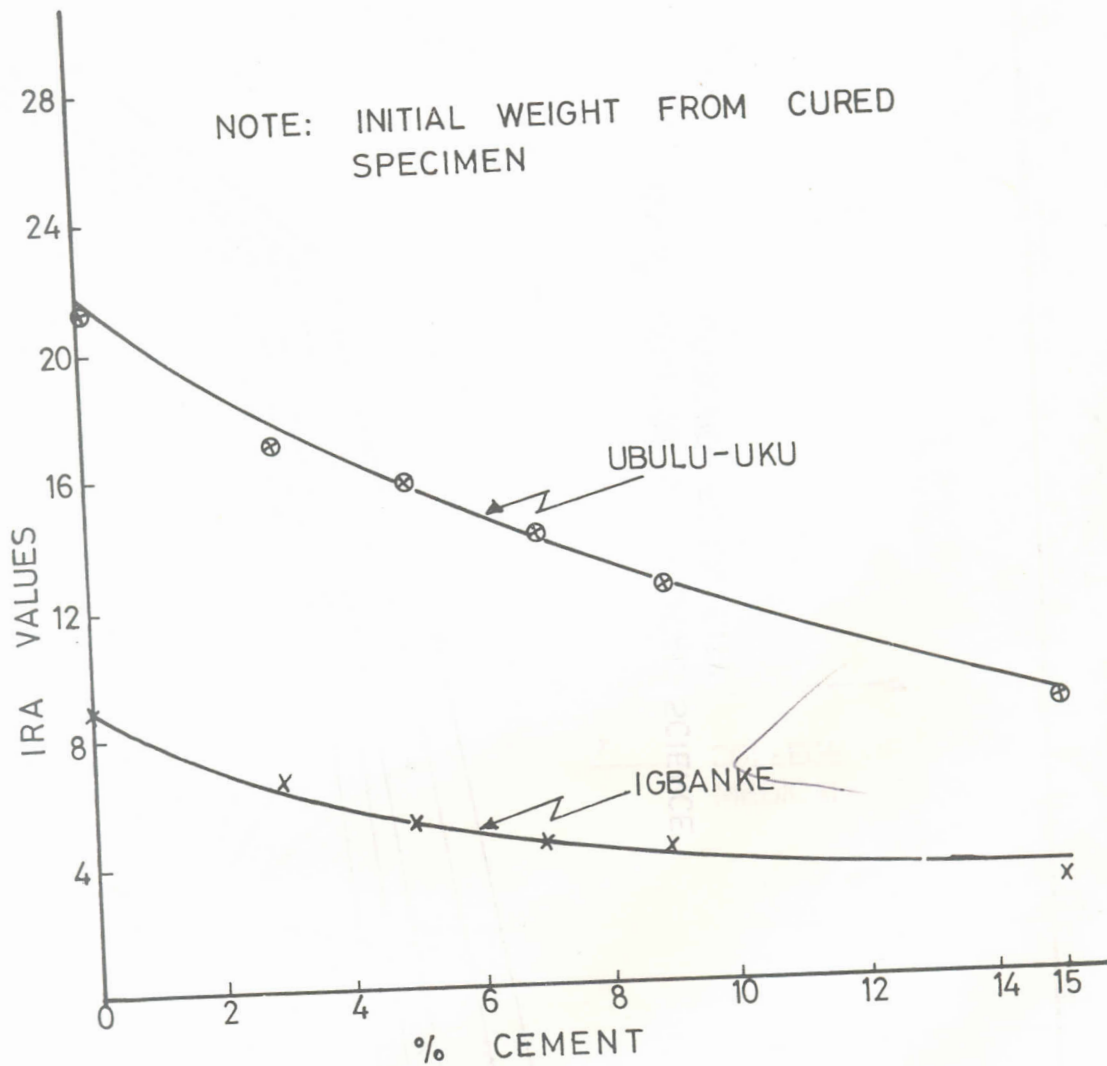


FIG. 18. IRA VALUES Vs  
% CEMENT

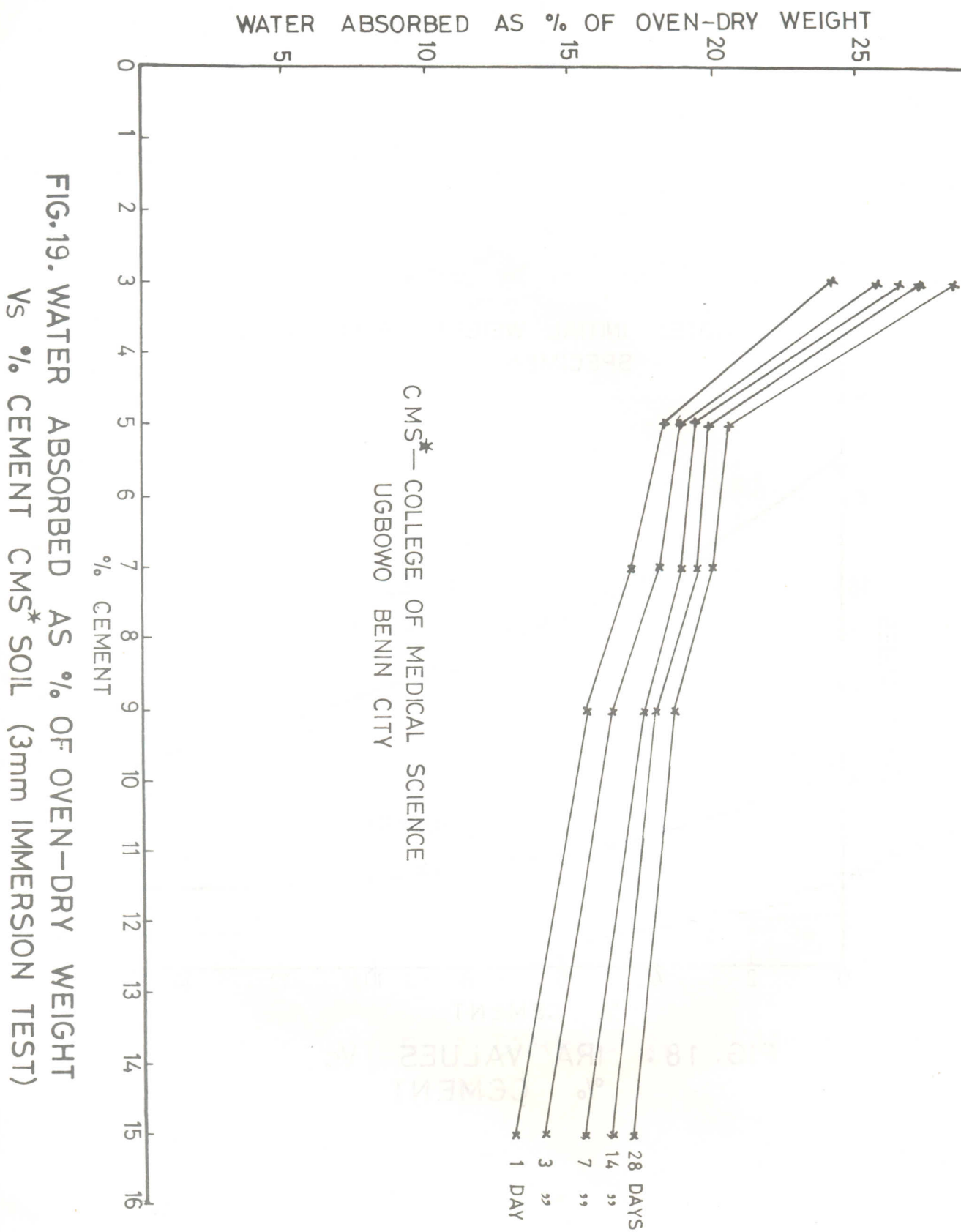


FIG.19. WATER ABSORBED AS % OF OVEN-DRY WEIGHT VS % CEMENT CMS\* SOIL (3mm IMMERSION TEST)

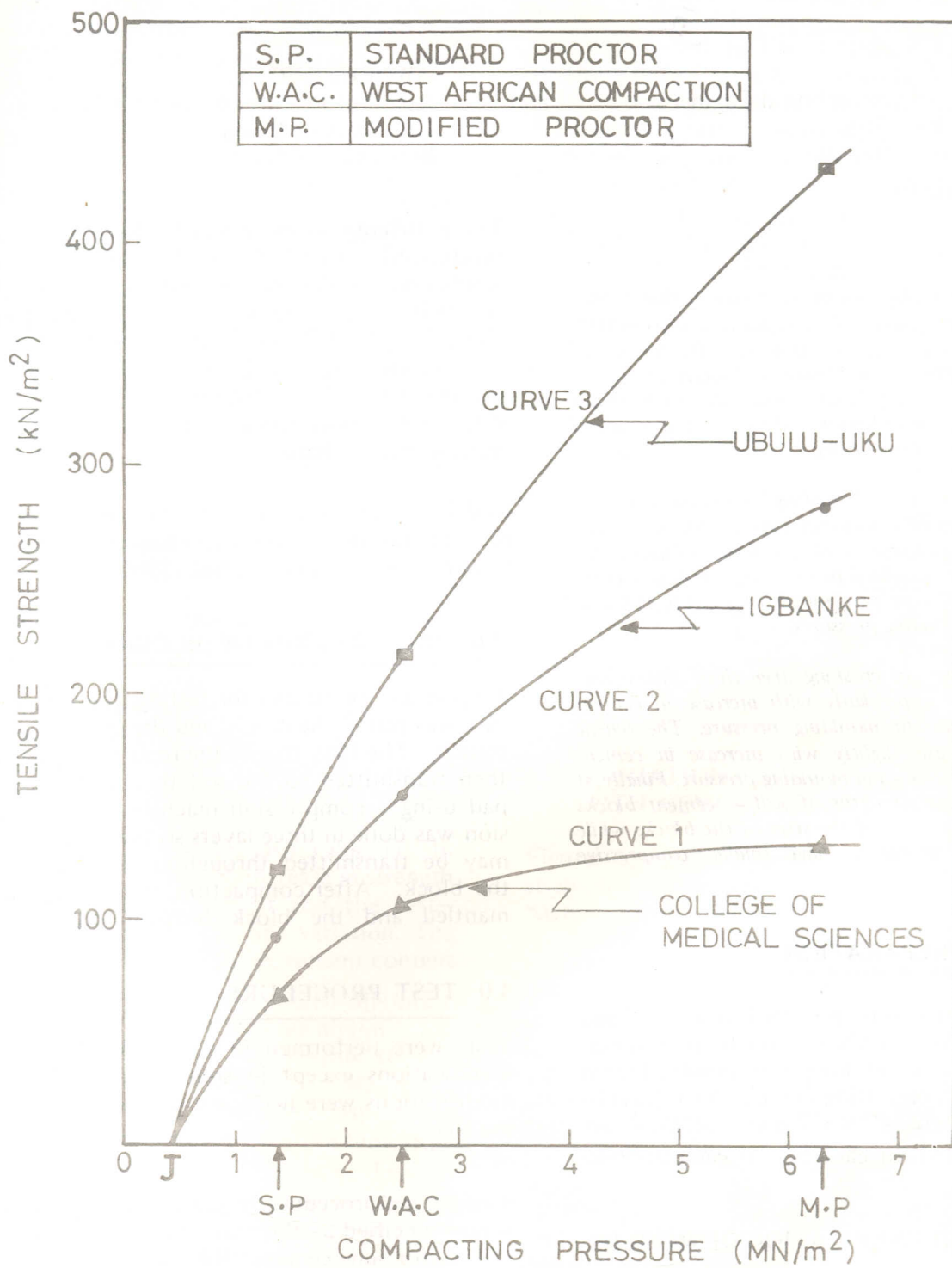


FIG. 20. TENSILE STRENGTH Vs COMPACTION PRESSURE

## SOIL STABILIZED COMPRESSED BLOCKS FOR CIVIL ENGINEERING WORKS

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### ABSTRACT

Past researches into clay bricks have shown that a large amount of money is saved in material cost as compared with sandcrete (cement) blocks. However, due to lack of availability of competent workmen in Nigeria to lay the normal size bricks, money saved in material cost is almost off-set by money spent on labour, and a lot of time is wasted due to the small size of the bricks.

In this paper, the results of crushing and tension tests of three different sizes of bricks (the largest being about the size of the normal sandcrete block) are presented and analysed. The bricks were moulded from a soil from Iguorakhi in Bendel State at different percentages of cement stabilization, and various moulding pressures.

The results show that the crushing strength of all the sizes of blocks increased appreciably with increase in cement content and increase in moulding pressure. The tensile strength also increase slightly with increase in cement content as well as increases in moulding pressure. Finally, it is found that tensile strengths of soil – cement blocks appear to be independent of the sizes of the blocks while larger size blocks appear to have smaller compressive strengths.

### 1. SAMPLE PREPARATION

Soil–cement mixes were prepared from the soil using 3%, 5%, 7% and 9% by weight of cement. Blocks of three different sizes were moulded from the soil–cement mixes using compactive efforts of 1 MN/m<sup>2</sup>, 2 MN/m<sup>2</sup>, 4MN/m<sup>2</sup> and 7 MN/m<sup>2</sup>. Six blocks were moulded for each mix at each compactive effort.

### 2. DESIGN AND FABRICATION OF MOULDS

The moulds for moulding the blocks used in this investigation were designed and fabricated in the Faculty of Engineering, University of Benin, Benin City, Nigeria using mild steel plates which were reinforced to resist the compactive efforts needed for moulding the bricks. Each mould has an accompanying steel pad for transmitting the pressure from the compression machine to the soil–cement.

Three different sizes of moulds were fabricated to produce blocks of 240 x 110 x 80 mm (9½" x 4½" x 3") thick which corresponds to the local brick size (LBS) used in most countries, 290 x 140 x 90 mm (11½" x 5½" x 3½") thick which corresponds to the Cinva–Ram (CR) size from Bogota, Colombia and 290 x 220 x 140mm (11½" x 9½" x 5½") thick and corresponds to the Tek–Block (TB) size from Kumasi, Ghana.

Details of the machines for making the various sizes of blocks and the addresses of the manufacturers can be obtained in Lunt (1980).

### 3.0 PREPARATION OF BLOCKS

To prepare the blocks for testing, the soil–cement mix was put in the mould and the pressure pad put over it. The load to give the required pressure was then transmitted to the soil through the pressure pad using a compression machine. The compression was done in three layers so that equal pressure may be transmitted throughout the thickness of the block. After compaction, the mould was dismantled and the block brought out carefully.

### 4.0 TEST PROCEDURE

Tests were performed in accordance with ASTM specifications except in some cases where a few modifications were necessary due to the nature of the soil.

The mixing procedure to get the soil–cement mix was as specified by the portland cement association (1959) for soil–cement. The soils were air–dried, pulverized, and divided into batches before each batch was thoroughly mixed with the stabilizer to uniform colour. Water was then added as rapidly as practicable before compaction. In all the experimental work, the cement used was a 'Typical Ordinary Portland Cement' to BS 12.

The following tests were carried out on each of the different groups of blocks under investigation.

## 4.1 COMPRESSIVE STRENGTH

The samples were cured by sprinkling with water for seven days. After curing, the specimens were tested in compression at a rate of  $1.72 \text{ MN/m}^2/\text{min}$  (250lb/sq. in/min) or at a rate of strain of about  $1.27 \text{ mm/min}$  (0.05 in/min). The moisture content of the specimen was determined after testing, using the fragments.

## 4.2 TENSILE STRENGTH

After curing, the specimens were tested in tension by screwing side plates to each end of the block. A stressing rate of about  $0.138 \text{ MN/m}^2/\text{min}$  was used. As the tensile strength of this soil-cement is much lower than  $1.1 \text{ MN/m}^2$ , it was assumed that there would be no slippage between the plates and the tensile specimens. This assumption was supported by the failure patterns which showed brittle characteristics and also confirmed by Bofinger (1970).

## 5.0 RESULTS

The results of tests conducted on the specimens are recorded on Table 1 and graphs Figs. 1 – 12.

### 5.1 VARIATION OF COMPRESSIVE STRENGTH WITH CEMENT CONTENT

Three specimens were tested at each cement content and compactive effort and the average compressive strength taken. Figs. 1, 2 and 3 show the variation of compressive strength with various cement contents for the three different sizes of bricks after 7 days curing (see also Table 1). In each case, there is a consistent increase in strength with increase in cement content and the best-fitting curve shows a straight line variation. The increases in strength for 3% to 9% cement content for the local brick sizes are from  $0.81 \text{ MN/m}^2$  to  $2.30 \text{ MN/m}^2$ ;  $1.12 \text{ MN/m}^2$  to  $2.60 \text{ MN/m}^2$ ;  $1.65 \text{ MN/m}^2$  to  $3.65 \text{ MN/m}^2$ ;  $2.1 \text{ MN/m}^2$  to  $4.96 \text{ MN/m}^2$  for compactive effort of  $1 \text{ MN/m}^2$ ,  $2 \text{ MN/m}^2$ ,  $4 \text{ MN/m}^2$  and  $7 \text{ MN/m}^2$  respectively. Similar increases were recorded for the Cinva-Ram size and the Tek-Block size of block. The soil evaluated in this investigation when compacted at a cement content of 3% exceeded the requirement for a one storey structure with light roofing where a strength of only about  $206.9 \text{ kN/m}^2$  is required; Lyon Associates (1971). At 5% cement content these strengths also exceeded the minimum recommended design value of  $1.4 \text{ MN/m}^2$ ; Ola (1983a). Also, the soil blocks at 7% cement content and compactive effort of about  $4 \text{ MN/m}^2$  and higher gave values that exceeded the minimum strength of  $2.8 \text{ MN/m}^2$  which is specified in BS 2028 for precast concrete blocks.

### 5.2. VARIATION OF COMPRESSIVE STRENGTH WITH COMPACTIVE EFFORT

Fig. 4 shows the variation of compressive strength with compactive effort for the local brick size for 3%, 5%, 7% and 9% cement contents. The curves show an increase in strength with increase in compactive effort from 1 to  $7 \text{ MN/m}^2$ . The increases in strength are from  $0.81 \text{ MN/m}^2$  to  $2.1 \text{ MN/m}^2$   $1.46 \text{ MN/m}^2$  to  $4.96 \text{ MN/m}^2$  for 3%, 5%, 7% and 9% cement content respectively. These recorded increases are quite significant and agree quite well with results obtained by Ola (1983b). The soil used in this investigation when compacted at about  $4 \text{ MN/m}^2$  gave strengths which exceeded the requirement for a one-storey structure with light roofing as specified by Lyon Associates (1971) and the minimum recommended design value by Ola (1983a). Also, the blocks compacted at these higher pressures exceeded the minimum strength of  $2.8 \text{ MN/m}^2$  which is specified in BS 2028 for precast concrete blocks.

Results from Lunt (1980) and Ola (1983b) indicate that the most economic optimum compaction might not be far from  $8 \text{ MN/m}^2$ . Similar results were recorded in this investigation as can be seen from Fig. 4.

### 5.3. VARIATION OF TENSILE STRENGTH WITH CEMENT CONTENT

Figures 5, 6, and 7 show the variation of tensile strength with cement content at different compactive efforts. In each of the cases, there is an increase in tensile strength with increase in cement content. From Table 1, it will be seen that the tensile strengths from 3% to 9% cement for the local bricks size increased from  $0.03 \text{ MN/m}^2$  to  $0.15 \text{ MN/m}^2$ ;  $0.06 \text{ MN/m}^2$  to  $0.17 \text{ MN/m}^2$ ;  $0.17 \text{ MN/m}^2$  to  $0.20 \text{ MN/m}^2$ ;  $0.19 \text{ MN/m}^2$  to  $0.2 \text{ MN/m}^2$  at  $1 \text{ MN/m}^2$ ,  $2 \text{ MN/m}^2$ ,  $4 \text{ MN/m}^2$  and  $7 \text{ MN/m}^2$  compactive efforts respectively. This accounts for an increase of between 18 per cent and 400 per cent. Similar increases were recorded by Bofinger (1970) when he got values of tensile strengths of  $0.27 \text{ MN/m}^2$ ;  $0.36 \text{ MN/m}^2$ , and  $0.42 \text{ MN/m}^2$  for test conducted on briquettes at 6%, 8% and 10% cement content respectively. Direct tensile tests on blocks  $304.8 \text{ mm} \times 76.2 \text{ mm} \times 76.2 \text{ mm}$  thick also yielded values of  $0.25 \text{ MN/m}^2$ ,  $0.36 \text{ MN/m}^2$  and  $0.43 \text{ MN/m}^2$  at 6%, 8% and 10% cement contents respectively. This accounts for an increase in tensile strength of about 72% between 6% and 10% cement content.

#### 5.4 VARIATION OF TENSILE STRENGTH WITH COMPACTIVE EFFORT

The graph of variation of tensile strength with compactive effort is shown in Figure 8 for local brick size. The value of tensile strength at compactive efforts of 2 MN/m<sup>2</sup> and 4 MN/m<sup>2</sup> can also be seen on Table 1. It will be observed that generally, slight increases in tensile strength were recorded. For instance, for the local brick size at 5% cement content, an increase from 0.12 MN/m<sup>2</sup> to 0.19 MN/m<sup>2</sup> is observed for compactive efforts from 1 MN/m<sup>2</sup> to 7 MN/m<sup>2</sup>. Similar results were obtained for the other brick sizes. Thus an increase in tensile strength which appears to have its maximum tensile strength at about 6 MN/m<sup>2</sup> (Fig. 8) was observed. A possible explanation derives from the macro structure of the material in which planes of weaknesses occur between the soil matrix and the stabilized matrix. With higher percentage of cement such planes of weaknesses are reduced, but this may not necessarily be the case with increase in compactive effort. A similar explanation based on macrostructure of soil-cement was also advanced by Bofinger (1970) to account for the difference in the behaviour of soil-cement under compressive and tensile loads.

#### 5.5 VARIATIONS OF COMPRESSIVE AND TENSILE STRENGTHS WITH SIZE OF BLOCKS

The variation in compressive strength with size of blocks is reflected in Figures 9 and 10 showing the variation of compressive strength with percentage cement content at 2 MN/m<sup>2</sup> and 4 MN/m<sup>2</sup> respectively for the three sizes of blocks. It is observed that in both cases, the Tek Block size which has the largest size (i.e. about 4 times the volume of the local size brick) has the lowest compressive strength in both cases in Figures 9 and 10. Results for the Cinva ram size and local brick size which are relatively close on size are inconclusive. More work is still going on in this area, but from all the results it appears that the larger size blocks appear to have smaller compressive strengths. The results of the tensile strengths shown in Figures 11 and 12 tend to indicate that no significant increase in tensile strength occurs after a cement content of 9% for all the various brick sizes. There was no consistent pattern for the effect of brick sizes on the tensile strength.

#### 6.0 CONCLUSIONS

1. The compressive strength of soil-cement blocks increases appreciably with increase in cement content.
2. The compressive strength of soil-cement blocks increases appreciably with increase in compactive effort up to a compactive effort of about 8 MN/m<sup>2</sup> when subsequent increase is no longer appreciable.
3. The tensile strength of soil-cement blocks increases with increase in cement content.
4. The tensile strength of soil-cement blocks increases with compactive effort up to a compactive effort of 6 – 8 MN/m<sup>2</sup>.
5. Tensile strengths of soil-cement blocks appear to be independent of the sizes of blocks. On the other hand, large size blocks appear to have smaller compressive strengths

#### ACKNOWLEDGEMENT

The work described in this paper is a research project of the writers in the Department of Civil Engineering of the University of Benin. They acknowledge the help of Maxwell Odivbri in the design and fabrication of the mould described in this paper.

Moulding Pressure (MN/m <sup>2</sup> )	Cement %	LOCAL BRICK SIZE				CINVA-RAM SIZE				TEK-BLOCK SIZE			
		1MN/m <sup>2</sup>	2MN/m <sup>2</sup>	4MN/m <sup>2</sup>	7MN/m <sup>2</sup>	1MN/m <sup>2</sup>	2MN/m <sup>2</sup>	4MN/m <sup>2</sup>	7MN/m <sup>2</sup>	1MN/m <sup>2</sup>	2MN/m <sup>2</sup>	4MN/m <sup>2</sup>	7MN/m <sup>2</sup>
Strength (MN/m <sup>2</sup> )	3%	0.81	1.12	1.65	2.1	1.15	1.55	1.10	1.35				
	5%	1.46	1.75	2.35	3.2	1.70	2.20	1.50	2.05				
	7%	1.77	2.16	3.20	4.15	2.25	2.85	2.00	2.85				
	9%	2.30	2.60	3.65	4.96	2.80	-	2.33	3.38				
Tensile Strength (MN/m <sup>2</sup> )	3%	0.03	0.06	0.17	0.19	0.04	0.05	0.06	0.05				
	5%	0.12	0.10	0.18	0.19	0.04	0.07	0.10	0.11				
	7%	0.14	0.15	0.19	0.20	0.14	0.15	0.14	1.17				
	9%	0.15	0.17	0.20	0.21	0.19	0.20	0.17	0.20				

TABLE 1: SUMMARY OF RESULTS OF COMPRESSION AND TENSION TESTS CARRIED OUT ON CLAY BLOCKS

5

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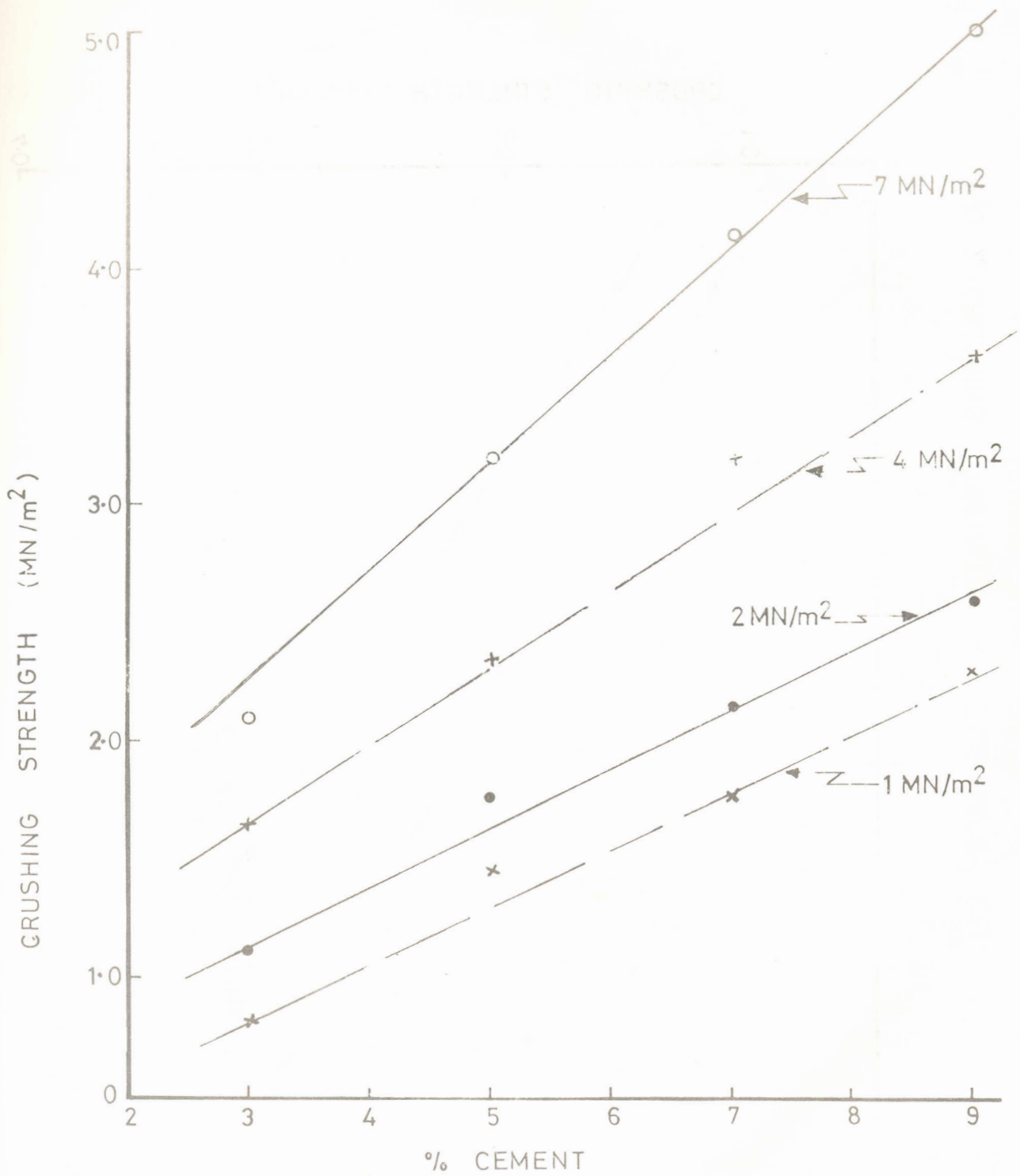


FIG. 1. CRUSHING STRENGTH Vs PERCENTAGE CEMENT  
( LOCAL BRICK SIZE )

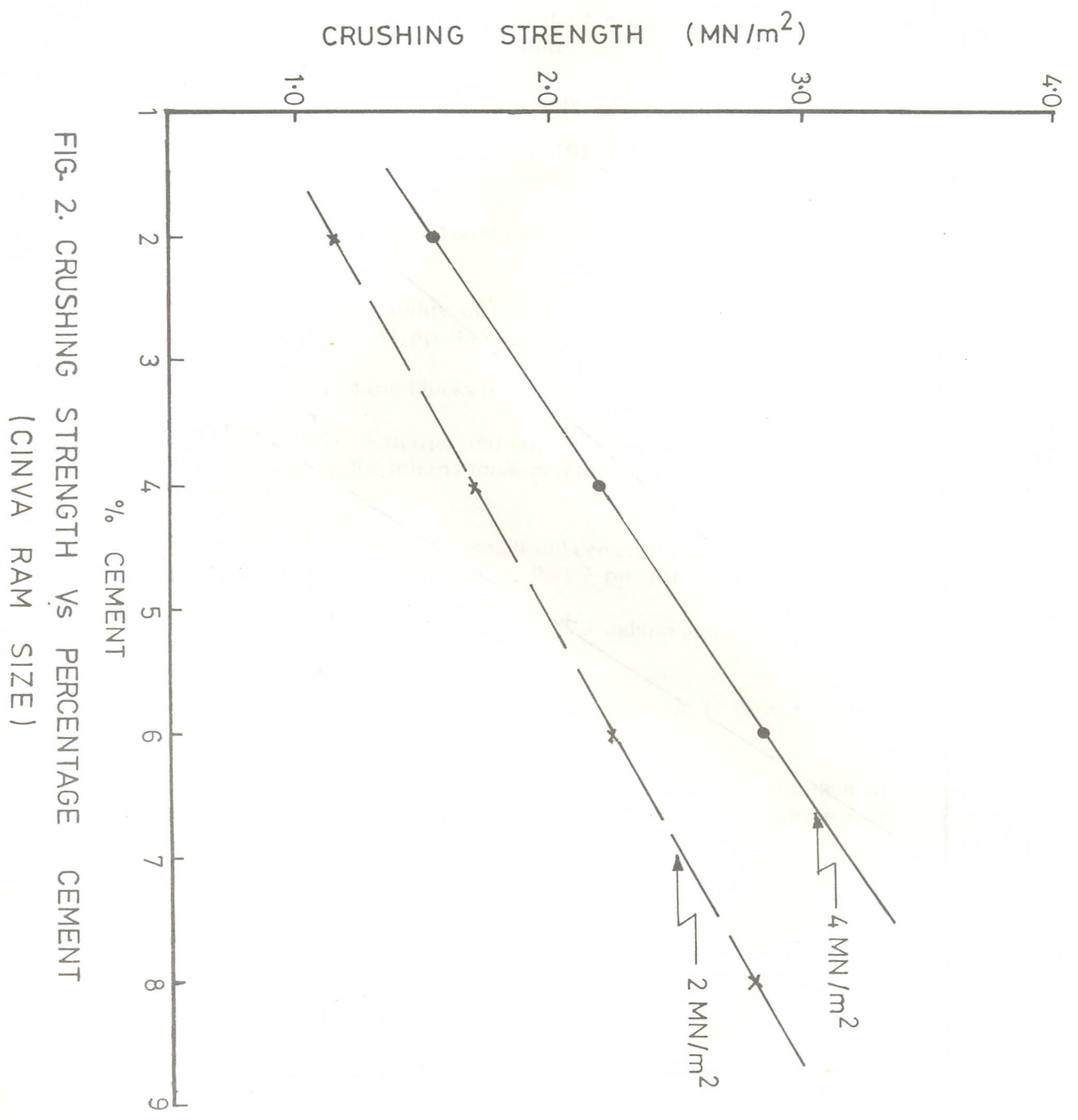


FIG. 2. CRUSHING STRENGTH VS PERCENTAGE CEMENT  
(CINVA RAM SIZE)

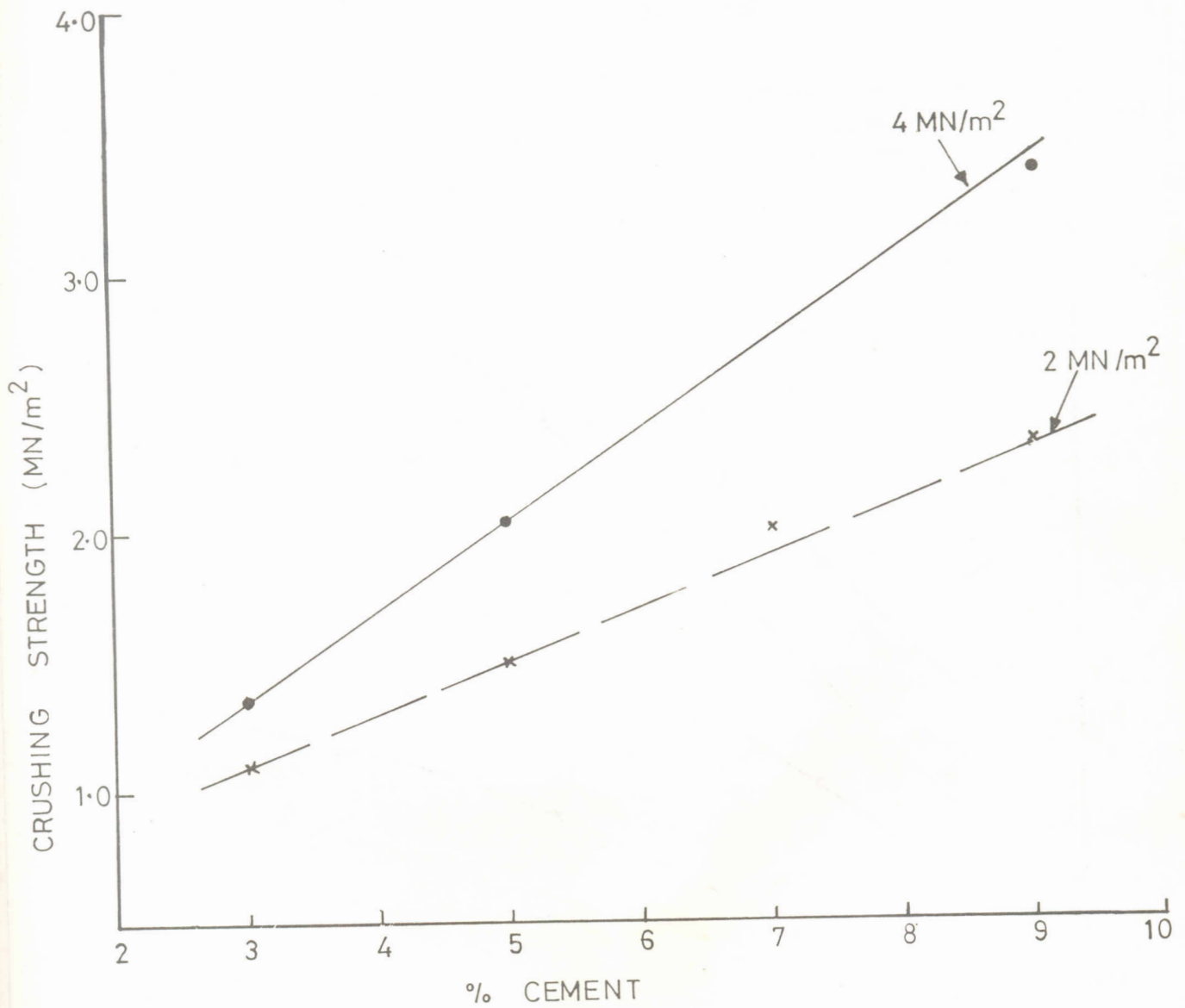


FIG. 3. CRUSHING STRENGTH Vs PERCENTAGE CEMENT  
(TEK BLOCK SIZE)

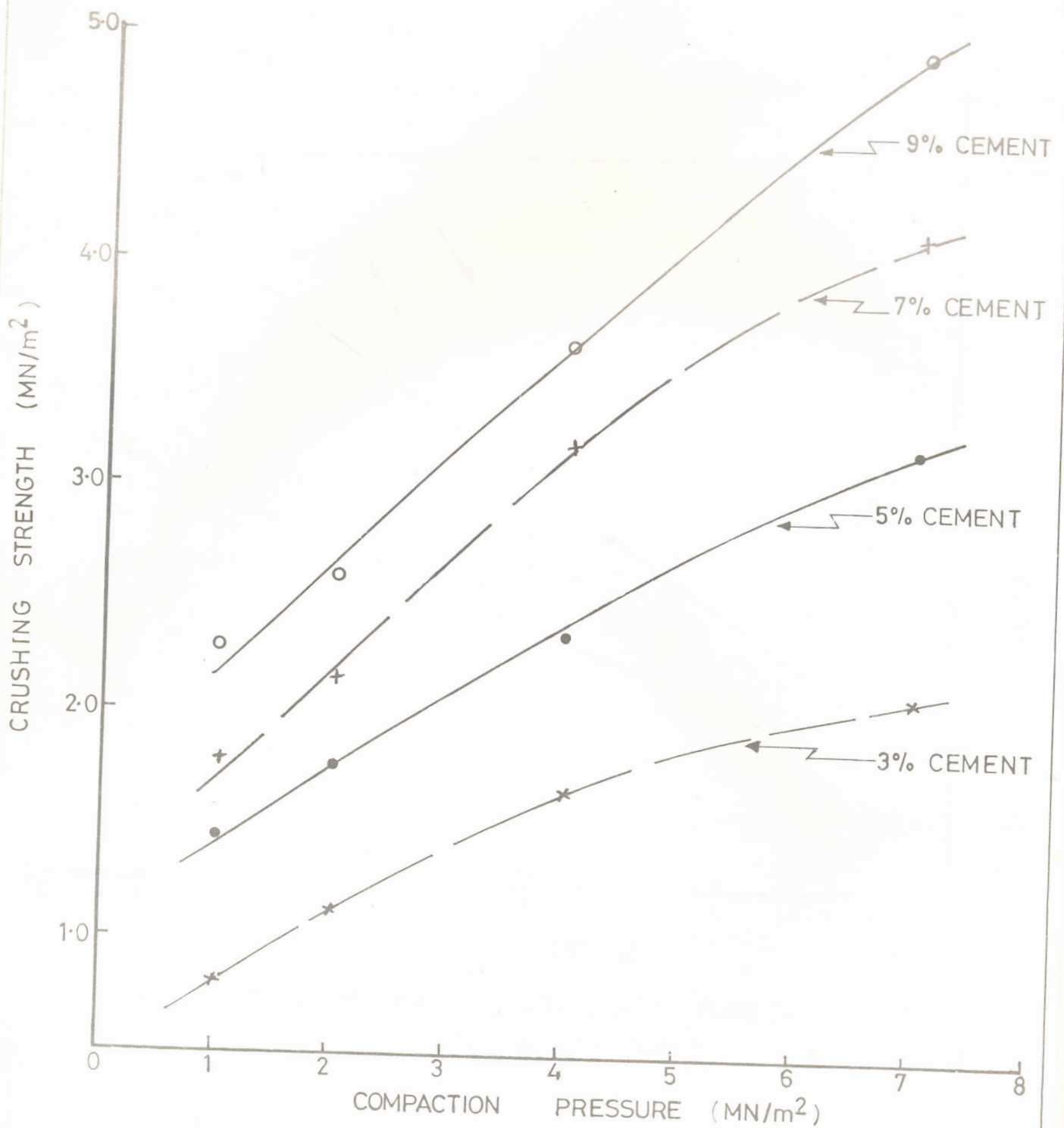


FIG. 4. CRUSHING STRENGTH VS COMPACTION PRESSURE  
(LOCAL BRICK SIZE)

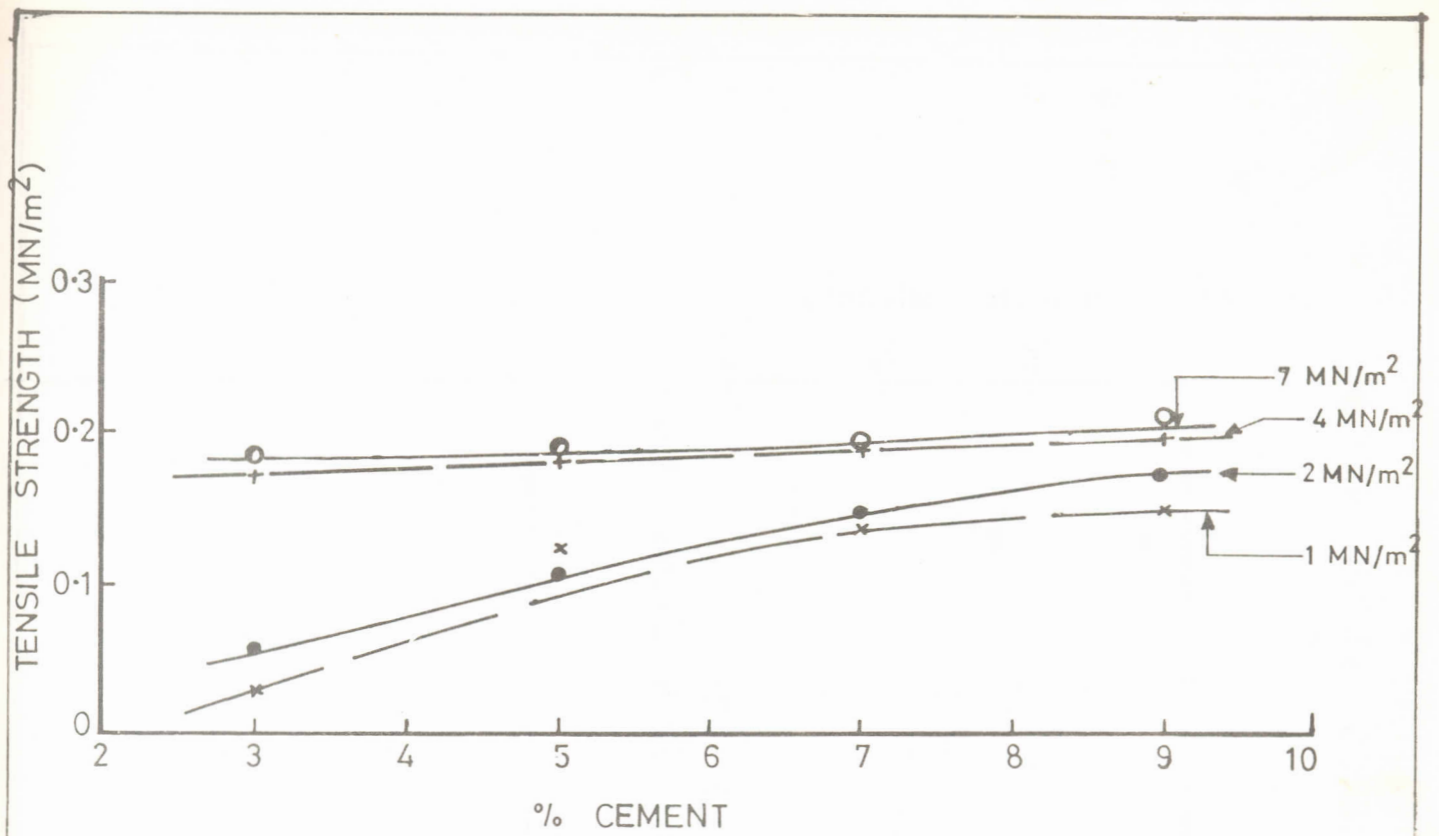


FIG. 5. TENSILE STRENGTH Vs PERCENTAGE CEMENT  
(LOCAL BRICK SIZE)

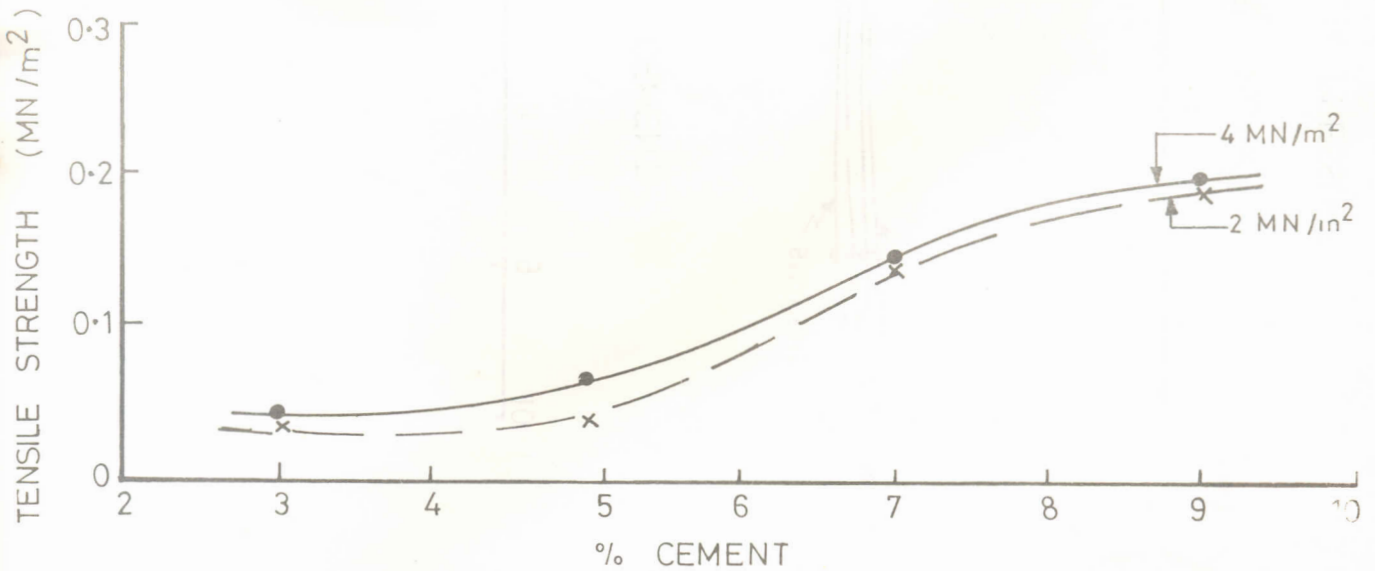


FIG. 6. TENSILE STRENGTH Vs PERCENTAGE CEMENT  
(CINVA RAM SIZE)

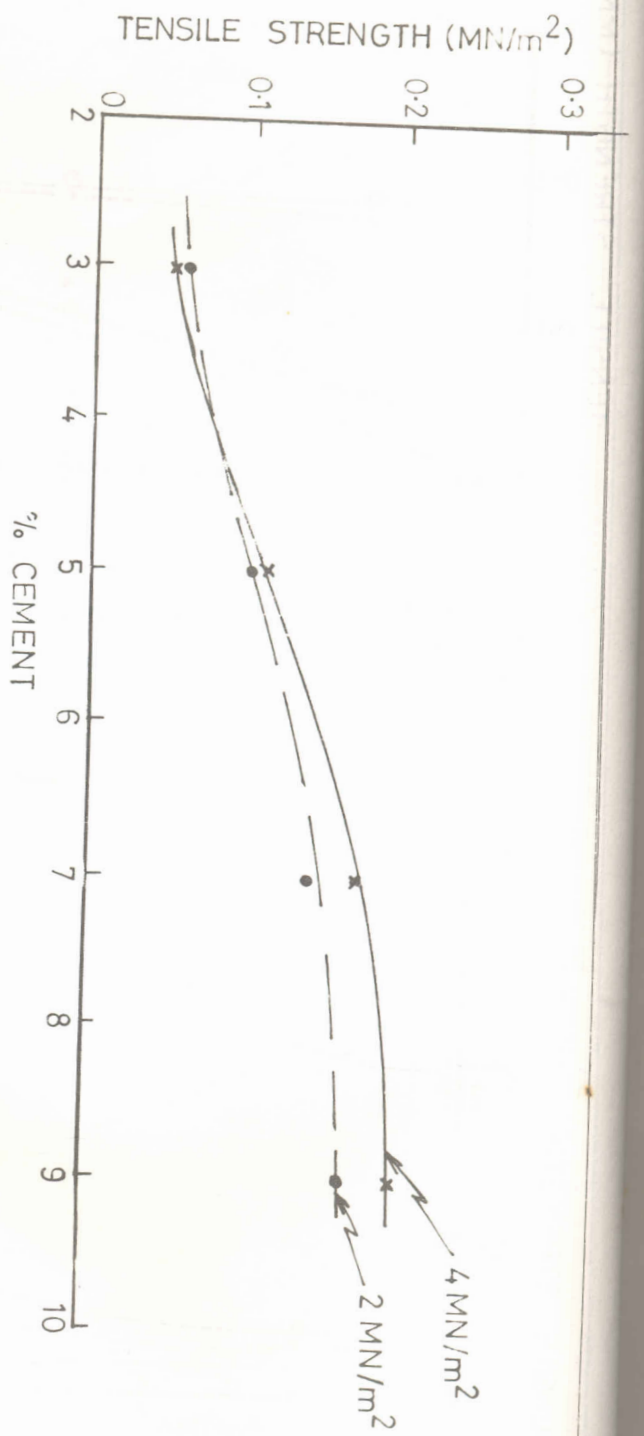


FIG 7 TENSILE STRENGTH VS PERCENTAGE CEMENT  
(TEK BLOCK SIZES)

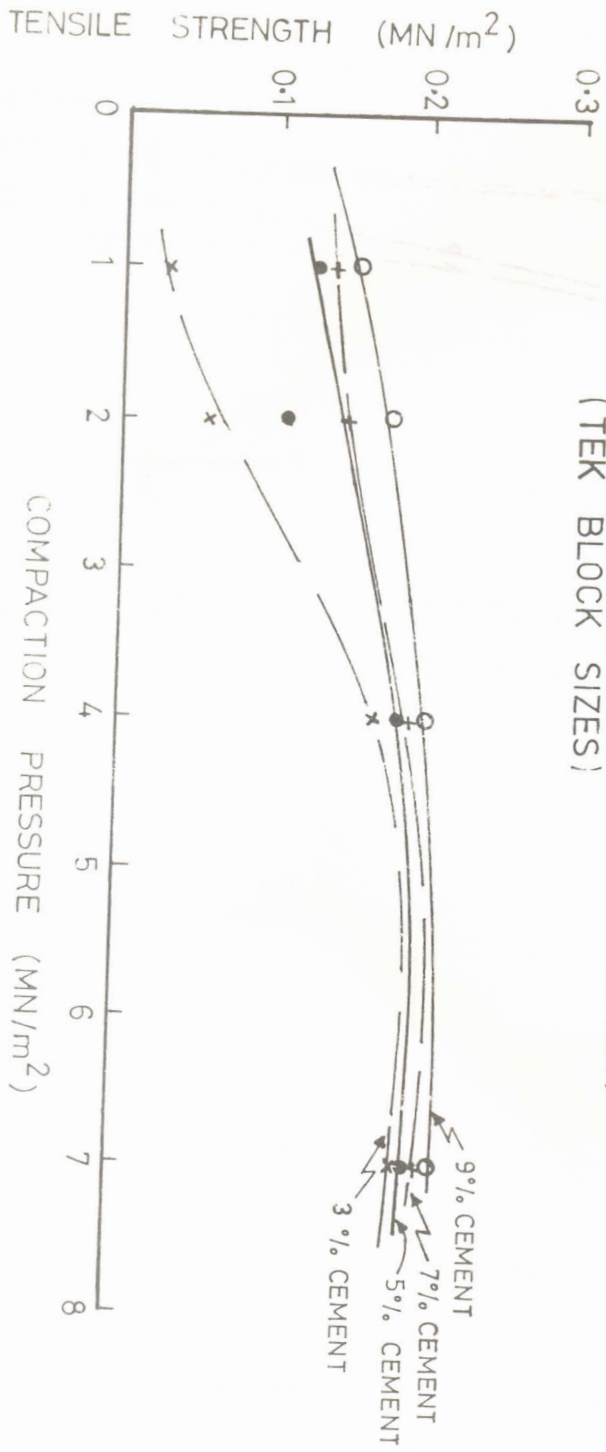


FIG. 8. TENSILE STRENGTH VS COMPACTION PRESSURE  
(LOCAL BRICK SIZE)

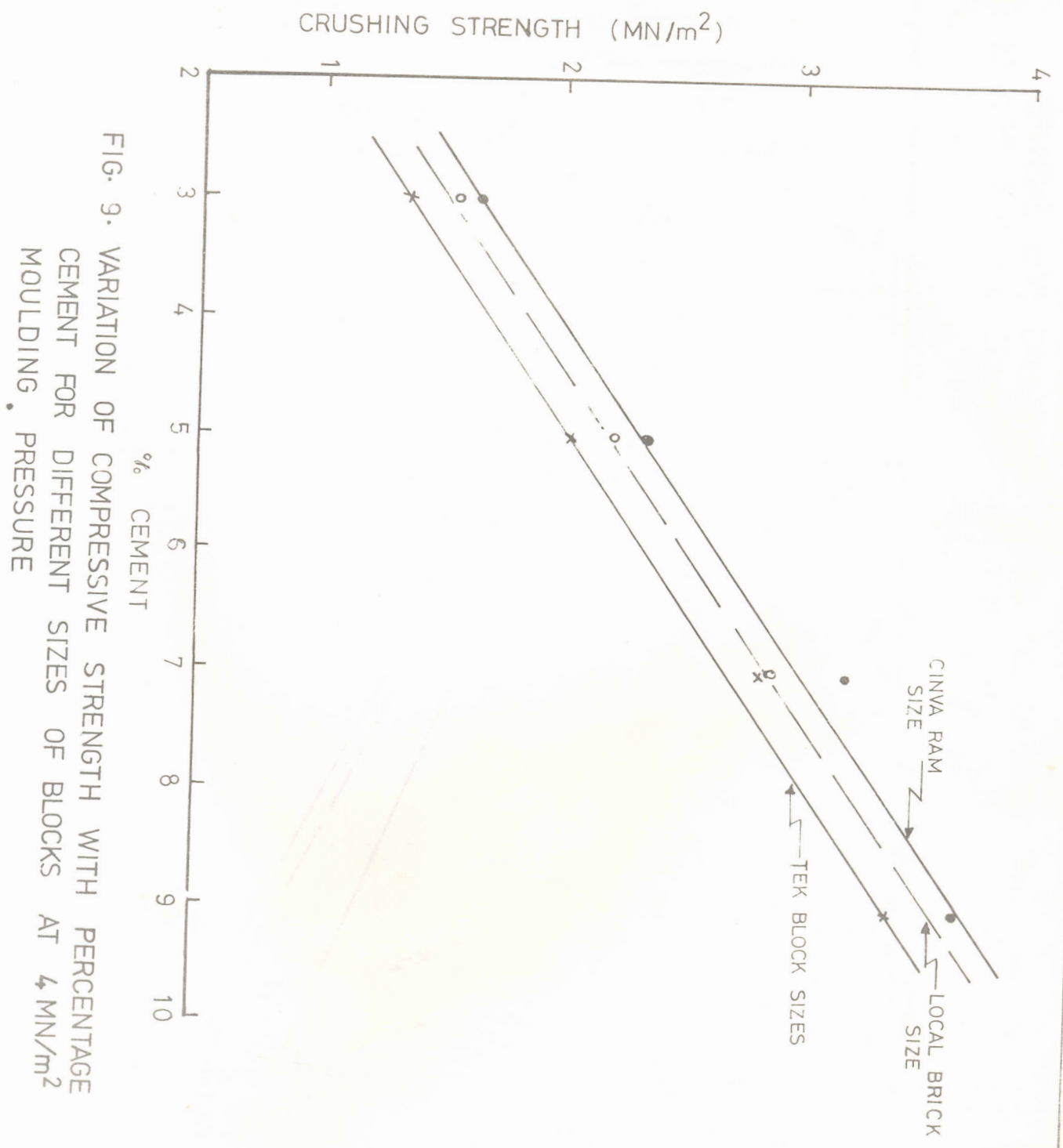


FIG. 9. VARIATION OF COMPRESSIVE STRENGTH WITH PERCENTAGE CEMENT FOR DIFFERENT SIZES OF BLOCKS AT 4 MN/m<sup>2</sup> MOULDING PRESSURE

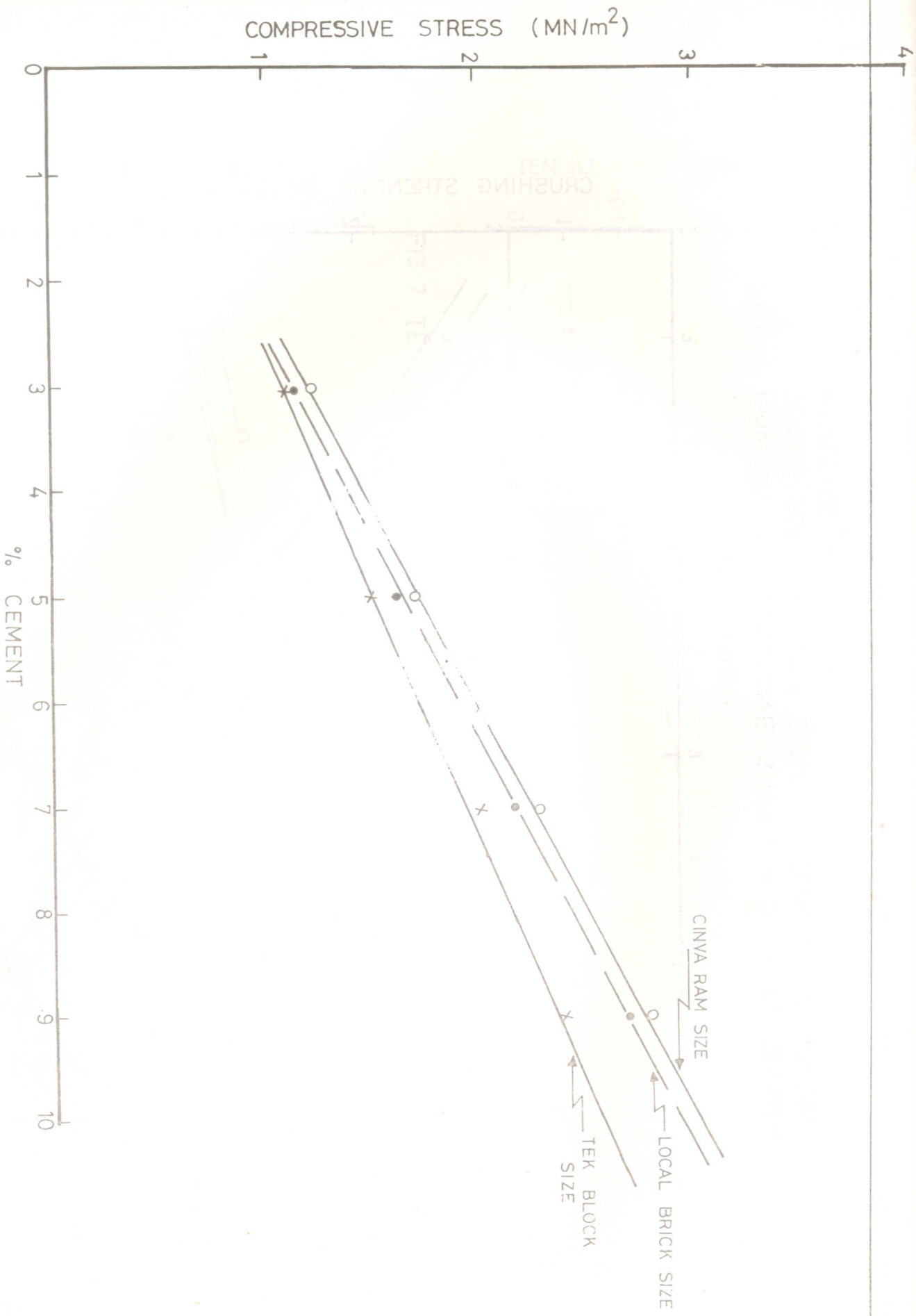


FIG 10 VARIATION OF COMPRESSIVE STRENGTH WITH PERCENTAGE CEMENT FOR DIFFERENT SIZES OF BLOCKS AT 2 MN/m<sup>2</sup> MOULDING PRESSURE

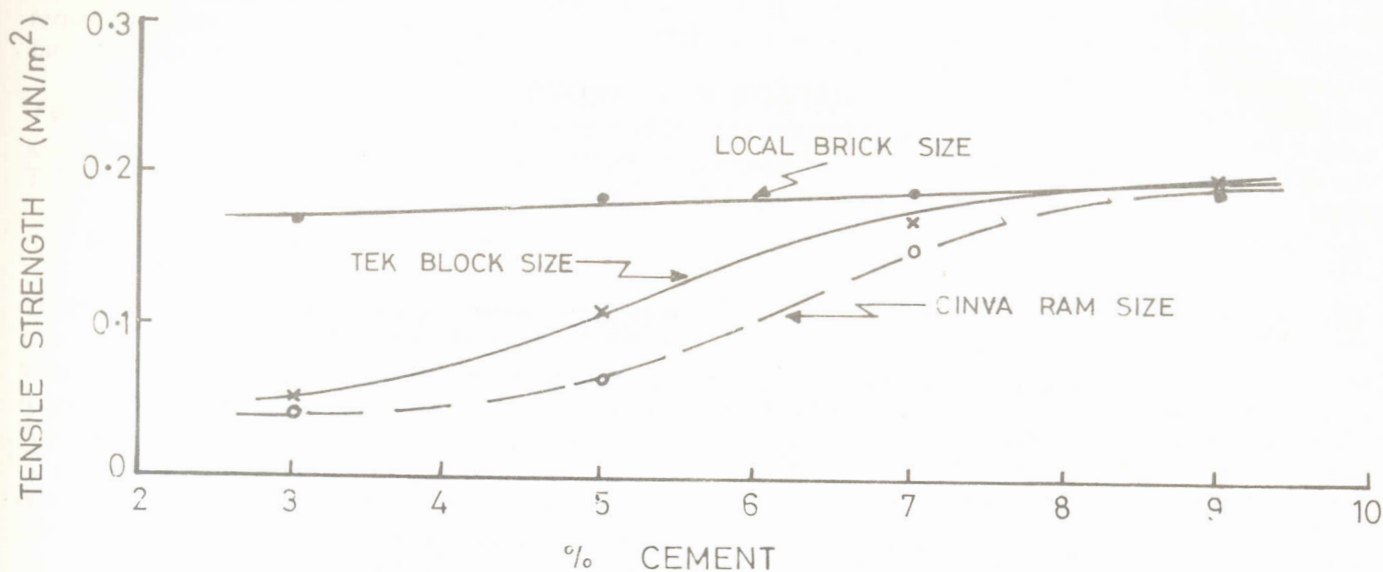


FIG. 11. VARIATION OF TENSILE STRENGTH WITH PERCENTAGE CEMENT FOR DIFFERENT SIZES OF BLOCK AT  $4 \text{ MN/m}^2$  MOULDING PRESSURE

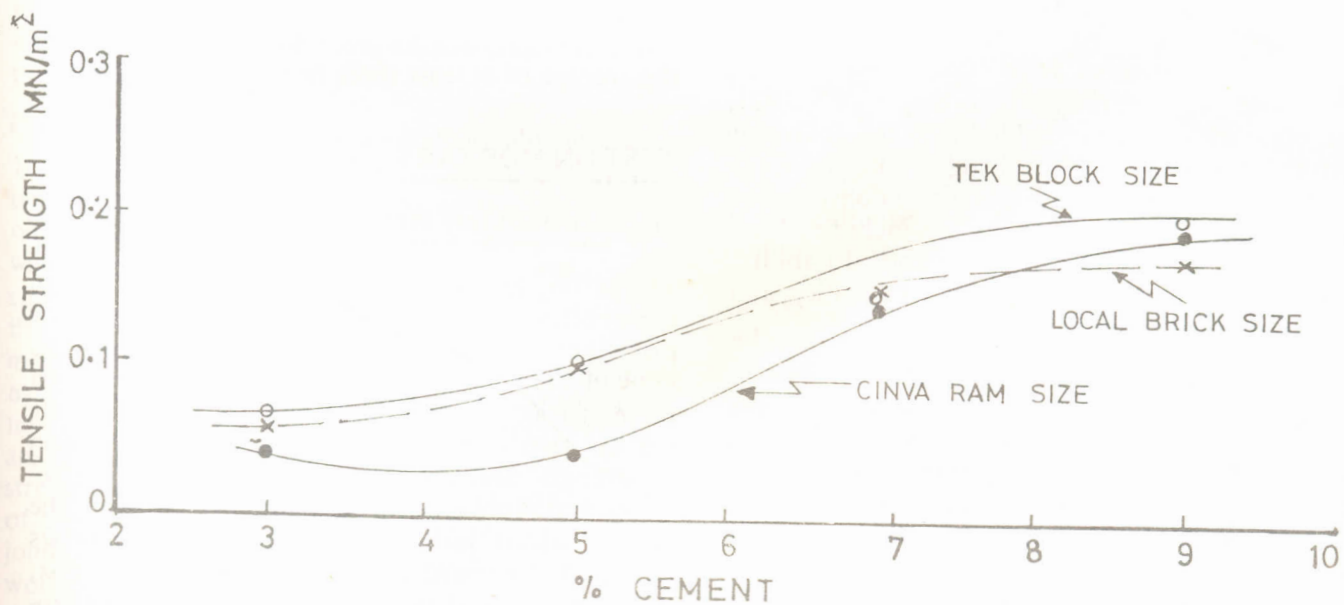


FIG. 12. VARIATION OF TENSILE STRENGTH WITH PERCENTAGE CEMENT FOR DIFFERENT SIZES OF BLOCK AT  $2 \text{ MN/m}^2$  MOULDING PRESSURE

## THE EFFECT OF DIFFERENT TYPES OF MORTAR ON THE STRENGTH CHARACTERISTICS OF BRICKWORK

By

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### ABSTRACT

*Mortar is the second component of brickwork. In deciding the type of mortar to be used for a particular brickwork, a few properties should be considered. This paper examines two types of mortars (cement - lime and bituminous mortars). Parameters varied included mortar composition, water/cement ratio and curing period. Tests performed included compressive and flexural tests. Similar tests were performed on composite materials, i.e. bricks and mortars. Results show that the strength of mortar decreases with increasing water/cement ratio; tensile strength of mortar is less sensitive to water/cement ratio and that for bituminous mortars, the cold-mixed mortars have better adhesive properties than those that were hot-mixed.*

### INTRODUCTION

Brickwork comprises mainly of two components, the bricks and the mortar used to hold the bricks together. Bricks are blocks of tempered clay moulded while in plastic condition to suitable shapes and sizes, dried in the sun and burnt (or fired), if so desired, so as to make them stronger, harder and more durable. According to BS 3921, fired clay bricks can be divided into the following classes - common bricks, facing bricks and Engineering bricks. Bricks are popular as a construction material due to a number of reasons including local availability, low cost, strength and durability. Bricks need to be bonded together to stability; and mortars are used to bond bricks together.

Mortars are materials which if added in a suitable form to a non-coherent assemblage of particles, will subsequently harden by physical or chemical means and bind the particles into a coherent mass. There are several types of mortars and they include the following groupings:- cement - lime mortars, bituminous mortars, epoxy-resin mortars, masonry mortars and Portland-cement mortars.

This paper examines some of the strength properties of mortars made of cement - lime - sand, bitumen - cement - sand and also the strength characteristics of brickwork as a composite material.

### PRELIMINARY INVESTIGATION

The durability of bricks is a function of their resistance to chemical attack and moisture penetration. Most clay bricks contain a small proportion of soluble salts. Well-fired bricks tend to contain a lower amount of soluble salts than under-fired bricks. Excessive water suction in the bricks can lead to a considerable reduction in brickwork strength. Such properties like suction rate, water absorption, crushing strength, and tensile strength were determined for the bricks as supplied by the manufacturers.

The bricks were supplied by the Clay Industry (Nigeria) Limited, Ikeja. They were perforated, each of them weighed 1.7kg and measured 250 x 120 x 60mm on the average. They were fired to temperature of between 950°C and 1120°C, manufactured from clayey soils obtained from Ikorodu, Lagos State, Nigeria.

The test results are shown in Table 1. Each result is the average of at least three bricks tested.

### TEST ON MORTARS

#### (a) Cement-Lime Mortar

The setting and subsequent gain in the strength of cement-lime mortar is due to the hydration taking place between the water added to the mix and some of the constituents of the cement and lime. Of these, tricalcium aluminate and tricalcium silicate are the two compounds responsible for early gain in strength and dicalcium silicate for the subsequent and more gradual strength development. The factors which influence the strength of mortars include the cement and lime content of the mix, the proportion of the cement to sand and the properties of the sand itself. Materials used were cement (OPC), lime and sand passing sieve 5.00mm. Three mortars mixed of 1: ¼ : 3, 1 : ½ : 4½ and 1 : 1 : 6 (cement : Lime : Sand respectively by weight) were used. The first two mixes had three different water/cement ratios. For each water/cement ratio in each mix two beams (100 x

100 x 400mm) and two cubes (100 x 100 x 100mm) were cast for the determination of strength development for seven days and twenty-eight days. Twenty-four hours after casting, the samples were removed from the moulds and stored in curing tank. The results are shown in Table 2

For the flexural test, beamspecimens of 100 x 100 x 400mm were tested. The results are shown in Table 3.

#### (b) Bituminous Mortar

Materials used here were sand (passing 5.00mm), bitumen (MCI) and ordinary Portland cement. Five samples of bitumen-cement-sand mix in the following ratio by weight (1 : 2 : 6, 1 : 2.75 : 4, 1 : 3 : 6.46 and 1 : 0 : 13.75) were prepared. The first two samples were mixed at room temperature (i.e. cold work), mixes three and four were hot-mixed at a temperature of about 120°C whilst the last mix did not contain any cement. In the preparation of the samples, the specified amount of sand and cement were first measured and mixed thoroughly. The required quantity of bitumen was then added to the cement-sand mix. The combined materials were then either hot or cold-mixed thoroughly.

#### TEST ON COMPOSITE MATERIALS (BRICK AND MORTAR)

Brickwork is a composite material with the brick as the building unit and the mortar as the adjoining material. In order to be able to investigate the effects of mortars on the strength characteristics of brickwork, a number of specimen patterns were prepared for testing.

The models are illustrated diagrammatically in Fig. 1. Model 'a' was subjected to crushing test to obtain the compressive strength of the brickwork on the 120 x 250mm face. Models 'b', 'c' and 'd' were subjected to the simple third-point flexural strength test. Model 'b' was particularly useful in the determination of the tensile bond at the brick / mortar interface. The tensile strength was obtained by assuming modulus of rupture to be approximately twice the tensile strength (Price, 1951). There are a number of factors which influence the strength of any brickwork and they include density of the bricks, time of curing, thickness of mortar joints, water suction of bricks and the quality of workmanship.

Masonry walls are mainly vertical load bearing elements and the main factor in design is resistance to compressive stress. These walls are however called upon, from time to time, to resist horizontal shear forces or lateral pressure from wind and hence the consideration of strength of brickwork in shear and in tension. Failure in brickwork under axial com-

pression is normally by vertical splitting due to the horizontal tension in the bricks or mortars. The reason for this type of failure is due mainly to the widely different strain characteristics of the bricks and mortar joints. Generally, the mortar is less rigid than the brick and under load its tendency is to spread laterally to a greater extent than the bricks. Differential movement is prevented by the bond between the brick and mortar and consequently the mortar is put into a state of biaxial compression and the brick into biaxial tension. Brickwork loaded in uniform compression usually fails by the development of tension cracks parallel to the axis of loading.

For the bituminous binders, only model 'a' was used to determine the compressive strength. The results are shown in Tables 4 to 8.

#### DISCUSSION OF RESULTS

The compressive strength of about 15N/mm<sup>2</sup> places the bricks supplied in the low strength bricks of 14 – 25N/mm<sup>2</sup> (Ovgori, 1983) or class 2 (BS 3921, 1965).

From Table 2 it will be observed that the compressive strength in all the three mortar mixes decreases with increasing water/cement ratio. The 28 day strength is on average about 1.31 times the 7 day strength. From the flexural strength test results, it will also be observed that the strength decreases with increasing water/cement ratio; however the flexural strength of mortar is less sensitive to water/cement ratio variations than the compressive strength. For example, for a mix of 1 : ¼ : 3, the 7 day flexural strength decreased by 20% when the water cement ratio was increased from 0.8 to 0.9. For identical mix and the same change in water/cement ratio, the 7 day compressive strength decreased by 62%.

For the bituminous mortar, the mortars that were cold-mix had more adhesive properties than those that were hot-mixed.

It will be observed from Table 4 that in no case did the strength of the brickwork exceed the strength of the individual bricks. On the other hand the brickwork compressive strength is higher than the mortar for identical mix and curing time. These confirm the findings of Hendry et al, 1981.

The tensile strength of the brickwork was observed to be less than 1/20th of the compressive strength, in some cases less than 1/100th. These values are far lower than values obtained by other researchers (e.g. Bofinger, 1970; Metcalf, 1966). For all mixes, model 'b' gave a better tensile strength than the other models.

## CONCLUSIONS

From the investigations carried out it can be concluded that compressive strength of the individual brick is greater than the brickwork which in turn is greater than the mortar used.

For the three mixes examined, the strength of the mortars decreased with increasing water/cement ratio; and for all the mortar mixes used, the water/

cement ratios of up to 2.0 can satisfactorily be used for brick laying.

The tensile strength of mortar is less sensitive to water/cement ratio variations than the compressive strength.

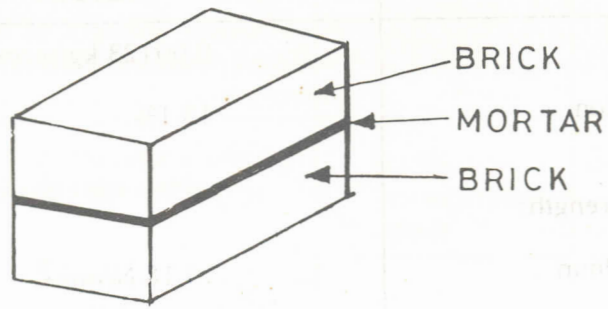
The tensile strength of the brickwork could be as low as 1/100th the compressive strength.

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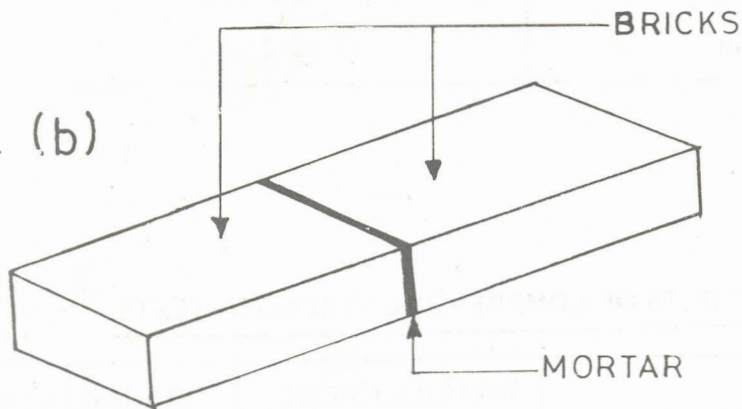
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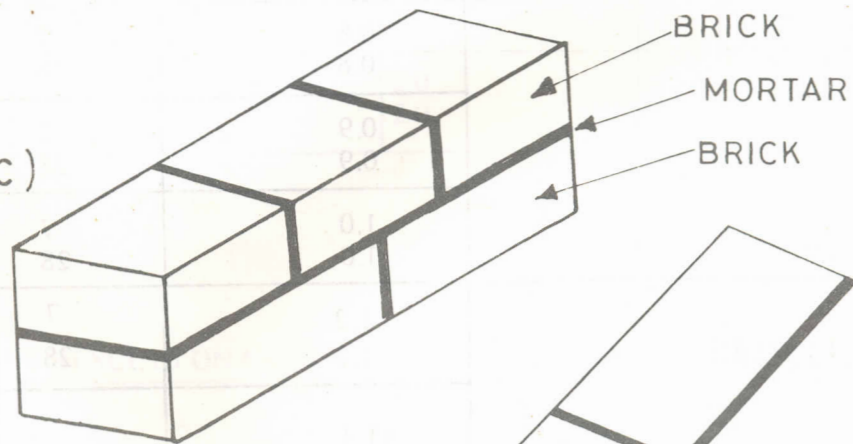
MODEL (a)



MODEL (b)



MODEL (c)



MODEL (d)

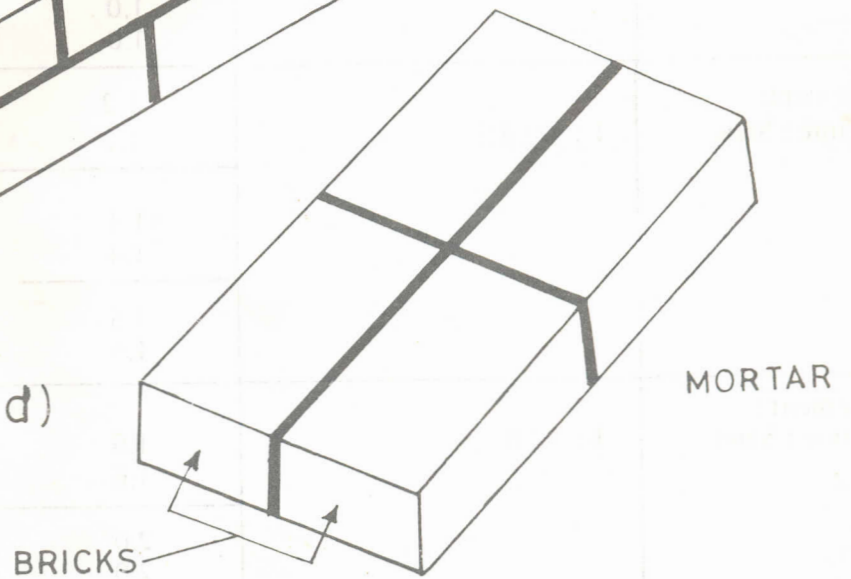


FIG. 1. DIFFERENT TYPES OF SPECIMEN MODELS USED

**TABLE 1: SOME ENGINEERING PROPERTIES OF BRICKS USED FOR THE TEST**

TEST	RESULT
Suction Rate	0.00123 kg/second
Water Absorption	13.1%
<b>Compressive Strength:</b>	
Area 250 x 120mm	15.18 N/mm <sup>2</sup>
Area 250 x 60mm	3.93 N/mm <sup>2</sup>
Area 120 x 60mm	11.83 N/mm <sup>2</sup>

**TABLE 2: RESULTS OF COMPRESSIVE STRENGTH TESTS**

MORTAR DESCRIPTION	MIX (CEMENT: LIME : SAND) BY WEIGHT	WATER/CEMENT RATIO (W/C)	CURING PERIOD (DAYS)	STRENGTH (N/mm <sup>2</sup> )
Cement: Lime : Sand	1 : ¼ : 5	0.8	7	14.6
		0.8	28	19.6
		0.9	7	8.0
		0.9	28	10.5
		1.0	7	5.6
		1.0	28	6.2
Cement: Lime : Sand	1 : ½ : 4½	1.2	7	6.2
		1.2	28	7.3
		1.4	7	5.0
		1.4	28	6.5
		1.5	7	2.9
		1.5	28	4.8
Cement : Lime : Sand	1 : 1 : 6	1.6	7	3,8
		1.6	28	5.1
		2.0	7	2.6
		2.0	28	3.05

TABLE 3: RESULTS OF FLEXURAL STRENGTH TESTS

MORTAR DESCRIPTION	MIX CEMENT: LIME: SAND	WATER/CEMENT RATIO (W/C)	CURING PERIOD (DAYS)	FLEXURAL STRENGTH (N/mm <sup>2</sup> )
Cement : Lime : Sand	1 : ¼ : 3	0.8	7	1.9
		0.8	28	2.28
Cement : Lime : Sand	1 : ¼ : 3	0.9	7	1.9
		0.9	28	2.24
		1.0	7	1.52
		1.0	28	1.28
Cement : Lime : Sand	1 : ½ : 4½	1.2	7	0.91
		1.2	28	1.28
		1.4	7	0.76
		1.4	28	0.91
		1.5	7	0.61
		1.5	28	0.84
Cement : Lime : Sand	1 : 1 : 6	1.6	7	0.69
		1.6	28	0.77
		2.0	7	0.48
		2.0	28	0.69

TABLE 4: TEST RESULTS ON MODEL 'a' BRICKWORK (COMPRESSIVE STRENGTH)

MIX CEMENT-LIME-SAND	WATER/CEMENT RATIO	STRENGTH AT 7TH DAY (N/mm <sup>2</sup> )	STRENGTH AT 28TH DAY (N/mm <sup>2</sup> )
1 : ¼ : 3 (Unsoaked Bricks)	1	9.4	11.56
1 : ¼ : 3 (Soaked Bricks)	1	10.3	14.67
1 : ½ : 4½	1.2	6.5	11.98
1 : 1 : 6	1.6	5.9	7.7

TABLE 5: FLEXURAL TEST RESULTS : MODEL TYPE 'b'

MIX	W/C RATIO	MODULUS OF RUPTURE		TENSILE STRENGTH	
		7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )	7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )
1 : ¼ : 3 (Unsoaked Bricks)	1	0.56	—	0.28	—
1 : ¼ : 3 (Soaked Bricks)	1	0.69	1.6	0.345	0.845
1 : ½ : 4½	1.2	0.43	0.74	0.215	0.37
1 : 1 : 6	1.6	0.30	0.41	0.15	0.205

TABLE 6: TEST RESULTS FOR MODEL TYPE 'c' (FLEXURAL TEST)

MIX	W/C RATIO	MODULUS OF RUPTURE		TENSILE STRENGTH	
		7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )	7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )
1 : ¼ : 3 (Unsoaked)	1	—	—	—	—
1 : ¼ : 3 (Soaked)	1	0.29	0.77	0.145	0.385
1 : ½ : 4½	1.2	0.19	0.43	0.095	0.215
1 : 1 : 6	1.6	0.14	0.12	0.07	0.06

TABLE 7 : TEST RESULTS FOR MODEL TYPE 'd' (FLEXURAL TEST)

MIX	W/C RATIO	MODULUS OF RUPTURE		TENSILE STRENGTH	
		7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )	7TH DAY (N/mm <sup>2</sup> )	28TH DAY (N/mm <sup>2</sup> )
1 : ¼ : 3 (Unsoaked)	1	0.47	0.65	0.24	0.33
1 : ¼ : 3 (Soaked)	1	0.54	0.69	0.27	0.35
1 : ½ : 4½	1.2	0.25	0.37	0.13	0.19
1 : 1 : 6	1.6	0.11	0.23	0.06	0.16

**TABLE 8: TEST RESULTS FOR MODEL TYPE 'a' (COMPRESSIVE STRENGTH TEST)**

**FOR BITUMINOUS MORTAR. AVERAGE JOINT THICKNESS – 10mm.**

MIX BITUMEN : CEMENT : SAND	NATURE OF MIXING	COMPRESSIVE STRENGTH OF BRICKWORK (N/mm <sup>2</sup> )
1 : 2 : 6	Cold-Mixed	2.37
1 : 2.75 : 4	Cold-Mixed	2.34
1 : 4 : 4	Hot-Mixed (120°C)	2.36
1 : 3 : 6.46	Hot-Mixed (120°C)	3.13
1 : 0 : 13.75	Hot-Mixed (120°C)	3.55

## SOILCRETE HOLLOW BLOCK AS A BUILDING UNIT

By

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### ABSTRACT

The paper deals with some properties of soilcrete hollow blocks tested over a period of two years. The content of this paper also deals with the wet to dry compressive strength ratio taking into account the different heights of blocks. Some physical properties like density, water absorption and dry shrinkage of soilcrete hollow blocks were also carried out.

### 1. INTRODUCTION

The need to use local materials for building units cannot be overemphasized. The growth of urban population in Nigeria is anticipated to double within the next one and half decades. This together with the increasing standard of living will certainly create a huge need for proper housing. This can easier be met by the use of cheap building units made of available local materials.

Soilcrete hollow blocks are essentially produced using local laterite, cement and water. The soilcrete hollow blocks under consideration are of 8% cement content by weight of local laterite. The amount of water added is that which is sufficient to mould the blocks. It is about 7½% of the laterite weight. The use of such blocks in building construction is increasing especially in the northern part of the country. Hence, the need to know its properties or specification for quality control are of paramount importance.

This paper discusses the compressive strength, preliminary density, drying shrinkage and moisture movement/water absorption for soilcrete blocks produced by Ocidental Construction Company, Zaria.

### 2. COMPRESSIVE STRENGTH

#### 2.1. Development of Dry Compressive Strength

Compressive strength of hollow blocks is normally taken as the ultimate axial load divided by the cross-sectional area of the block including holes (1, 2). The actual ultimate stress in the net area of material of the tested hollow block is then much higher than the normal compressive strength. Blocks are usually walling units other than that used for bonding which has dimensions like the sandcrete blocks. Usually the height of a block should not exceed its length or six times its width (7). The soilcrete hollow block as

3  
produced by Ocidental Construction Company, Zaria has the dimensions of 400 x 150 mm in plan section and 150 mm in height. Most tests were carried out on these blocks.

The compressive strength tests of soilcrete hollow blocks has been going on in the Department of Civil Engineering, Ahmadu Bello University, Zaria in collaboration with N.B.R.R.I., Lagos for the past three years. Tests have shown that the lowest strength is obtained when blocks are tested wet after soaking in water for 24 hours. Standard curing to obtain a high strength is by soaking the blocks into water after twenty-four hours of age for two days. It is then removed and allowed to cure under laboratory atmosphere for 28 days prior to testing (6). This is referred to as standard method of curing. For an assessment of the influence of packing materials between the blocks and the platens of testing machine, softboards of 10mm thickness is found to be the most suitable packing materials. The development of dry compressive strength of the blocks show that strength of the blocks were developed within the first week as shown in fig. 1 (6)

The above results only show the strength development within a month. The need to carry out such strength development for a longer period is important. This led to more tests over the years and the strength development for twenty-four months is shown in fig.2

The blocks were cured in the same way as that in figure 1. This is done by spraying with water in the morning and evening and covering with cellophane for at least a week. It is then allowed to cure under the laboratory atmosphere until it is the age for test as shown on the graph. Figure 2 clearly shows that the development of strength continues over the years though at a diminishing rate compared to the first week development. This shows that the process of hydration which is a function of high strength continues over the years.

#### 2.2. Minimum wet to dry strength ratio

The minimum wet compressive strength to dry compressive strength ratio of the previous test was

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++Lecturer in Civil Engineering.

about 0.4 (6). This is the ratio of the wet strength after soaking in water for twenty four hours to the corresponding dry strength. In order to check this ratio over the years, the corresponding wet strength after twenty-four hours soaking were tested and the result is shown in Figure 3.

This shows that the minimum wet to dry strength ratio over the years is the same as the earlier ratio. One can therefore say that the minimum strength ratio is about 40% of the dry strength. It was also tested and found that the average wet to dry compressive strength ratio is about 65% (6).

### 2.3 Different heights of blocks Produced

Most of the soilcrete hollow blocks produced by Occidental Construction Company – Zaria, have varying heights. About 60% of the blocks produced have heights of 150mm while 35% and 5% have heights of 155 to 159mm and 160 to 165mm respectively. One wonders whether this is as a result of varying compaction pressure or some variation in the volume of mixed materials poured into the dial box at the time of production. From the tests carried out on the blocks for three consecutive years, the following results were obtained as shown in figures 4, 5 and 6

Figures 4 and 5 show that there is no direct relation between the compressive strength and the height or weight of the blocks. On the other hand, figure 6 which is the relationship between the weight and height of the blocks indicate clearly that the greater the height, the more the weight of the block which is quite obvious. Assuming the compaction pressure is kept constant and the volume of material poured into the dial box is varied, it follows that the greater the height, the more the weight and the more the volume of materials poured in, which is again obvious. If the volume is now constant and the compaction pressure varied, a high compaction pressure results to a block of smaller height and vice versa. These relationships are not reflected in figures 4 and 5. It therefore follows from figure 6 that the varying height is as a result of varying volume of mixed materials poured into the dial box prior to compaction.

### 3. Preliminary Density Tests

The density and other properties of a building unit forming either solid or hollow blocks will mainly be determined by the type of aggregate (1). Light-weight aggregates give units of lower density and better thermal insulation. It is also known that the thermal transmittance of hollow blocks is determined by the type of blocks and the size and disposition of the cavities (1, 7). In determining the density, the blocks are taken at random and dried to a constant weight. The drying is done in an oven heated up to 110°C. The dimensions and weights of the blocks are determined. (1) The result is as shown in Table 1.

Table 1. Determination of Preliminary Density results

Sample No.	Dry Weight (kg)	Volume of blocks (m <sup>3</sup> )	Volume of Hollow (m <sup>3</sup> )	Net volume of blocks (m <sup>3</sup> )	Density kg/m <sup>3</sup>
A.	8.50	0.00892	0.00437	0.00455	1868
B.	8.60	0.00898	0.00447	0.00451	1907
C.	8.10	0.00848	0.00848	0.00434	1866
Average Density =					1880 kg/m <sup>3</sup>

#### 4. Preliminary water absorption/moisture movement

Water absorption is the difference between the dry weight and the final wet weight expressed as a percentage of dry weight (2). B.S. 2028 referred to water absorption as moisture movement. This is calculated as the difference between the dry and final wet lengths as a percentage of the dry length. The tests were carried out according to B.S. 2028 using Demec strain gauges of standard length (100mm). The Nigerian Industrial Standard 74, 1976 limits the water absorption of burnt clay building units to 25%. On the other hand, B.S. 2028 limits the moisture movement of sandcrete blocks to 0.05% for type B. blocks. The above mentioned figures are however not applicable to soilcrete hollow block.

Both the water absorption and moisture movement were measured and the results are shown in Tables 2 and 3.

TABLE 2. WATER ABSORPTION TEST RESULTS

Sample No.	A	B	C
Dry weight (kg)	8.50	8.60	8.10
Wet weight (kg)	9.60	9.60	9.10
Water absorption (%)	12.90	11.60	12.30
Average Water absorption			= 12.3%

#### 5. Preliminary Drying Shrinkage

The drying shrinkage of the soilcrete hollow blocks were measured according to B.S. 2028. The test is purely on preliminary basis and accurate tests are in progress. The results are as shown in Table 4.

B.S. 2028, 1970 limits the drying shrinkage to 0.08 per cent for type C blocks. Soilcrete hollow block has a drying shrinkage of 0.08% but has a higher compressive strength than type C block as recommended by B.S. 2028. The high drying shrinkage is as a result of laterite. Drying shrinkage of 0.06 was recommended by B.S. 2028 for type B block. The shrinkage cracks were not observed on the tested blocks.

TABLE 3: MOISTURE MOVEMENT TEST RESULTS

Sample No.	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4
Dry length (mm)	100.74	100.93	100.80	100.74	100.72	100.44	100.82	100.88	100.61	100.83	100.88
Wet length (mm)	100.81	101.01	100.89	100.81	100.79	100.54	100.90	100.95	100.70	100.89	100.96
Moisture movement (%)	0.069	0.079	0.089	0.069	0.069	0.10	0.079	0.069	0.089	0.060	0.079
Average Moisture movement = 0.077 = 0.08%											

TABLE 4: DRYING SHRINKAGE TEST RESULTS

Sample No.	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4
Dry length (mm)	100.74	100.93	100.80	100.74	100.72	100.44	100.82	100.88	100.61	100.83	100.88
Wet length (mm)	100.83	101.01	100.88	100.80	100.79	100.52	100.89	100.99	100.69	100.90	100.94
Dry Shrinkage (%)	0.09	0.08	0.08	0.06	0.07	0.08	0.07	0.11	0.08	0.07	0.06
Average Drying Shrinkage is 0.08%											

## 6. CONCLUSIONS

From the tests carried out so far, the following conclusions could be derived;

- a) Development of dry compressive strength of soilcrete hollow blocks continues over the years since complete hydration of cement mixed with laterite cannot be attained. The dry compressive strength is about  $3 \text{ N/mm}^2$  after 28 days of hardening.
- b) The minimum wet to dry compressive strength ratio is 0.4. This was confirmed from the tests carried out over the years. The average wet to dry compressive strength ratio for the blocks is about 0.65.
- c) The different heights of blocks produced by Occidental Construction Company is as a result of varying volume of mixed material poured into the dial box prior to compaction. The compaction pressure is constant.
- d) The density of the soilcrete hollow block is about  $1880 \text{ kg/m}^3$ .
- e) The soilcrete hollow block has water absorption of about 12% which may be acceptable.
- f) Drying shrinkage as determined according to B. S. 2028 is about 0.08%.
- g) The soilcrete hollow blocks have moisture movement of about 0.08%.
- h) Some research has to be done to avoid different heights of blocks. The density, water absorption/moisture movement and drying shrinkage also needs more research to ensure reliable quantification of their magnitudes.

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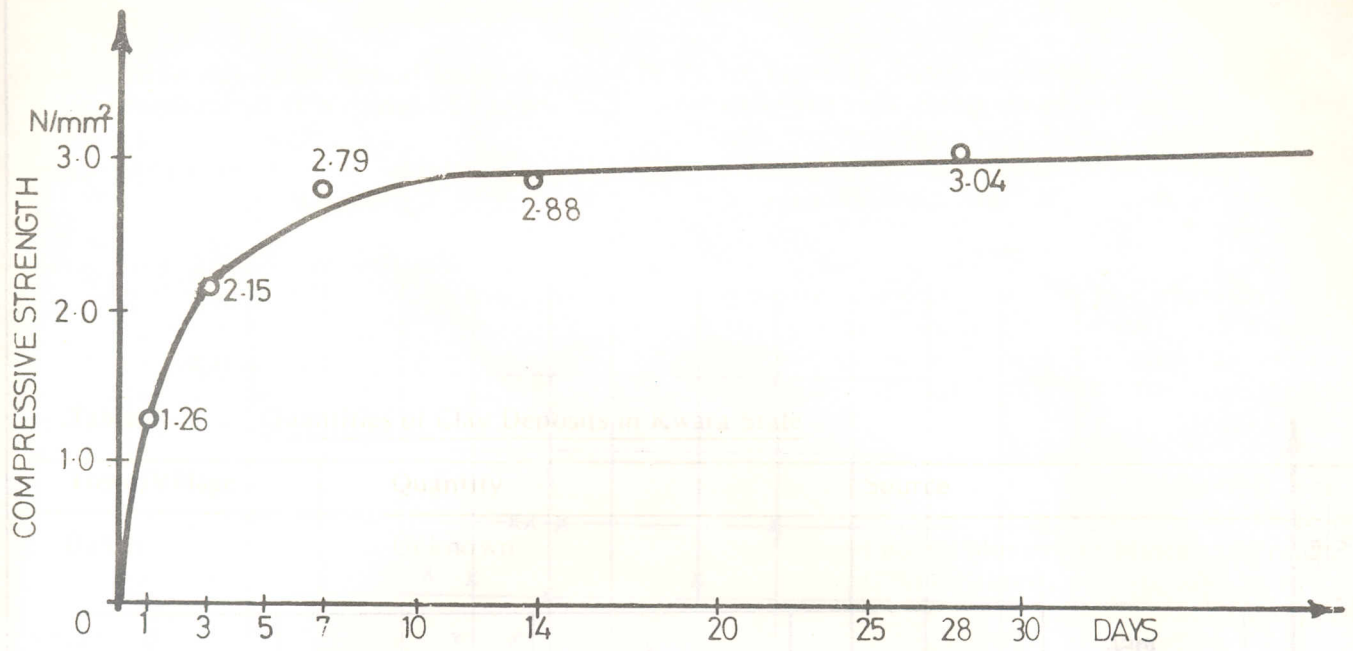


FIG. 1 DEVELOPMENT OF DRY STRENGTH

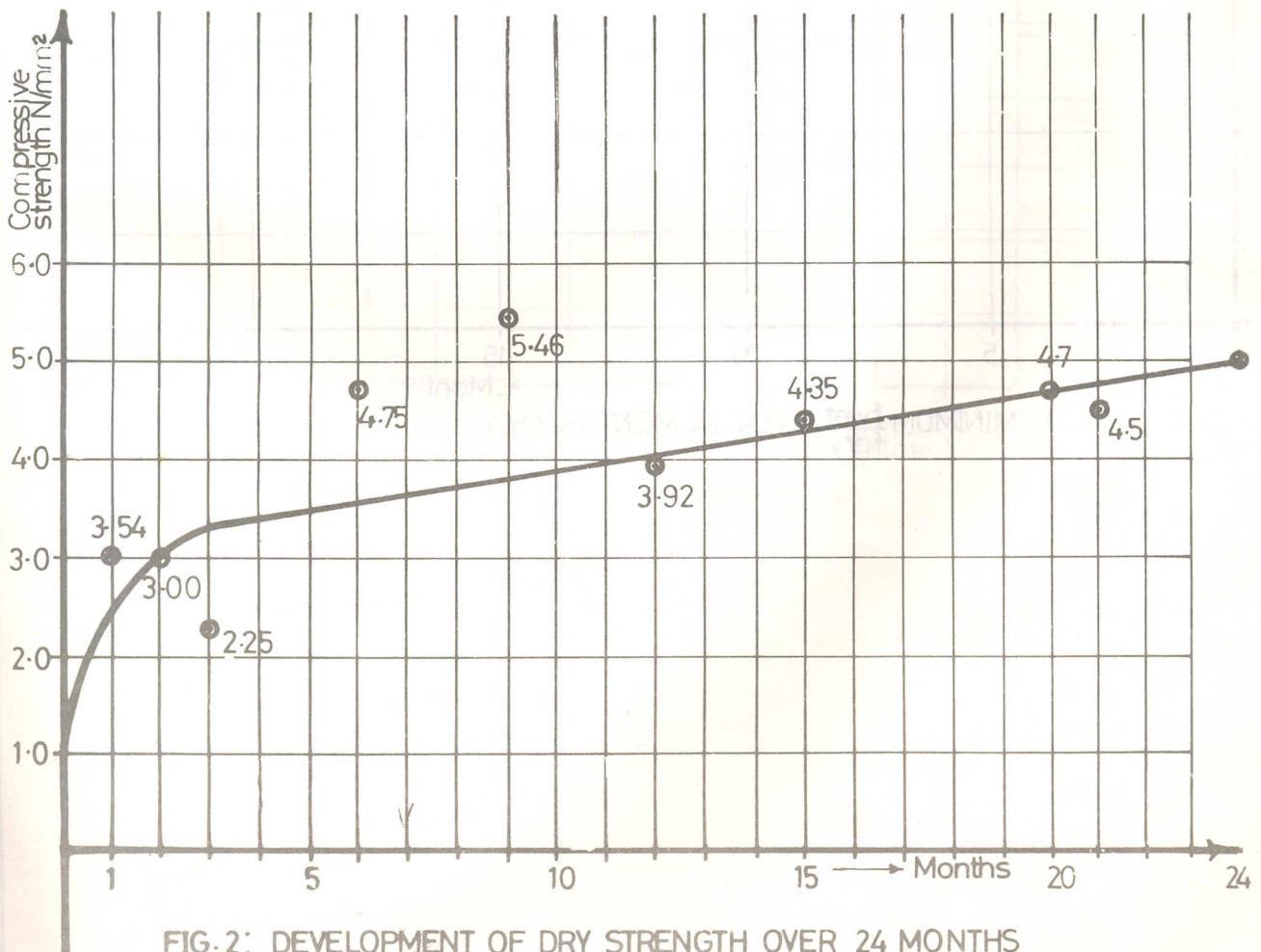


FIG. 2: DEVELOPMENT OF DRY STRENGTH OVER 24 MONTHS

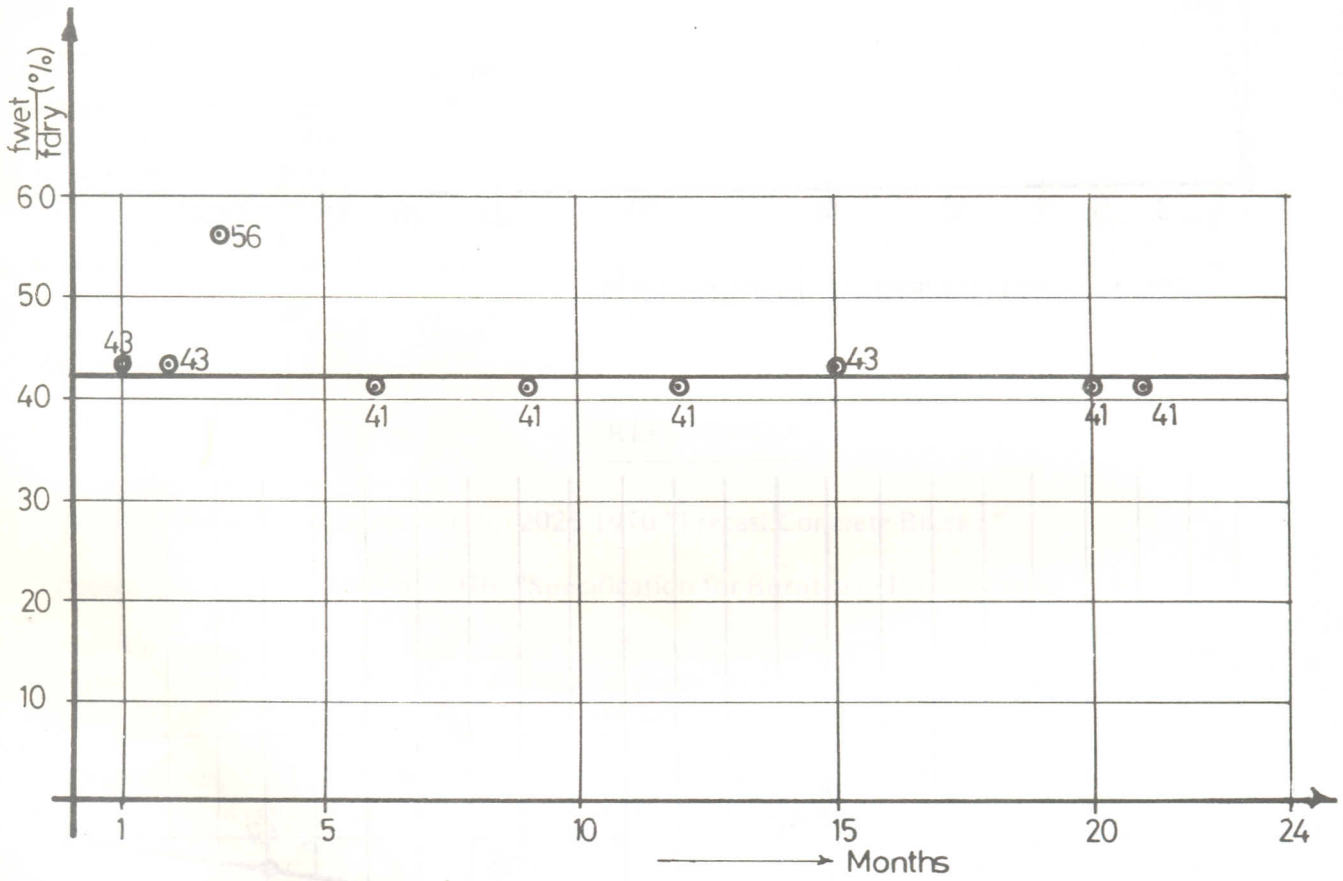


FIG. 3: MINIMUM  $\frac{fwet}{fdry}$  OVER 24 MONTHS (%)

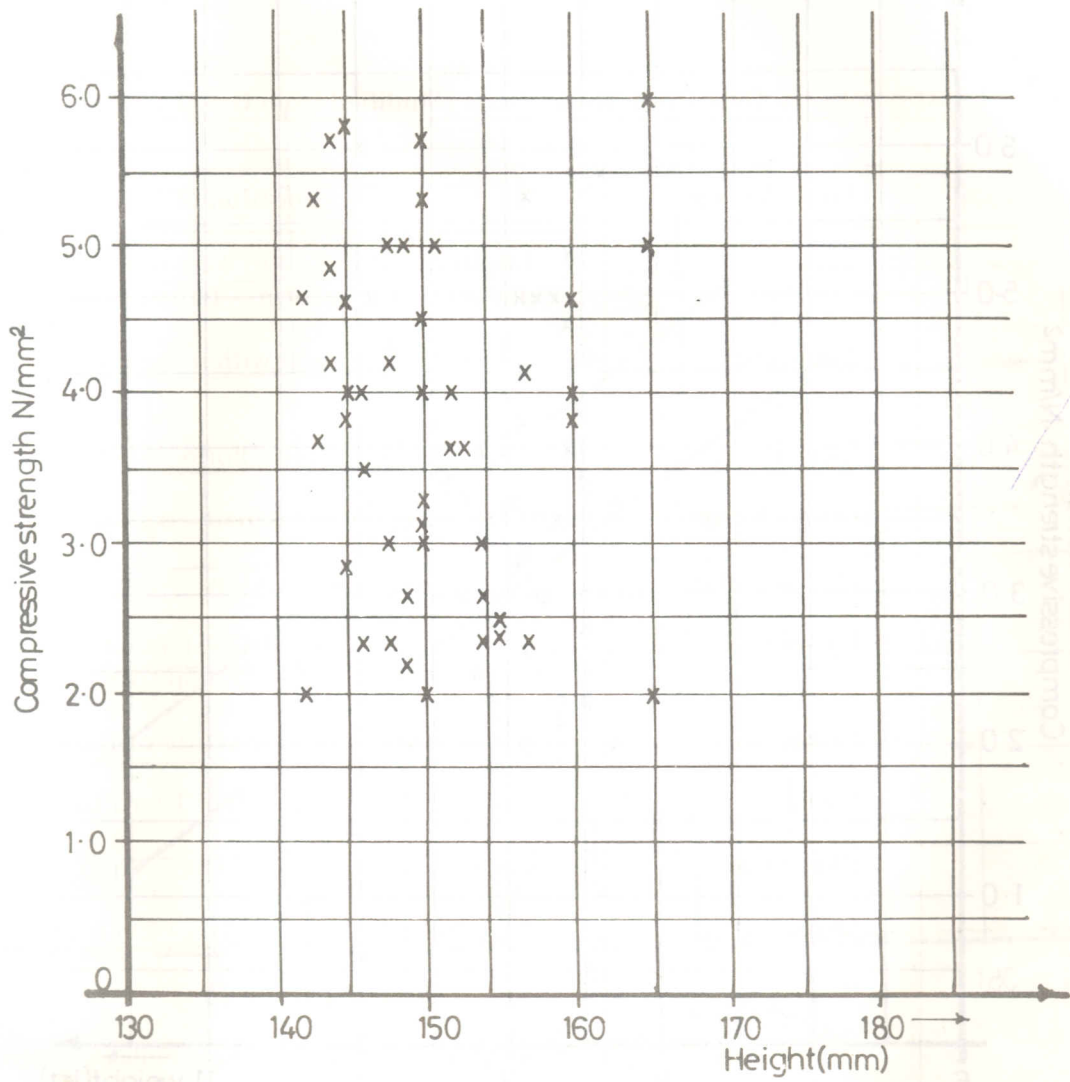


FIG. 4 COMPRESSIVE STRENGTH/HEIGHT(mm)

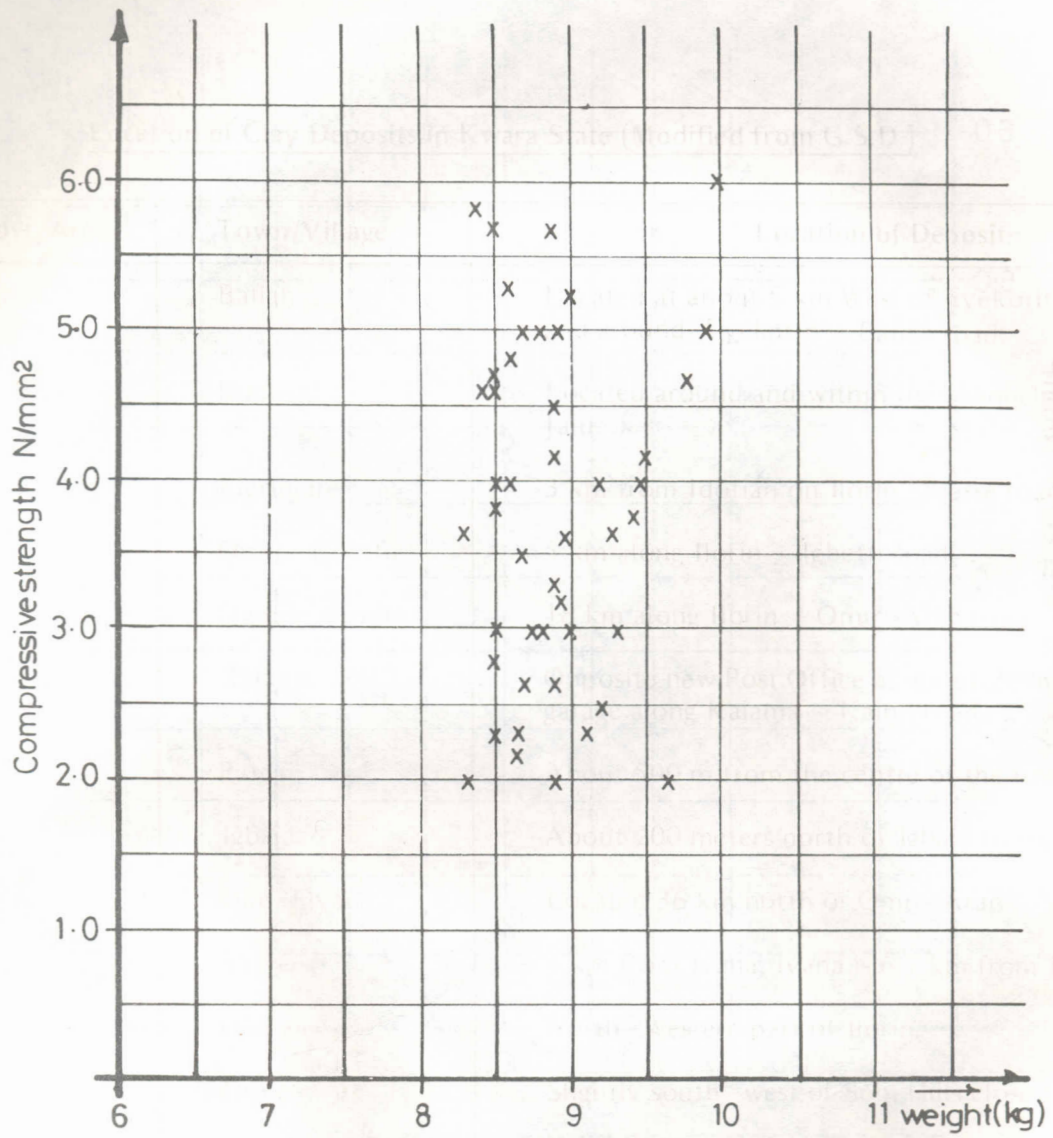


FIG. 5: COMPRESSIVE STRENGTH / WEIGHT (kg)

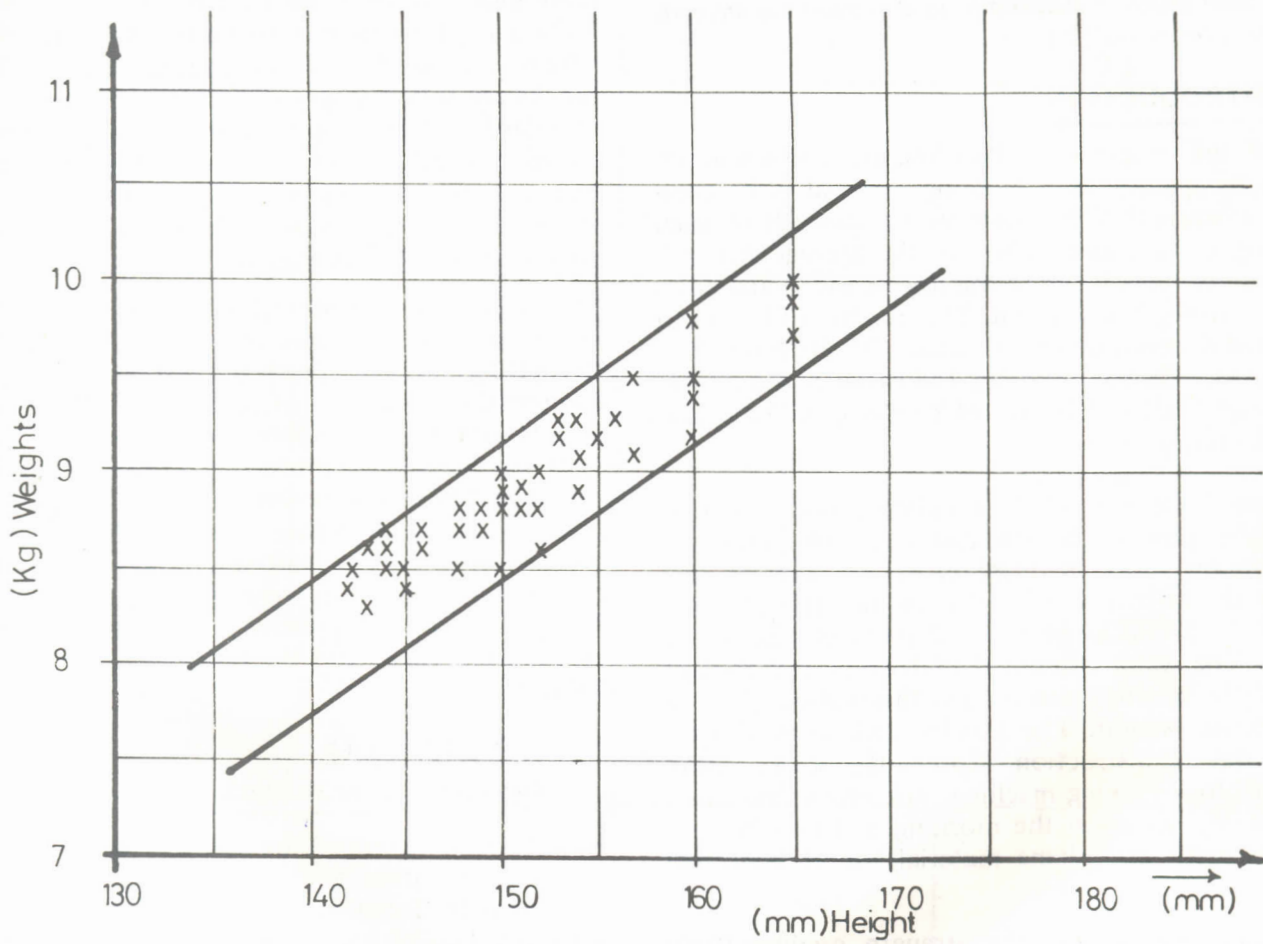


FIG. 6: WEIGHT AGAINST HEIGHT mm

## STRENGTH QUALITIES OF SOILCRETE HOLLOW BLOCKS

By

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### ABSTRACT

The paper is concerned with dry and wet compressive strength of soilcrete hollow blocks. About 134 samples of soilcrete blocks were tested at different ages. Samples were cured by either soaking or spraying of water prior to testing. The tested results were analysed statistically to determine the strength qualities of the block.

### 1. INTRODUCTION

One of the properties of building units which determines its quality as a building material is its compressive strength. The compressive strength of such building units could either be the average strength of a number of blocks or the lowest individual compressive strength test result. The number of blocks to be tested depends on the standards. BS 2028 specifies 12 blocks, whereas Nigerian Industrial Standard 74, 1976 and Federal Ministry of Works specified 6 and 3 blocks respectively.

Soilcrete hollow block is a building unit which is essentially cement, laterite and water (4). The soilcrete hollow block in question has 8% cement content of the laterite weight. It is in the ratio of 1:12, that is 1 part of cement to 12 parts of laterite by weight. The water content is that which is sufficient to bind the mixing materials and this is about 7½% of the laterite weight. The blocks were produced by Occidental Construction Company, Zaria using Tecmor block making machine. The blocks are cured by spraying water in the morning and evening and covering with cellophane material for at least one week.

This paper points out the strength qualities of soilcrete hollow block by presenting some results of the compressive strength tests and analysing them statistically. This tests were carried out in the Department of Civil Engineering, Ahmadu Bello University, Zaria in collaboration with Nigerian Building and Road Research Institute, Lagos. The tested blocks were randomly chosen from production in different days within a period of 24 months.

### 2. COMPRESSIVE STRENGTH

The soilcrete hollow block is classified as type B block according to BS 2028 though its density puts it in the type A block. B.S. 2028 requires at least 2.76

N/mm<sup>2</sup> and the lowest individual strength should not be less than 2.07 N/mm<sup>2</sup>. The blocks are tested after saturation with water. The Federal Ministry of Works specify the average compressive strength of 3 sandcrete blocks to be at least 2.1 N/mm<sup>2</sup> and the lowest individual strength not to be less than 1.7 N/mm<sup>2</sup> which is about 80% of the average strength (3). The blocks are tested in dry state. The Nigerian Industrial Standard 74, 1976 specify the average compressive strength of 2.5 N/mm<sup>2</sup> for burnt clay building units, but did not specify the lowest individual tested strength. The number of bricks to be tested is about six bricks. The bricks were tested in wet state.

The soilcrete hollow block has the size of (400 x 150) mm in plan and 150 mm in height. The compressive strengths were determined by testing the blocks in compression machine of capacity 2500KN. Softboards of 10mm thickness were used as packing materials between the blocks and the platens of the machine. The block is well centred under the compression machine before load is applied. All the blocks tested were at least seven days of age prior to test. The strength tests were of two groups. These are the wet and dry compressive strength test. About 134 blocks were tested and the results are as presented in Table 1.

### 3. TEST RESULTS

#### Dry compressive strength test

Results of dry compressive strength with their mean, standard deviation and coefficient of variation are as shown in Table 1. The blocks were tested after different days of hardening as indicated in the table.

#### Wet compressive strength

The wet compressive strength was obtained by soaking the blocks in water for at least 24 hours prior to test. Some were soaked up to 15-days. On removal from water, the blocks were tested between softboard of 10mm thickness used as packing materials between the platens of machine and the block. All the blocks were cured by spraying with water in the morning and evening and covering with cellophane materials for at least a week. It was then left to cure in the laboratory atmosphere for at least 28 days prior to soaking and testing. The results are as presented in Table 2.

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TABLE 1. DRY COMPRESSIVE STRENGTH TEST

S/No	Gross X-sectional area (m <sup>2</sup> )	Failure load (KN)	Compressive strength (N/mm <sup>2</sup> )	Average strength (N/mm <sup>2</sup> )	Standard deviation (N/mm <sup>2</sup> )	Coefficient of variation (%)	Age (days/month)
1.	0.06	200	3.33				7 days
2.	"	230	3.83				
3.	"	170	2.83				
4.	"	180	3.00				
5.	"	160	2.67				
6.	"	160	2.67	3.06	0.41	13.4	
7.	"	160	2.67				14 days
8.	"	180	3.00				
9.	"	150	2.50				
10.	"	200	3.33	2.88	0.32	11.1	
11.	0.06	200	3.33				28 days
12.	"	190	3.17				
13.	"	170	2.83				
14.	"	170	2.83	3.04	0.22	7.2	
15.	"	210	3.50				21 days
16.	"	141	2.35				
17.	"	200	3.33	3.06	0.51	16.7	
18.	"	135	2.25				28 days
19.	"	220	3.67				
20.	"	160	2.67				
21.	"	160	2.67	2.82	0.52	18.4	
22.	"	140	2.33				1 month
23.	"	140	2.33				
24.	"	210	3.50				
25.	"	190	3.17				
26.	"	180	3.00	2.87	0.47	16.4	
27.	0.06	160	2.67				
28.	"	180	3.00				
29.	"	180	3.00				
30.	"	240	4.00				
31.	"	200	3.00	3.10	0.45	14.6	
32.	"	160	2.67				3 months
33.	"	140	2.33				
34.	"	125	2.00				
35.	"	140	2.33	2.25	0.36	16.0	
36.	"	300	5.00				
37.	"	180	3.00				

S/No.	Gross X-sectional area (m <sup>2</sup> )	Failure load (KN)	Compressive strength (N/mm <sup>2</sup> )	Average strength (N/mm <sup>2</sup> )	Standard deviation (N/mm <sup>2</sup> )	Coefficient of variation (%)	Age (days/months)
38.	0.06	300	5.00				
39.	"	320	5.30				
40.	0.06	240	4.00				
41.	"	300	5.00	4.55	0.80	17.7	6 months
42.	0.06	360	6.00				
43.	"	380	6.30				
44.	"	350	5.83				
45.	"	280	4.67				
46.	"	220	3.67				
47.	"	320	5.33	5.33	0.90	16.9	9 months
48.	"	250	4.17				
49.	"	230	3.83				
50.	"	220	3.67				
51.	"	240	4.00	3.92	0.19	4.8	12 months
52.	"	240	4.21				
53.	"	230	3.83				
54.	"	170	2.83				
55.	"	180	3.00				
56.	"	280	4.67				
57.	"	280	4.67	3.87	0.73	19.0	15 months
58.	0.06	340	5.70				
59.	"	240	4.00				
60.	"	280	4.70				
61.	"	240	4.00				
62.	"	240	4.00				
63.	"	340	5.70	4.68	0.76	16.2	20 months
64.	"	290	4.83				
65.	"	220	3.67				
66.	"	270	4.50				
67.	"	300	5.00	4.50	0.51	11.4	21 months
Average of 67 blocks				3.66	1.06	29	

TABLE 2: WET COMPRESSIVE STRENGTH

S/No.	Gross X-sectional area (m <sup>2</sup> )	Failure load (kN)	Compressive strength (N/mm <sup>2</sup> )	Average strength (N/mm <sup>2</sup> )	Standard deviation (N/mm <sup>2</sup> )	Coef. of variation (%)	Age at soaking	No. of days soaked
1.	0.06	92	1.53					
2.	"	65	1.08					
3.	"	75	1.25					1 day
4.	"	76	1.27	1.28	0.16	12.5	28 days	
5.	"	94	1.57					
6.	"	81	1.35					
7.	"	79	1.32					
8.	"	67	1.12	1.34	0.16	11.9	28 days	2 days
9.	"	85	1.45					
10.	"	102	1.70					
11.	"	64	1.07					
12.	"	87	1.45					
13.	"	108	1.80	1.49	0.25	13.9	28 days	3 days
14.	0.06	98	1.63					
15.	"	110	1.83					
16.	"	102	1.70					
17.	"	130	2.17	1.83	0.21	11.5	28 days	6-days
18.	"	128	2.13					
19.	"	125	2.08					
20.	"	160	2.67					
21.	"	93	1.55					
22.	"	128	2.13	2.11	0.35	16.6	28 days	9-days
23.	"	102	1.70					
24.	"	140	2.33					
25.	"	120	2.00					
26.	"	115	1.92	1.99	0.23	11.6	28 days	12-days
27.	"	110	1.83					
28.	"	140	2.33					
29.	"	110	1.83					
30.	"	96	1.60					
31.	"	130	2.17	1.95	0.26	13.3	28 days	15-days
32.	0.06	60	1.00					
33.	"	91	1.57					
34.	"	82	1.37					
35.	"	77	1.28	1.29	0.18	14.0	1 month	1 day
36.	"	69	1.15					
37.	"	78	1.30					

S/No.	Gross X-sectional area (m <sup>2</sup> )	Failure load (kN)	Compressive strength (N/mm <sup>2</sup> )	Average strength (N/mm <sup>2</sup> )	Standard deviation (N/mm <sup>2</sup> )	Coeff. of variation %	Age at soaking	No. of days soaked
38.	0.60	77	1.30					1 day
39.	„	86	1.43	1.29	0.10	7.8	2 months	
40.	„	123	2.05					
41.	„	123	2.05					
42.	„	98	1.63					day
43.	„	123	2.05	1.95	0.18	9.2	6 months	
44.	„	148	2.47					
45.	„	143	2.38					
46.	„	115	1.92					1 day
47.	„	130	2.17	2.24	0.21	9.4	9 months	
48.	0.06	103	1.72					
49.	„	94	1.57					
50.	„	90	1.50					
51.	„	98	1.63	1.61	0.08	5.0	12 months	1 day
52.	„	120	2.01					
53.	„	83	1.39					
54.	„	145	2.45					
55.	„	145	2.43	2.06	0.42	20.4	15 months	1 day
56.	„	160	2.70					
57.	„	68	1.10					
58.	„	71	1.20					
59.	„	120	2.00					
60.	„	140	2.30					
61.	„	140	2.30	1.93	0.59	30.6	20 months	1 day
62.	„	70	1.17					
63.	„	135	2.25					
64.	„	150	2.50					
65.	„	97	1.62					
66.	„	105	1.75					
67.	„	130	2.17	1.91	0.45	23.6	21 months	1 day
Average of 67 blocks +				1.77	0.44	24.9		

#### 4. DISCUSSIONS

One observes that in the dry compressive strength, no individual test strength was below  $2.0 \text{ N/mm}^2$  and the average compressive strength for the 67 blocks tested was  $3.7 \text{ N/mm}^2$ . The dry compressive strength ranges from  $2.0 \text{ N/mm}^2$  to  $6.30 \text{ N/mm}^2$  approximately.

In the wet compressive strength, lowest compressive strength was usually obtained when soaked for 24 hours. After 24 hours of soaking in water, the strength increases due to hydration. The initial 24 hours of soaking is used for intake of moisture for the hydration process to get initiated. Even though the lowest strength occurred after one day soaking in water, one observes that no individual test strength is less than  $1.0 \text{ N/mm}^2$ . This is too low to be acceptable, but it will not occur in the wall since full soaking is impossible. Moreover the additional soaking in water for some days increases the strength of soilcrete due to the hydration of cement as earlier stated. The dry compressive strength after curing for about a week by spraying of water and covering with cellophane materials is about  $3.0 \text{ N/mm}^2$ . On the whole, one can say that the average dry compressive strength could be  $3.0 \text{ N/mm}^2$  for soilcrete blocks. Overseas Building Research Establishment (3) specify that the wall strength of stabilized soil should be one-third of the dry compressive strength. The lowest strength in the tests is within this limit.

The BS 2028 1970 specify that the average compressive strength of twelve sandcrete blocks should be at least  $2.76 \text{ N/mm}^2$  and the lowest individual strength should be at least  $2.07 \text{ N/mm}^2$  for type B block. In the dry and wet compressive strength tests conducted, this provision was satisfied. In BS 2028, the wet compressive strength is the strength after the sandcrete blocks have been soaked in water until the cubes made of the same batch used for bedding sandcrete blocks stored in water have attained a compressive strength of  $28 \text{ N/mm}^2$  to  $41 \text{ N/mm}^2$ . This requires about 8 to 10 days soaking or at least a week. Observing the blocks soaked in water for 9-days, no individual test result is less than  $2.07 \text{ N/mm}^2$  except one which is  $1.55 \text{ N/mm}^2$ . Soilcrete hollow block if well cured has a wet compressive strength up to

$2.3 \text{ N/mm}^2$ . One could attribute such a low strength of  $1.55 \text{ N/mm}^2$  as being due to production fault rather than a property of the soilcrete hollow blocks. The volume of mixed material poured into dial box is not constant thus leading to various heights which are not uniformly compacted since compaction pressure is constant.

The Overseas Building Research Establishment proposed the minimum average wet compressive strength of  $1.4 \text{ N/mm}^2$  for soil-stabilized block. The Civil Engineering Department of Ahmadu Bello University (4, 5) in collaboration with Nigerian Building and Road Research Institute, Lagos, proposed the minimum average wet compressive strength of  $1.5 \text{ N/mm}^2$  and 10 samples of soilcrete hollow blocks for establishing the compressive strength.

#### 5. CONCLUSION

The soilcrete hollow blocks with 8% cement content by weight of laterite reveal the following after its compressive strength tests:

- (i) The block has a good compressive strength quality if well produced and properly cured.
- (ii) It satisfies the Federal Ministry of Works specification on compressive strength for sandcrete blocks;
- (iii) The dry compressive strength satisfy the BS 2028 specification for compressive strength of type B block;
- (iv) Specification for such building unit is urgently needed as the use of these blocks are on the increase;
- (v) Lowest compressive strength of blocks was obtained when soaked for 24 hours only.
- (vi) Soilcrete hollow block is mainly laterite, cement and water. The predominant material laterite is abundant in Nigeria and such building unit with the specification above should be emphasised for local production.

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TABLE 2: VARIATION OF OPTIMUM MOISTURE CONTENT AND MAXIMUM DRY DENSITY AT DIFFERENT CEMENT CONTENTS.

Cement Content %	Rumuolumeni		Eleme		Epebu		Peremabiri	
	M/C %	MDD kg/m <sup>3</sup>	M/C %	MDD kg/m <sup>3</sup>	M/C %	MDD kg/m <sup>3</sup>	M/C %	MDD kg/m <sup>3</sup>
0	11.6	1758	13.0	1790	16.3	1728	14.3	1699
3	14.3	17.00	16.6	1697	11.3	1812	13.6	1747
5	15.5	1665	17.0	1712	15.5	1745	14.3	1745
8	13.3	1786	18.3	1767	16.6	1675	15.9	1748
10	14.0	1725	19.6	1770	17.0	1738	15.6	1718
12	16.3	1687	16.4	1796	16.6	1635	14.6	1770
15	19.4	1635	17.0	1805	18.8	1639	14.6	1790

M/C = Moisture Content

MDD = Maximum Dry Density

In both approaches, the soil types has to be determined first and the blocks compacted to maximum density at the optimum moisture content, or close to maximum density. The blocks after compaction should be cured, preferable air cured at room temperature. They could also be wrapped in polythene paper and moist cured under wet sand. However, moist curing of laterite blocks is likely to slow down the rate of strength development.

Other recommendations, aside from the laboratory study included the necessity for keeping dry, after construction the walls of houses built with the stabilized laterite block to avoid the damage effect of water. This could be accomplished by (i) the provision of adequate eave width to reduce wall erosion and effect of rain splash (ii) constructing the foundation of the house up to DPC level with stabilized blocks or mud mortar to minimize the effects of water caused damage to the base of the wall and (iii) plastering the walls with cement mix which apart from protecting the wall from water caused damage improves the wall aesthetically.

Figure 7 is a section of a 3 bedroom experimental low cost housing unit suggested in the study.

### CONCLUSION

From the results of this study, it can be concluded that the strength and durability characteristics of the deltaic laterite blocks stabilized with 5 to 7½% cement are comparable to those of sandcrete blocks. However, good construction practices are essential in the use of cement stabilized laterite blocks; the quality and finish of the blocks would depend on the skill of the tradesmen. With mechanized production, especially when constant pressure or constant volume presses are used, higher quality blocks of more than 4N/mm<sup>2</sup>

## STABILIZED LATERITE BLOCKS FOR RURAL HOUSING IN THE RIVERS STATE.

by

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5

### INTRODUCTION

Right from the dawn of history, housing has been universally acknowledged as the second most important human need, after food. Thus house ownership is one of the most cherished cultural acquisitions. Unfortunately, because the bulk of the population is poor, many Nigerians are unable to afford to own houses of their own. The desire to own houses has largely eluded them because of the high cost of building materials.

Given the circumstances which now prevail in Nigeria, it has become absolutely necessary to find ways of cutting building construction costs, especially in providing low cost homes in the rural areas. The use of local materials, such as lateritic soils, for building purposes is an apparent solution.

In this regard, the Rivers State Government, through the Department of Civil Engineering of the Rivers State University of Science and Technology recently carried out studies to investigate the suitability of using cement stabilized deltaic laterite soil blocks for low cost housing in the rural areas of the State. The primary objective of the study was to promote the use of cement stabilized laterite blocks for housing, with an intent to encourage the rural dwellers to build their own cheap and durable houses.

This paper presents the results of laboratory investigations conducted on deltaic laterites obtained from four locations in the Rivers State for the study<sup>1</sup>. Various mixes of laterite-cement and laterite-cement blocks compacted at the optimum moisture content were tested to arrive at the most economic mix satisfying strength and durability requirements.

### DESCRIPTION AND CLASSIFICATION OF SOIL SAMPLES

Laterite, generally called 'red earth' is one of the most common burrow materials in Nigeria. The lateritic soils of the Rivers State could be termed deltaic laterites, in that they are found in an area which physiographically belongs to the lower del-

taic plane of the River Niger. The area is made up of river deposited sediments, which vary in grain size from coarse grained sediments (mainly sand) to fine grained sediments (silts and clays). The complete stratigraphy of the area is composed of the Akata, the Agbada and the Benin formations.

The four deltaic laterites used in the study were obtained from the following locations in the Rivers State:

- (i) Rumuolumeni – Port Harcourt Local Government Area
- (ii) Eleme – Okrika, Tai, Eleme, Obigbo Local Government Area
- (iii) Epebu – Brass Local Government Area
- (iv) Peremabiri – Yenagoa Local Government Area.

Table 1 shows some engineering properties and classification of the deltaic laterites. Using the consistency limits and particle size analysis, the laterites have been classified according to AASHTO method<sup>2</sup>. All the samples are in the A-2 group (silty or clayey gravel and sand), with the Peremabiri Sample in A-2-4 subgroup and the other three (Rumuolumeni, Eleme and Epebu) in the A-2-6 subgroup. The particle size analysis also showed that the deltaic laterites were made up of 65 to 75% sand, with the proportion of silts and clays together varying from 25.8 to 35.24% (percentage No. 200 sieve), and that most of the lateritic soils in the Rivers State are likely to contain less than 20% of clay in them. These characteristics of the deltaic laterites are in agreement with the recommendations by Fitzmaurice<sup>3</sup> for the selection of soils for cement stabilized soil blocks for permanent buildings in areas with annual rainfall exceeding 760mm.

## Compaction Characteristics

The standard Proctor compaction procedure was used to compact the laterite-cement mixes, whereby a cylindrical mould of  $0.001\text{m}^3$  in volume was filled with a mixture of laterite, cement and water in 3 layers, each layer compacted by 25 blows of a 2.5kg weight hammer with a drop of 300mm each blow. For each of 0%, 3%, 5%, 8%, 10%, 12%, and 15% cement contents, tests were carried out for at least 5 moisture content conditions, and the dry densities determined.

Figure 1 is a plot of moisture content versus dry density for the Rumuolumeni sample, to determine optimum moisture content (OMC) and maximum dry density (MDD) for each cement content. Table 2 shows variation of optimum moisture content and maximum dry density at different cement contents for all four samples. These results showed that it was desirable to mix and compact the laterite-cement blocks at the optimum moisture content, in order to achieve maximum compaction.

Figure 2 shows a linear relationship between the optimum moisture/cement ratio<sup>x</sup> and laterite/cement ratio<sup>y</sup>, for the four samples. The laterite/cement ratio increases with increasing optimum moisture/cement ratio. The corresponding linear regression equations for the four samples are given as:

- (i) Rumuolumeni:  $Y_1 = -1.961 + 6.114X$   
with correlation coefficient,  $r^2 = 0.980$
- (ii) Eleme:  $Y_1 = -1.874 + 5.127X$   
 $r^2 = 0.992$
- (iii) Epebu:  $Y_1 = -7.276 + 8.676X$   
 $r^2 = 0.993$

These relationships also indicate the existence of an optimum moisture/cement ratio for any given laterite/cement mix.

### Compressive Strength Characteristics

After the mixing of laterite-cement with pre-determined quantity of water in an electrically driven laboratory mixer, blocks were made in 150mm cube moulds, compacted with the standard proctor procedure. For each cement content, 12 blocks were made at the optimum moisture content.

After compaction, the blocks were removed from the moulds, covered with water-proof paper and then allowed to cure at room temperature. The blocks were then crushed with a compression Testing Machine after 7 and 28 days of curing, to determine their strength.

Figures 3 and 4 are plots of compressive strength versus cement content for the 7 and 28 days old blocks. The compressive strength (S) increased with increases in age and cement content. The increase in strength for the first 7 days was considerable, with a continued increase up to the 28 days at a steady rate. The average percentage 7 days strength to 28 days strength was found to be about 70% for Rumuolumeni, 60% for Eleme, 75% for Epebu and 50% for Peremabiri. It was also observed that the increase in cement content initially increased the compressive strength very rapidly. This rapid increase was more pronounced from 0% to 8% cement content, but thereafter, compressive strength increases were at a slower rate.

Figure 5 shows a relationship between optimum moisture/cement ratio (X) and 28 days compressive strength (S) for the four samples. It can be seen that the compressive strength S decreases with increase in the optimum moisture/cement ratio X. The relationship can be described by a log regression equation as follows:

- (i) Rumuolumeni :  $S = 5.486 - 2.426 \ln X$   
with Correlation coefficient  $r^2 = 0.965$
- (ii) Eleme :  $S = 7.896 - 3.342 \ln X$   
 $r^2 = 0.991$
- (iii) Epebu :  $S = 5.872 - 3.020 \ln X$   
 $r^2 = 0.960$
- (iv) Peremabiri :  $S = 4.519 - 2.263 \ln X$   
 $r^2 = 0.982$

In conjunction with the optimum moisture/cement ratio versus laterite/cement ratio curve (Figure 2), it is therefore possible to estimate the compressive

strength of the deltaic laterite blocks from Figure 5, for any given optimum moisture/cement ratio.

Several minimum compressive strength requirements for soil cement blocks have been recommended by various organizations and individuals. Bawa<sup>4</sup> recommended  $1.76\text{N/mm}^2$  for 28 days wet strength and  $2.76\text{N/mm}^2$  for 28 days dry strength. The Nigerian Standards Organisation<sup>5</sup> specified an individual minimum 28 days strength of  $2.5\text{N/mm}^2$  for eight samples in the lowest class of blocks. Ola<sup>6</sup> also suggested that generally most soils which are reasonably well compacted will be strong enough for single storey houses and a mini-

imum crushing strength in the dry state of  $2.76\text{N/mm}^2$  would appear to be adequate. Most other recommendations<sup>7</sup> for soil wall blocks vary from 2.1 to  $3.5\text{N/mm}^2$ . If a 28 days compressive strength of  $2.76\text{N/mm}^2$  in the dry state is taken as the minimum, the strength requirements could be satisfied with the values of cement content, optimum moisture/cement ratio and Laterite/cement ratio, suggested in Table 3 for the four deltaic laterites.

TABLE 3: VALUES SATISFYING MINIMUM STRENGTH REQUIREMENTS

Sample	Cement Content %	Optimum Moisture/Cement ratio	Laterite/Cement Ratio
Rumuolumeni	4.8	3.1	5.0
Eleme	3.8	4.6	22.5
Epebu	5.4	2.7	17.5
Peremabiri	7.3	2.2	13.5

TABLE 1: SOME PROPERTIES AND CLASSIFICATION OF THE DELTAIC LATERITES

Sample Location	Liquid Limit %	Plasticity Index %	% Passing No. 200	Sand Content %	Specific Gravity gm/cc	AASH TO Classification	Description
Rumuolumeni	37.5	21.0	25.8	74.2	2.68	A-2-6	Reddish Brown
Eleme	35.05	19.72	26.9	73.1	2.65	A-2-6	Reddish Brown
Epebu	35.7	18.76	30.8	69.2	2.70	A-2-6	Reddish Brown
Peremabiri	26.5	9.5	35.24	64.76	2.71	A-2-4	Reddish Yellow
Recommendations by Fitzmeurice <sup>3</sup>	40% Max	Between 2.5 to 22%	Clay content between 5 and 20%	33%min	—	—	—

### Durability Characteristics

Most parts of Nigeria have heavy rains during the rainy season and a subsequent hot weather in the dry season. As such, soil walls built in this country have been susceptible to rain erosion and loss of stability with water absorption, and develop shrinkage cracks on drying. In the Rivers State, the annual rainfall in the coastal towns of Brass and Bonny is as high as 4000mm, while Peremabiri and Eleme have about 3000mm and 2500mm respectively. High temperatures of up to  $35^{\circ}\text{C}$  and above and low temperatures of  $14^{\circ}\text{C}$  have also been recorded for Port Harcourt and Peremabiri.<sup>8</sup>

Because of this weather condition in the State, it was necessary in this study to investigate the weather resistance of the cement stabilized deltaic laterite blocks by using the Wet-Dry test recommended by the Portland Cement Association (PCA)<sup>9</sup> for evaluating the durability of soil-cement. Five cylindrical laterite-cement specimens of 50mm diameter, 100mm high were prepared for each cement content and at the optimum moisture content, using the standard Proctor compaction procedure. The specimens were cured at room temperature for 7 days and then subjected to 12 cycles of wetting and drying, each of 24 hours duration, to determine their percentage loss of weight.

The procedure used was slightly different from the PCA procedure. After 7 days of curing, the specimens were submerged in tap water for 3 hours (instead of 5 hours for the PCA) and then dried in an oven at 60°C (instead of 71°C) for 21 hours (instead of 42 hours). The specimens were then given two firm strokes on all sides with a soft hair brush (instead of wire scratch brush) to remove materials loosened during the wetting and drying cycles. This procedure is less stringent than the PCA method and was adopted because it seemed unrealistic to apply the same stringent measures used for temperate environments for roads to be applied to housing in the Tropics.

Figure 6 is a plot of cement content against percentage loss of weight for the four deltaic laterites. The PCA recommended that soil-cement losses during 12 cycles of the wet-dry test should conform to the following limits for the highest grade road base construction:

- (i) Soil Groups A - 1, A - 2 - 4, A - 2 - 5, and A - 3, not over 14%
- (ii) Soil Groups A - 2 - 6, A - 2 - 7, and A - 5, not over 10%
- (iii) Soil Groups A - 6 and A - 7, not over 7%.

Lower minimum values of about 5% were recommended by Fitzmaurice<sup>3</sup> for permanent building development for areas with more than 508mm of annual rainfall. For the rural housing in the Rivers State, not over 10% loss of weight was recommended for both the A - 2 - 4 and A - 2 - 6 deltaic laterite-cement blocks. This requirement was satisfied in Figure 6 at

5.0% cement content for Rumuolumeni sample  
 4.2%     "     "     "     Elemé     "  
 5.3%     "     "     "     Epebu     "  
 7.6%     "     "     "     Peremabiri     "

### RECOMMENDATIONS

From the study, it was observed that although the compressive strength characteristics results were important, they were considered to be of secondary importance when compared to results of the durability test, which determined for the particular soil material, the amount of cement needed to hold the mass together permanently and maintain stability under shrinkage and expansive forces that could occur due to changes in weather. Therefore, it was suggested that the cement contents, laterite/cement ratios, optimum moisture/cement ratios satisfying strength requirements be checked to make sure that they also satisfied durability requirements. Two approaches were recommended as follows:

- (i) For any laterite-cement block, the cement content to be utilized must first satisfy minimum compressive strength requirements (Figure 4). This cement content is then checked to see whether it satisfied durability requirements (Figure 6) for that laterite-cement.
- (ii) For any given laterite/cement ratio, the optimum moisture/cement ratio be determined (Figure 2), and the compressive strength corresponding to the optimum moisture/cement ratio obtained (Figure 5). The compressive strength so obtained should satisfy the minimum strength requirements. The cement content at that strength (Figure 4) is then used to check whether durability requirements are satisfied (figure 6) for that laterite-cement.

The second approach provided a better check on the strength and durability requirements.

For the 4 deltaic laterites, specific values of cement content, optimum moisture/cement ratio and laterite/cement ratio were recommended to maintain durability of the blocks under all weather conditions and at the same time raise the strength of the blocks to a very acceptable and economic level. These values are presented in Table 4.

Table 4: VALUES RECOMMENDED, SATISFYING BOTH STRENGTH AND DURABILITY REQUIREMENTS'

Sample	Cement Content %	Optimum Moisture/Cement Ratio	Laterite/Cement Ratio
Rumuolumeni	5.0	3.10	18.0
Elemé	5.0	3.40	16.0
Epebu	5.5	2.87	19.0
Peremabiri	7.5	2.09	12.0

strength can be achieved with the cement contents and optimum moisture/cement ratios recommended<sup>10</sup>

Finally, there is abundance of lateritic soils all over the rural areas of Nigeria. Majority of the rural dwellers are in no position to build sandcrete block houses. Since stabilized soil block construction has been proved to be economical in many developing countries, especially Asia<sup>11</sup>, there is need to emphasize the concept for house construction in the rural community. This requires Government participation and encouragement in the research and development of the methods and procedures of utilizing the stabilized soil blocks. It also requires the Government's implementation of the research findings by the construction of demon-

stration low cost houses using the stabilized soil blocks. The best way to awaken the rural community to the need for use of locally available materials is for the community to actually visualize how the Government has used the materials, and that is in the form of demonstration type of project. The acceptance and implementation of the laterite-cement block concept will therefore be of enormous benefits not only to the rural dwellers, but to the Government in her effort to provide durable, low cost houses for the people of this country.

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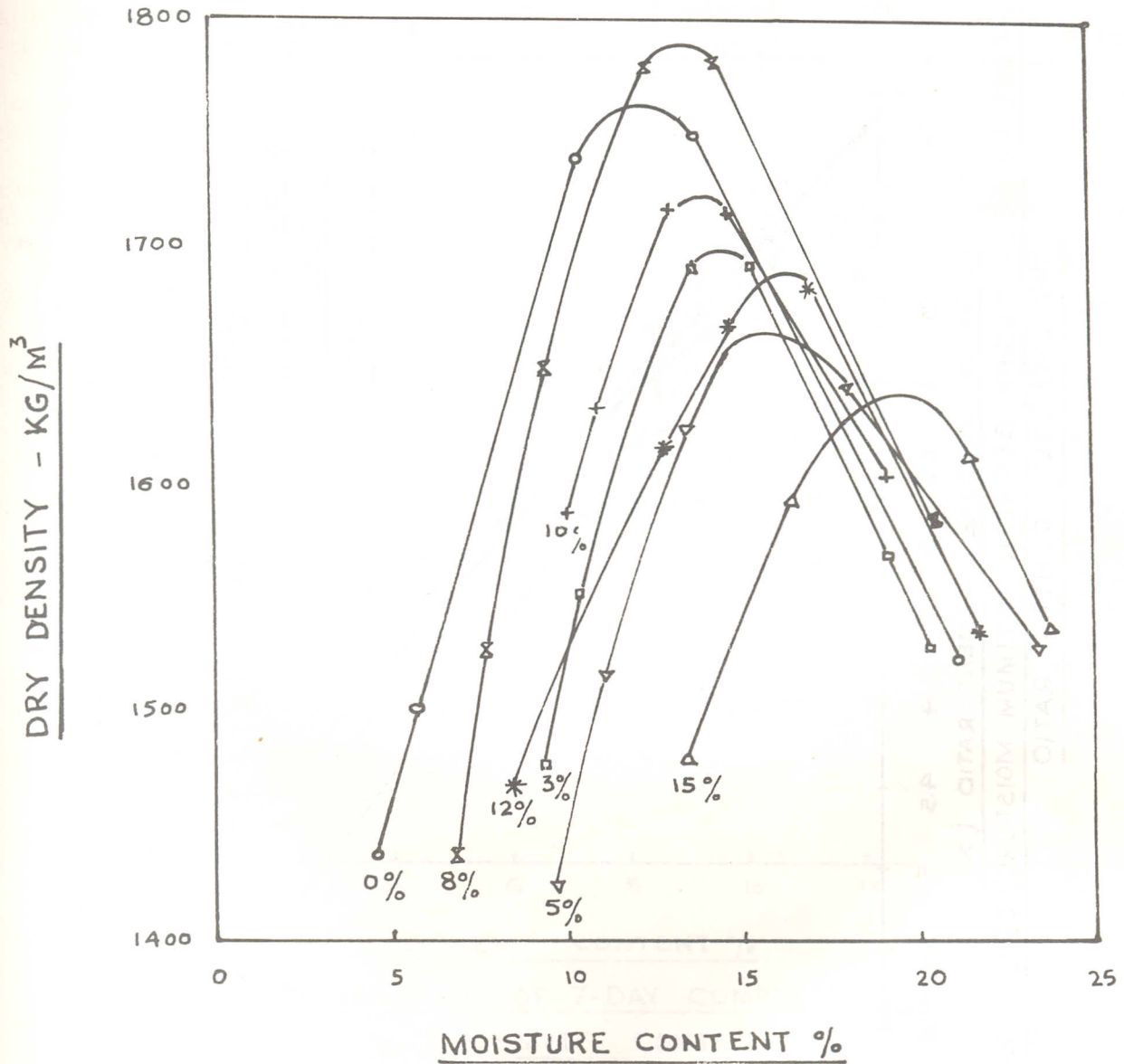


FIGURE 1 : MOISTURE - DENSITY CURVES FOR VARIOUS  
SOIL-CEMENT MIXES - RUMUOLUMENI SAMPLE

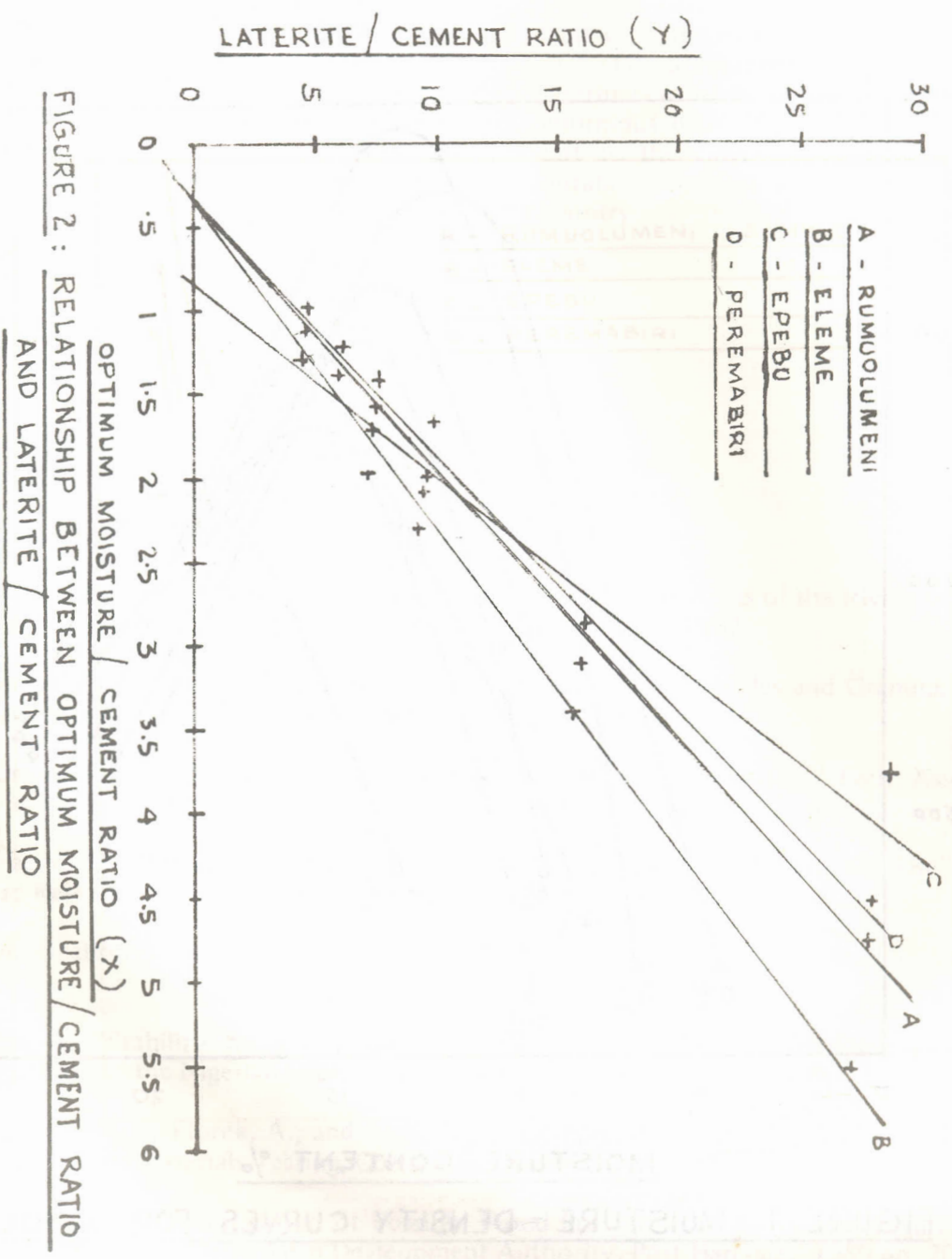


FIGURE 2: RELATIONSHIP BETWEEN OPTIMUM MOISTURE / CEMENT RATIO AND LATERITE / CEMENT RATIO

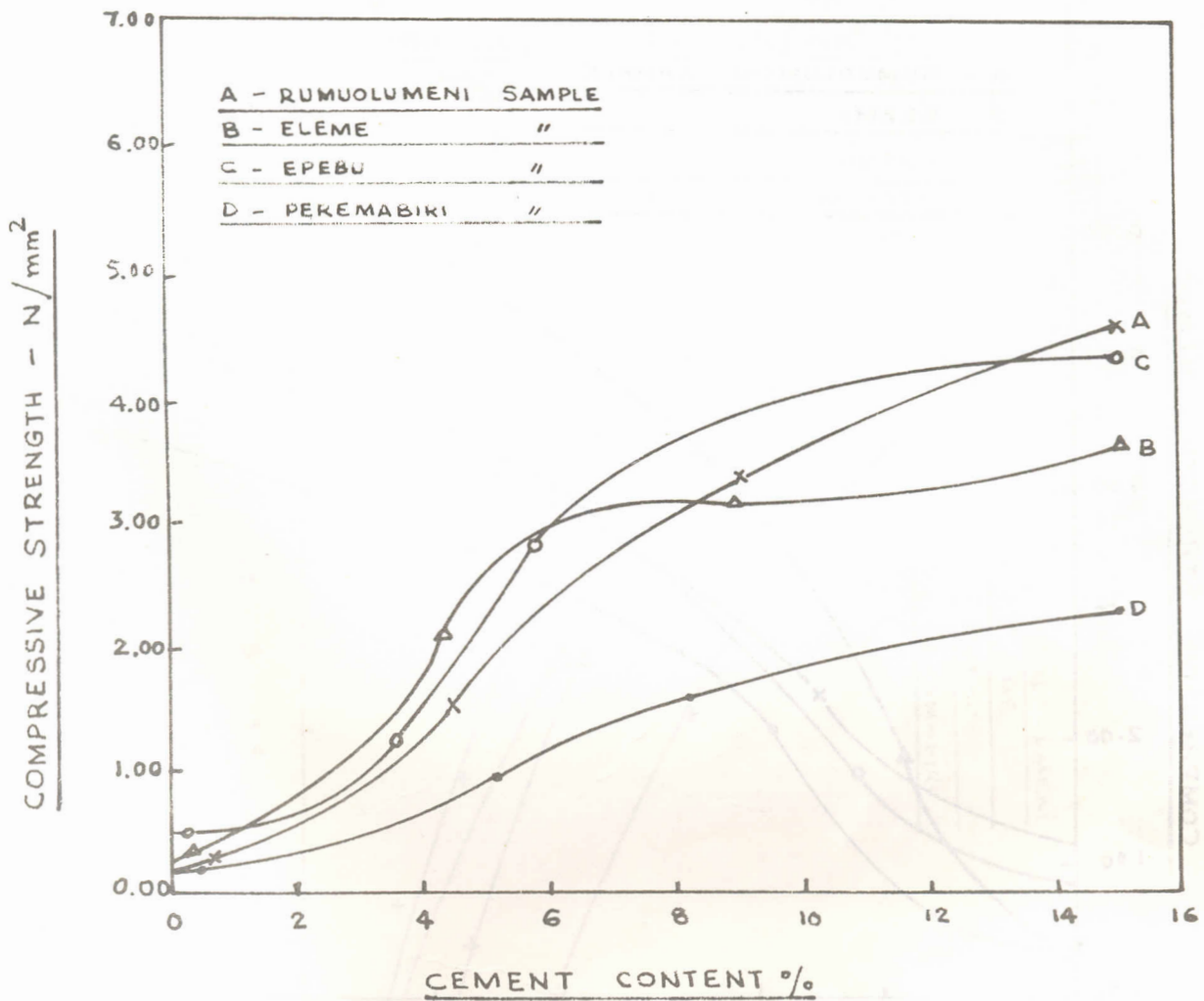


FIGURE 3 : VARIATION OF 7-DAY COMPRESSIVE STRENGTH WITH CEMENT CONTENT

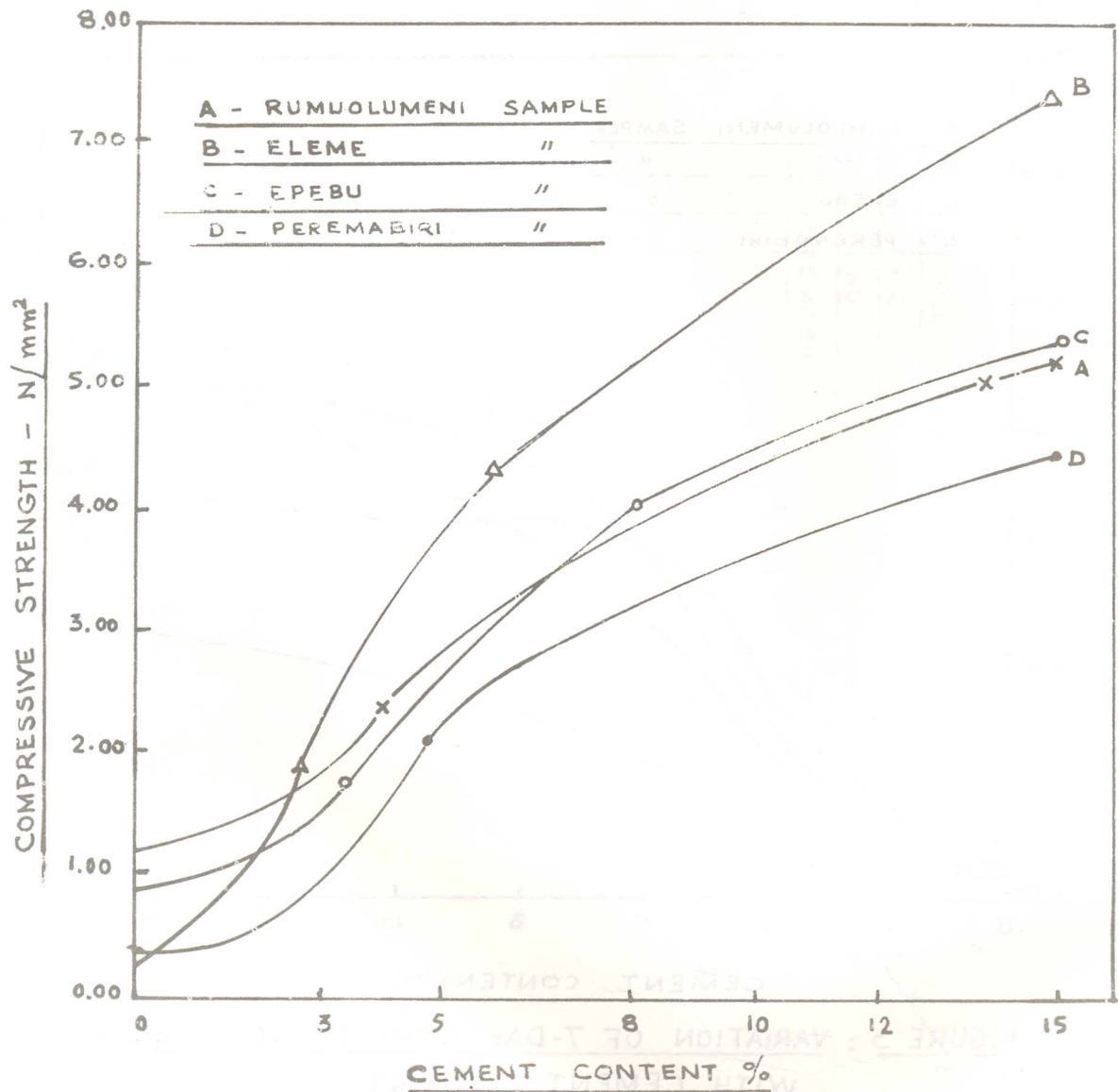


FIGURE 4 : VARIATION OF 28-DAY COMPRESSIVE STRENGTH WITH CEMENT CONTENT

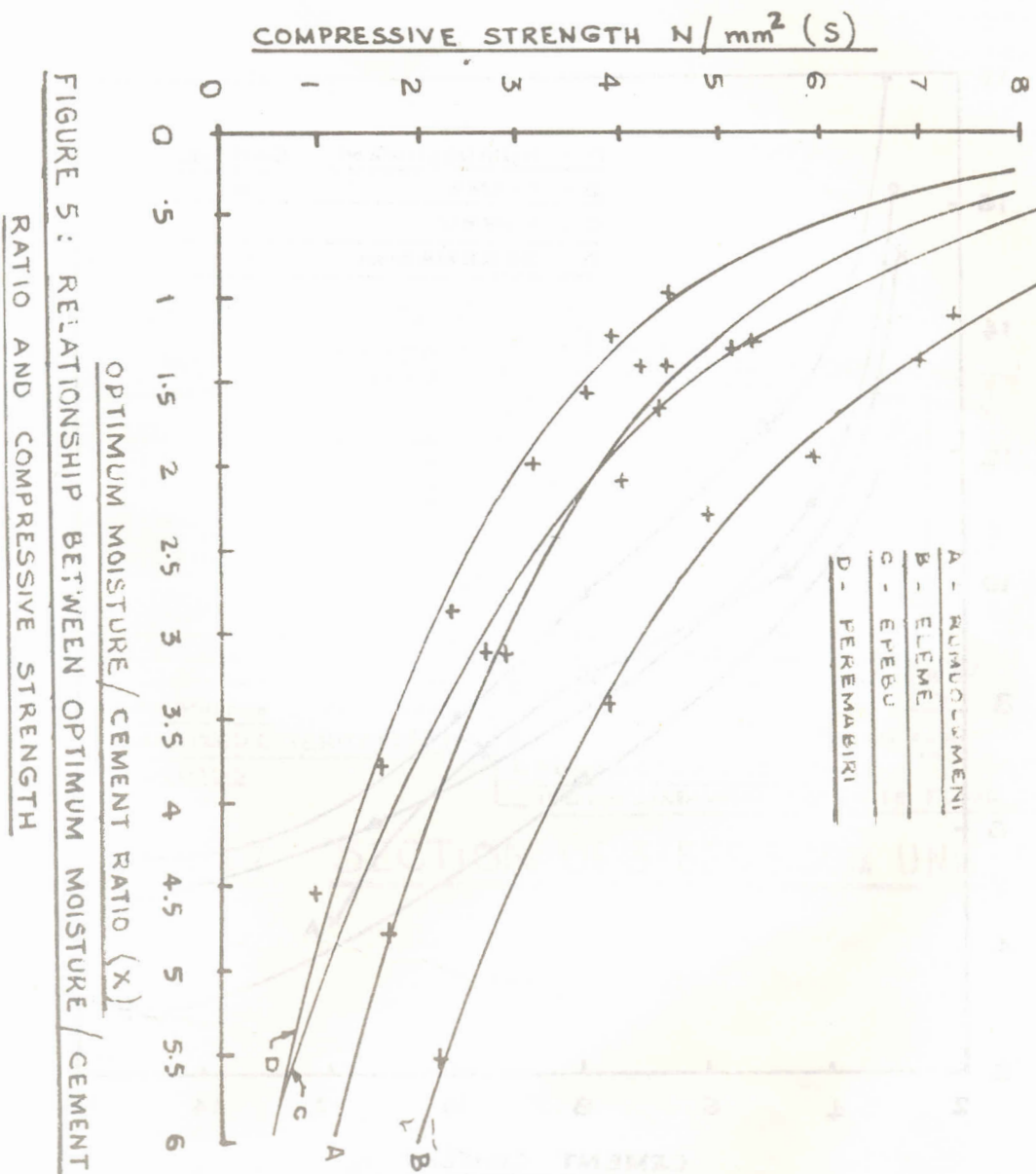


FIGURE 5: RELATIONSHIP BETWEEN OPTIMUM MOISTURE / CEMENT RATIO AND COMPRESSIVE STRENGTH

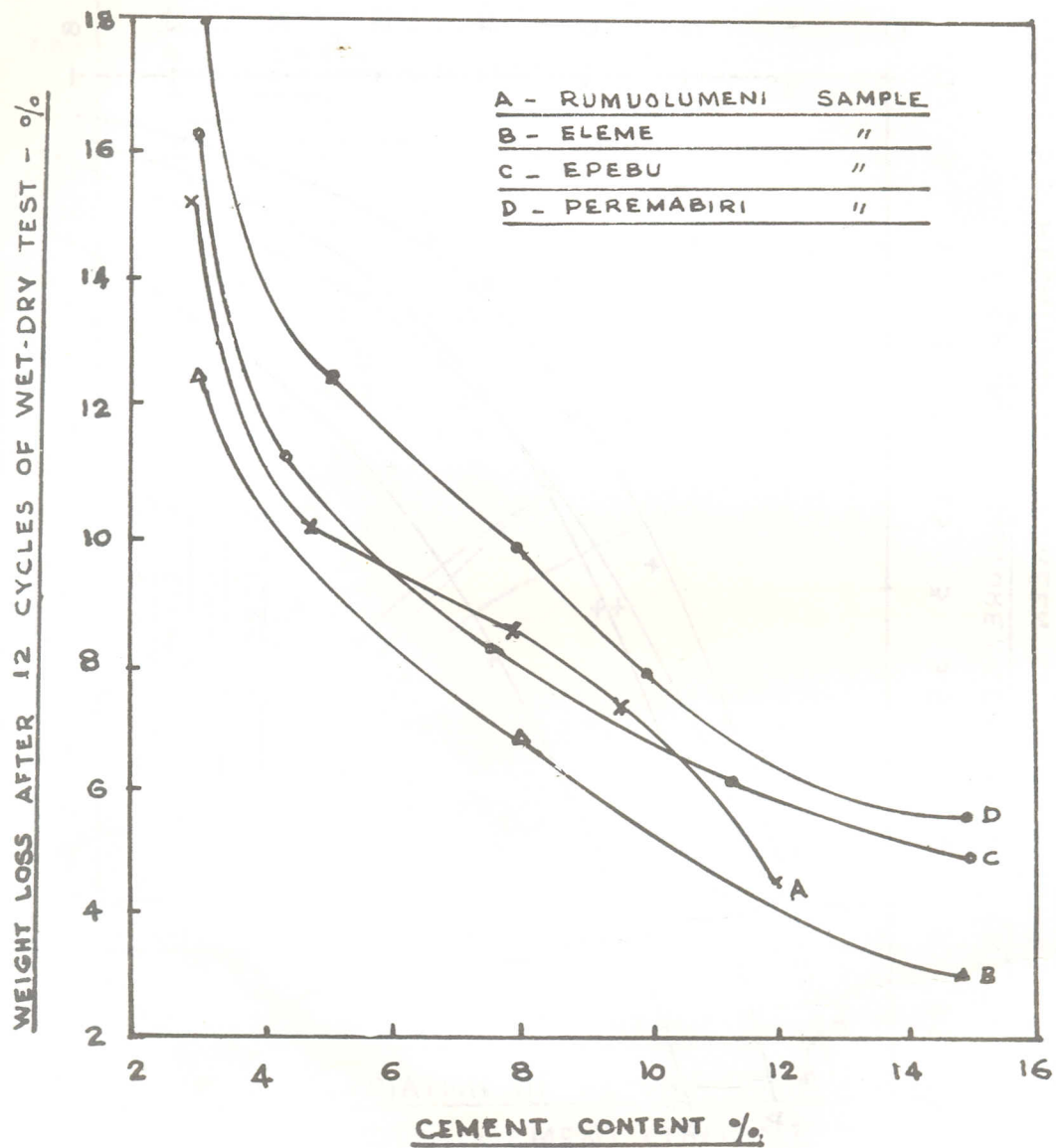
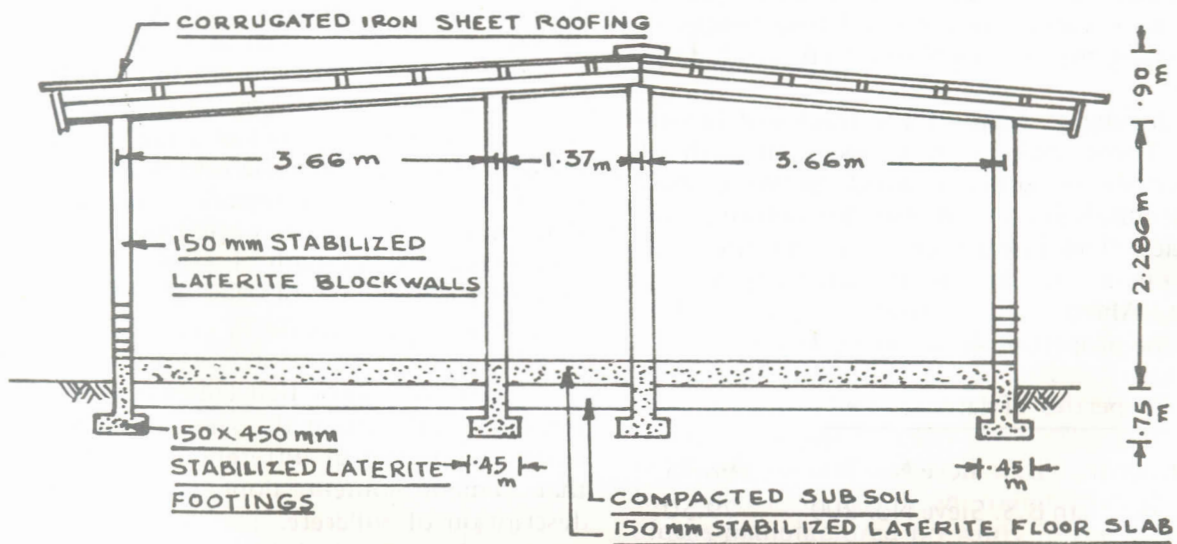


FIGURE 6: VARIATION OF WEIGHT LOSS WITH CEMENT CONTENT



**FIG. 7 SECTION OF 3-BED ROOM UNIT**

# SOME PROPERTIES OF SOILCRETE AS CONSTRUCTION MATERIAL

By

A. FLOREK<sup>+</sup> AND E. V. EZETAH<sup>++</sup>

## ABSTRACT

*One of the most economical wall units are the soilcrete precast blocks. Some of the physical properties of the material were tested, and analysed in this paper. Soilcrete blocks are formed by the mixing of laterite, cement and water.*

## 1. INTRODUCTION

Red clay laterite is widely used in construction of houses in the tropics. Nowadays, it is commonly mixed with cement or lime and water. Several laboratory tests were carried out on soilcrete blocks of different shapes, mixes, curing times etc. /1, 2, 3, 4/.

This paper highlights some of the results of laboratory tests. These include compressive strength of different shapes of soilcrete block samples, their compaction, durability and stress-strain deformations characteristics. The laterite used for the tests was obtained from a site close to the Civil Engineering Department, Ahmadu Bello University, Zaria. The laterite has the properties shown in Table 1.

Table 1 — Properties of laterite used

Percentage finer than B.S. Sieve No. 7	—	98.75
Percentage finer than B.S. Sieve No. 200	—	79.50
Percentage of sand	—	20.00
Percentage of silt	—	60.00
Percentage of clay	—	20.00
Liquid limit	—	35%
Plastic limit	—	14%
Plastic index	—	20%
AASHO classification	—	A6

The properties of the laterite are in accordance with Professor S.A. Ola's classification /8/ and very close to Professor D. Adepegba's classification /1/.

## 2. COMPRESSIVE STRENGTH TESTS

The compressive strength of soilcrete specimen was tested by crushing cubes of size 70.7mm and cylinders with diameter of 103 mm and length of 200 mm. The full size hollow blocks 400 x 150 x 150 mm were also tested to evaluate the strength of

the blocks as construction units. The specimens were tested in dry state and in wet state by soaking in water for 24 hours prior to the tests. Testing of wet specimens after 24 hours of soaking gives the lowest strength of soilcrete samples /8/. The lowest strength is called the critical wet strength. The minimum wet/dry compressive strength ratio of soilcrete is about 0.40 irrespective of compaction pressure used, type and size of specimen. /3/.

Tables 2 and 3 give the average dry compressive strength of cubes crushed at various ages with their corresponding compaction pressures, cement content and water content during casting. The tables also show the different shapes of samples and their compressive strengths /4/. The results as shown on these tables are plotted in figures 1 and 2. This shows that increase in cement content produces an increase in compressive strength of the cubes up to 12.0 percent cement content. Similar increase in strength is seen with an increase in compaction pressure up to 4.0N/mm<sup>2</sup> compaction pressure used in the test. The results also show that cubes of different cement contents could attain the same compressive strength when compacted at different pressures. It indicates that cement content alone is not enough in the description of soilcrete. The soilcrete hollow blocks are more sensitive with higher moisture content. This is because they present higher surface area than cubes of the same volume of soilcrete and hence higher dry strength of blocks is required. In the alternative, the blocks are tested after one day of soaking /8/.

Effect of shape on compressive strength of soilcrete blocks is shown in Table 4. For each height/diameter ratio of the cylindrical specimens, three cylinder samples are tested. The results show that the average compressive strength ranges from 7.0 N/mm<sup>2</sup> for height/diameter ratio of less than one (0.95) to 0.8 N/mm<sup>2</sup> for height/diameter of 2.4.

Recommended ratio for testing the soilcrete hollow blocks is 1.5. This ratio is more suitable for assessing the strength properties of soilcrete hollow blocks.

Table 5 contains results of the average compressive strength of different shapes of soilcrete specimens cast with the same compaction pressure.

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Tables 2: The average dry compressive strength of 8% cement soilcrete cubes (70.7mm) crushed at different ages.

Compressive strength (N/mm<sup>2</sup>)

Compaction pressure of cubes	Age			
	3 days	7 days	14 days	28 days
1 N/mm <sup>2</sup>	1.0	1.7	3.4	4.0
2 N/mm <sup>2</sup>	1.6	4.6	6.5	6.5
3 N/mm <sup>2</sup>	1.8	4.7	8.5	8.6
4 N/mm <sup>2</sup>	2.1	7.5	8.8	9.2

Table 3: Average dry compressive Strength of 8%, 10% and 12% cement content soilcrete cubes (70.7mm) crushed after 14 and 28 days.

Compressive strength (N/mm<sup>2</sup>)

Compaction Pressure of cubes	8% cement Age = 28 days N/mm <sup>2</sup>	10% cement Age = 14 days N/mm <sup>2</sup>	10% cement Age = 28 days N/mm <sup>2</sup>	12% cement Age = 28 days N/mm <sup>2</sup>
1 N/mm <sup>2</sup>	4.0	3.6	3.6	3.7
2 N/mm <sup>2</sup>	6.5	7.1	7.8	7.8
3 N/mm <sup>2</sup>	8.6	9.1	9.2	11.1
4 N/mm <sup>2</sup>	9.2	9.5	9.8	13.3

Table 4: The average dry compressive strength of 8% cement soilcrete cylinders compacted at pressure of 4 N/mm<sup>2</sup>, with varying height/diameter

Height/diameter ratio	Average dry compressive strength (N/mm <sup>2</sup> )
0.95	7.0
1.02	6.4
1.39	4.5
1.71	2.6
1.90	2.1
2.13	1.4
2.49	0.8

Table 5 Average dry and wet compressive strengths of various shapes of soilcrete specimen

S/No	Cement content (%)	Shape	Wet Comp. strength (N/mm <sup>2</sup> )	Dry Comp. strength (N/mm <sup>2</sup> )	Wet/dry Ratio	Age (days)
1.	8	cubes	3.6	9.0	0.40	28
2.	8	„	3.5	8.8	0.40	14
3.	8	„	3.5	8.5	0.41	14
4.	12	„	5.0	13.3	0.38	28
5.	12	Cylinder h/d = 2	1.4	3.7	0.38	14
6.	8	h/d >.2	0.7	1.3	0.54	14
7.	8	hollow blocks	1.4	3.4	0.40	14
8.	12	„	2.1	5.3	0.40	14

Average ratio of wed/dry strength = 0.41

Various bodies have suggested a minimum strength of 1.4 N/mm<sup>2</sup> for soilcrete blocks to be used in buildings /5/. The Federal Ministry of Works stipulates that the average of three sandcrete blocks should not be less than 2.1 N/mm<sup>2</sup> for sandcrete blocks. This is lower than the British Standard requirements, since the presumed conditions for British Standard specifications do not exist in Nigeria /4/. The specifications by the Federal Ministry of Works is however not indicative of immersion in water prior to testing of the blocks. It has been found that the sandcrete blocks manufactured presently in the Northern parts of Nigeria do not satisfy the Federal Ministry of Works specifications /5/ although these blocks are extensively used in the construction industry. /4/.

### 3. STRESS-STRAIN RELATION IN SOILCRETE

The aim of the stress-strain deformation tests is to study the deformation of the soilcrete block with reference to different compaction pressures and cement contents.

The standard method for testing of concrete /9/ was adopted as a guideline for the test. T.M.L.PL 10 and T.M.L. P.C 10 strain gauges with gauge factors 2.08 and 2.11 respectively were used to record the strains in the specimen while the stresses were applied by the Universal Denison testing machine. The specimens were soilcrete cylinders with height to diameter ratio of 2. The soilcrete cylinders were of two groups. The first group were cylinders of 8% cement content by laterite weight. The water content was 14% also by laterite weight. The cylinder specimens in this group were compacted with compaction pressures of

1, 2, 3 and 4 N/mm<sup>2</sup>. For each compaction pressure three cylinder specimens were prepared. In the second group, the cylinder specimens were of 12% cement content by laterite weight. It has the same amount of water content as the first group but with only 4.0 N/mm<sup>2</sup> compaction pressures. Both the first and second group of specimens were cured by soaking in water for six days and air-dry in the laboratory atmosphere for seven days. The specimens were subjected to stresses and the corresponding strains were recorded. The maximum stress a specimen is subjected to is about one-third of the ultimate strength. The result is shown in Fig. 4

#### 4. DURABILITY TESTS

Durability of a material is its ability to withstand a particular recurrent effect such as wind and rain without failure. The determination of durability employs accelerated tests which is not a sure method of predicting the durability of a material. This is because some materials which have failed under accelerated durability tests have performed quite well in practice /6/.

There are two main durability tests in use for stabilized soils. The more commonly used durability test was developed to simulate the weathering of soil-cement road base /6/. Here, stabilised soil specimens are soaked in water, dried to constant weight and then given a specified number of strokes with a wire brush. The sample is then re-weighed and the total loss in weight is calculated as a percentage of the original weight. A maximum weight loss has been stipulated as limits for the acceptance of a building material /6/. Most authorities consider this test too severe and some modify the brush to nylon or soft hair.

Another durability test involves the spraying of water from a shower head against the face of a specimen for a given number of hours. This test is intended to simulate the effect of wind and rain on a walling unit. It has been suggested that in the absence of adequate data to correlate the actual performance with these tests, the water spray test seems to be the most suitable for building purposes /6/.

Durability tests were carried out on six soilcrete cubes of size 70.7mm. The cubes were of 8% cement content and 14% water content both of laterite weight. The Compressive strength after 28 days of hardening was 9.0 N/mm<sup>2</sup>. The cubes were moulded at compaction pressure of about 4.0 N/mm<sup>2</sup>.

Six of these cube specimens were prepared for the test as follows. Each cube was placed under a shower of water with pressure head of about 2.5m. The water is allowed to spray on the cube with the face of the cube 20mm from and parallel to the shower face.

The spray was continuous for six hours. It was observed that there was no sign of erosion or pitting on the cubes after the tests. It was assumed that soilcrete would likely have good durability.

#### 5. CONCLUSIONS AND RECOMMENDATIONS

From the test results and observations of production, the following conclusions can be derived:

- (a) Soilcrete cylinder compressive strength is significantly affected by the height/diameter ratio of the specimen. The soilcrete cylinder with height/diameter ratio of 1.5 is the most suitable for assessing the strength of soilcrete hollow blocks.
- (b) The compressive strength of soilcrete cylinder with height diameter ratio of 2 is about 26% of the cube strength and about 55% of the hollow block strength and it is not suitable for assessing its strength.
- (c) The wet to dry compressive strength ratio of soilcrete is about 0.40. This ratio does not seem to vary for each type of specimens (i.e. cubes, cylinders and hollow blocks) nor with the compaction.
- (d) Considering the safety precautions to be achieved by some designs and the different uses and conditions to which soilcrete blocks will be subjected, there is the need for meticulous use of the wet compressive strength for soilcrete blocks. Also there is the need for classification and differing specifications for soilcrete blocks according to use.
- (e) The elastic modulus of soilcrete tends to increase when compaction pressure of the specimen increases for a particular cement content. It also tends to increase for an increase in the cement content only.
- (f) In describing or stating a particular soilcrete mix, the *cement content* and the *compaction pressure* should be specified (not only one of them).
- (g) Detailed, full research should be continued on the durability, shrinkage, creep (long lasting load) and other properties of the soilcrete.
- (h) The soilcrete block moulding machines should be produced and commercialized. The necessary modification should include making the sides of the moulds collapsible.

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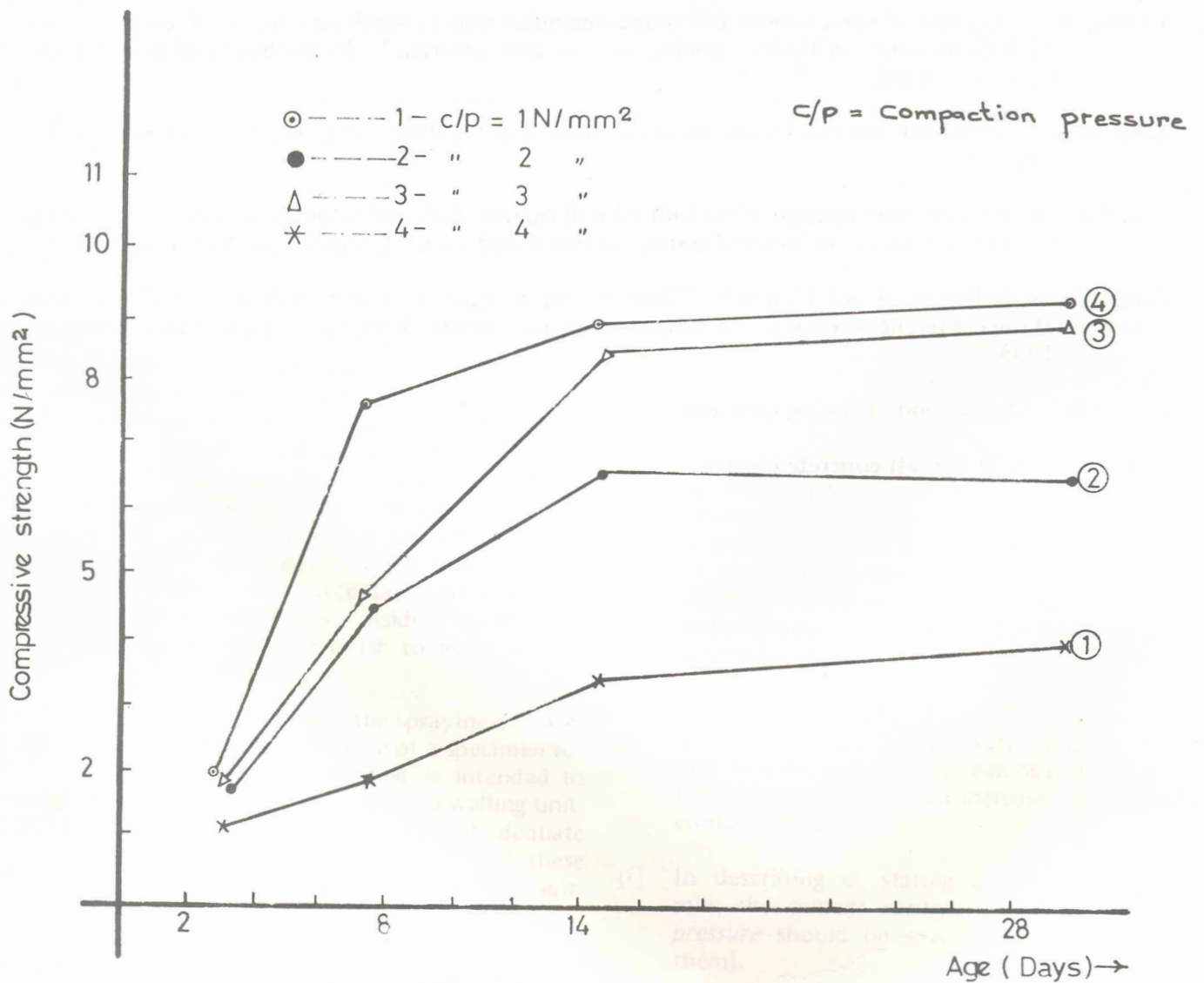


FIG. 1: Compressive Strength Development with time of 8% cement cubes, of various compaction pressures

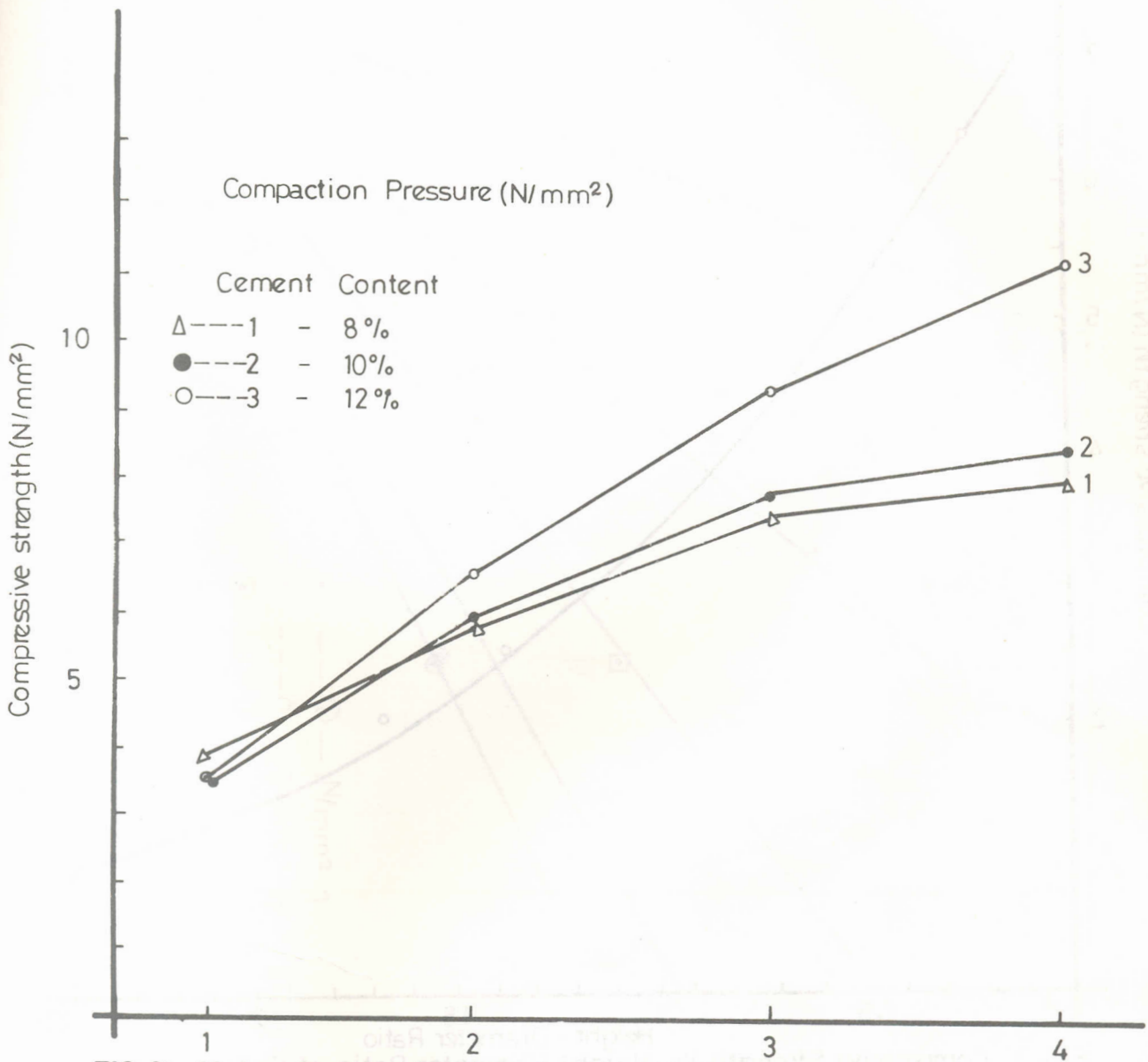


FIG. 2: 28 day Compressive Strength with 4 N/mm<sup>2</sup> compaction pressure for different Cement Contents.

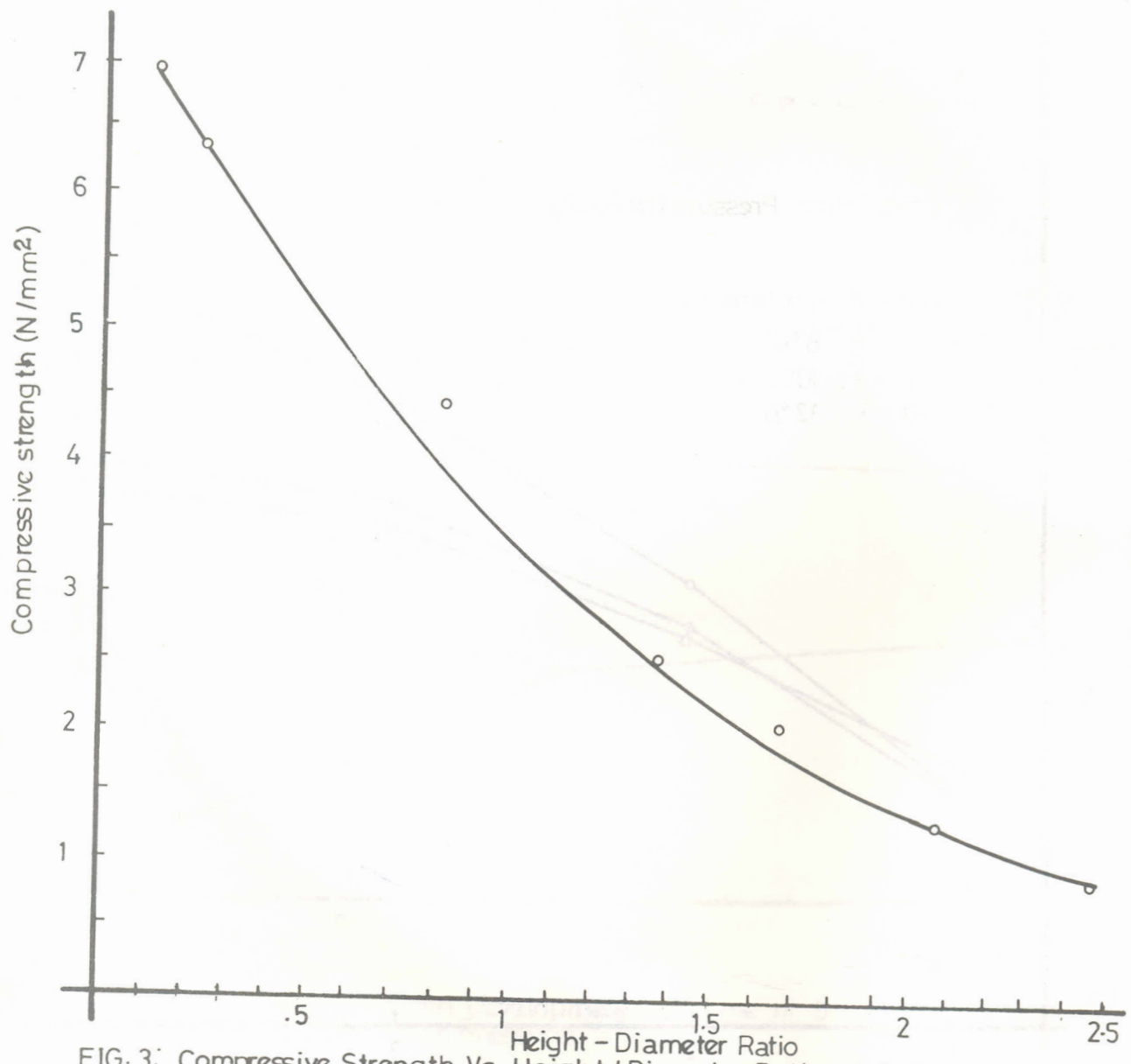
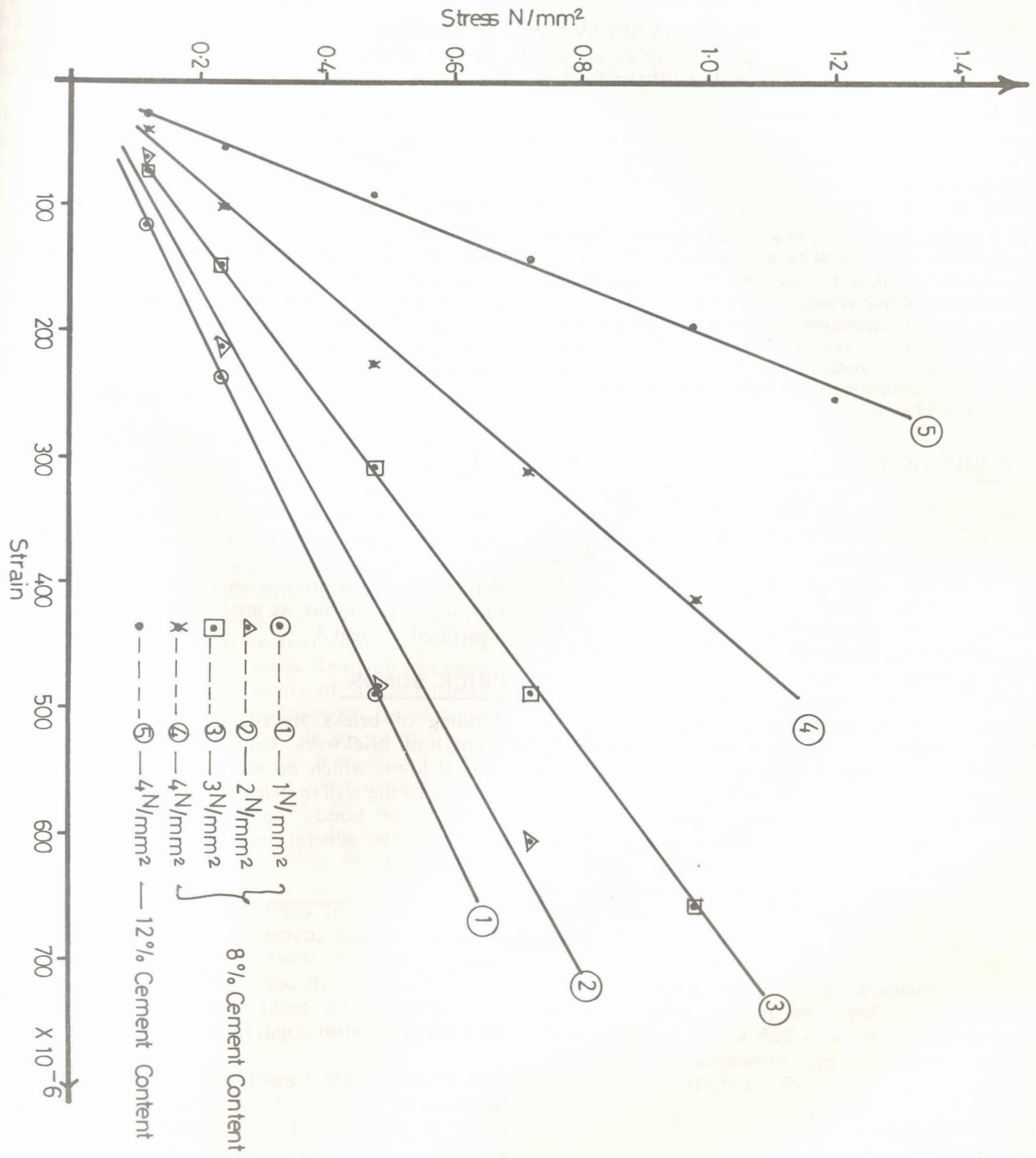


FIG. 3: Compressive Strength Vs Height / Diameter Ratio of Soilcrete Cylinder

FIG. 4: STRESS - STRAIN RELATION



## POTENTIALS OF BRICK IN BUILDING CONSTRUCTION

By

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### ABSTRACT:

*Brick is produced from clay, which is abundantly available in Nigeria. The bricks in Nigeria is being re-introduced in construction industry in order to minimise the consumption of imported material like cement. This paper discusses the versatility of brick as building and construction material. It brings out that brick can be depended upon in construction of low cost houses and in reducing the requirement of cement. Further, the construction shall be indigeneous, form vernacular and environment local.*

### INTRODUCTION:

Recent emphasis by the Government on the use of local building materials in construction has very well been received by professionals in the country. Whatever be the definitions of local materials, clay, from which bricks are made, will fall well within these definitions. The progress in the science and technology of materials has made possible the production of bricks from any type of clay. The colour and texture of burnt bricks differ with the chemical composition of the clay, and this also applies to its strength. It is a labour intensive product, and a highly popular building materials with architects and builders in most parts of the world. In Nigeria, the use of brick in construction has been discontinued for many decades, but in recent times, architects and builders have shown interest in its use. It is therefore necessary that light should be thrown on the basic principles of brickwork, and to highlight that brick is one of the very versatile building and construction materials.

The paper discusses the brick and its various uses in construction of low cost houses. Internationally, accepted size of brick is 225 x 112 x 75 mm and this has been taken into consideration in the discussion.

### USE OF BRICKS:

In the construction of houses, bricks can be used in foundation, walls, columns, lintels, roofs and floors. Walls could be either solid or cavity walls in various thicknesses. Door and window openings are covered with lintels, either flat or arched, of different types. The bricks are used to construct roofs as reinforced brickroofs, or as vaults, domes and arches.

Over-burnt bricks can be used as aggregates in foundation concrete and for laying sub-base for floors in low cost housing and light structural buildings. Bricks ground to powder can be used as an alternative cementing material to ordinary portland cement for masonry mortar and plaster and lime concrete. In foundation, lime and burnt clay pozzolana mortar is economical in construction work, where lime is available.

The exposed brickwork in walls are aesthetically sound and has potential for numerous decorative treatments using different bonds. Such walls are economical, since they eliminate plaster and painting, and they are easy to maintain.

Before the use of brick is discussed in detail, some of the important terms as applicable to brickwork is illustrated in sheet 1

### BRICK BONDS:

Bonding of bricks are required in order to attain strength of brickwork. Unbonded walls create many vertical joints which do not provide any strength or stability to the wall or brickwork. There are a number of types of bonds, but the well known bonds commonly in general use are flemish bond and English bond.

The flemish bond combines alternate headers and stretchers in each course. (Sheet 2G) This bond has large number of short continuous vertical joints (Sheet 2E, F) which occur in the longitudinal direction. These joints make this bond comparatively weaker than English bond. (Sheet 2 H).

The English bond consists of alternate courses of headers and stretchers. In each header course a queen closer is placed next to a corner header. (Sheet 2A-D). The remaining bricks of the course are headers. With the introduction of the queen closer, lap of joints are obtained and the vertical joints are avoided. It is this comparative lack of straight joints that gives the English bond its characteristic strength.

The illustration on sheets 2 to 4 details out various uses of brick in construction of buildings.

## WALLS:

The solid walls in brick are identified with their thickness i.e. half-brick thick wall; one-brick wall, one-and-half brick or two-brick thick walls and so on. The wall thicknesses are also known by their dimensions i.e. multiples of its width, which is half of its length. As an example, a brick size is (L) 225 x (W) 112 x (H) 75 mm. Half brick wall means 112mm thickness, whereas 225mm thickness is one brick wall thickness and 337mm is one and a half brick wall thickness and so on.

The half brick thick wall is generally used for partitioning or non-load bearing walls. One and a half brick or two-brick thick walls are structurally safe for any type of construction and are thermally very good. They consume more space in walls. A very lean mortar could be used to construct such walls. One-brick thick wall is used generally for the construction of low cost houses. It is more economical and thermally comfortable. With designed brickwork, one-brick thick wall can be used for four storey residential buildings.

Details of the English bond walls at external corner, T-junction and cross junction are sketched out in sheet No. 3.

## CAVITY WALL:

Bricks can be used to construct cavity walls of different thicknesses. A combination of different thicknesses of leaves will make different types of cavity wall. The purpose of cavity wall is to create better thermal environment and better protection from rain penetration to the inner leaf of the walls. Research and experiments have shown that a cavity of 50mm between two leaves of the wall is good enough for effective thermal performance. The two leaves of the walls are held together by wall ties, which are placed at bed joints across the cavity 500mm apart vertically and 1000mm horizontally (Sheet 4A, C). The ties are used to strengthen the stability of the wall, and they are of several types, the simplest being made of

galvanised wire. It is dented 'V' shaped in the middle to facilitate the moisture drop (Sheet 4B). Brick can also be used as wall ties, but it increases the chance of water absorption to inner leaf through itself. The cavity should be kept free of mortar droppings. The top of the cavity wall and the sides at door, window openings must be closed by one or two brick course, or by door and window frames (Sheet 4D, E). Care should be taken that on the top of the cavity walls, load should be shared by both leaves of the wall.

## ROOF; LINTEL; AND ARCHES:

Brick lintels are laid horizontally. It is comparatively weak as a structural member hence it is used for small spans. Cement mortar is used in the construction and reinforcement is provided as per design. For a roof, the reinforcement is designed and bricks are used in place of concrete in compressive zones. This type of roof is called reinforced brick roof. In many developing countries, such roofs are common and it is much more economical when compared to RCC roof. It is suitable in dry climates where the rusting of reinforcement is remote.

The most effective use of brick in covering spans is in the arch. A number of types of arches have been developed, where brick has been used. An arch is a structure comprising of a number of small units like bricks, which are wedge-shaped. They are joined together with mortar, and because of their wedge-like form, the units support each other. The load tends to make them compact and enable them to transmit the pressure downwards to their supports.

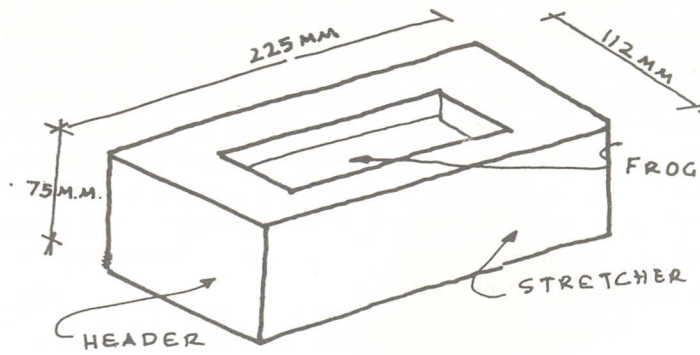
## CONCLUDING REMARKS:

From the above description it is clear that brick as a material can be used in various elements of construction. The use of bricks can considerably reduce the requirements of portland cement and cost of building. The brick can be produced locally with local technical know-how. There is need that indigenous innovative techniques of construction be developed so that it suits the Nigerian artisans and masons.

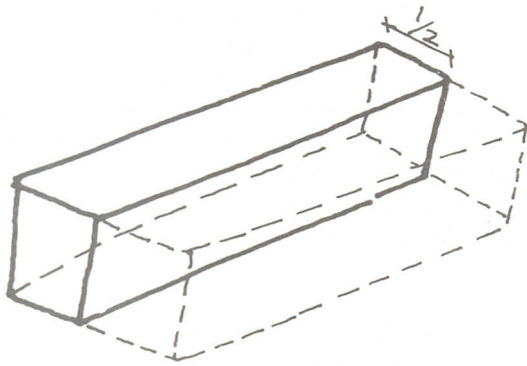
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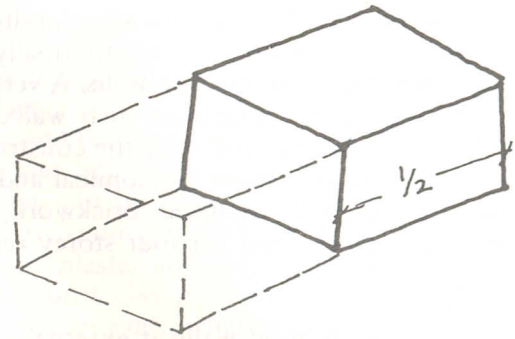
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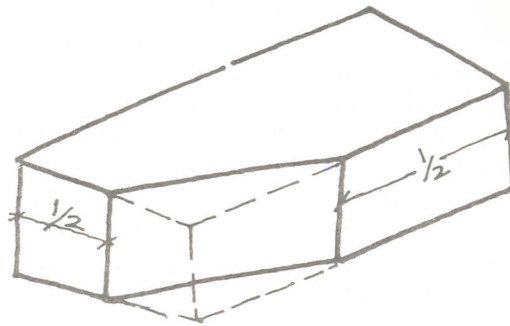
BRICK.



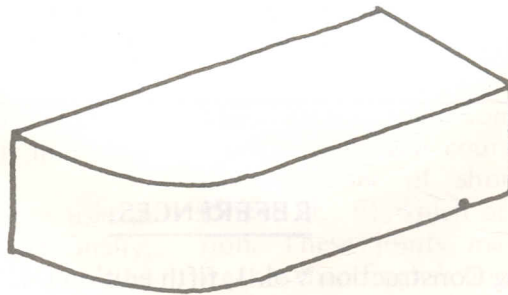
QUEEN CLOSER



HALF BAT



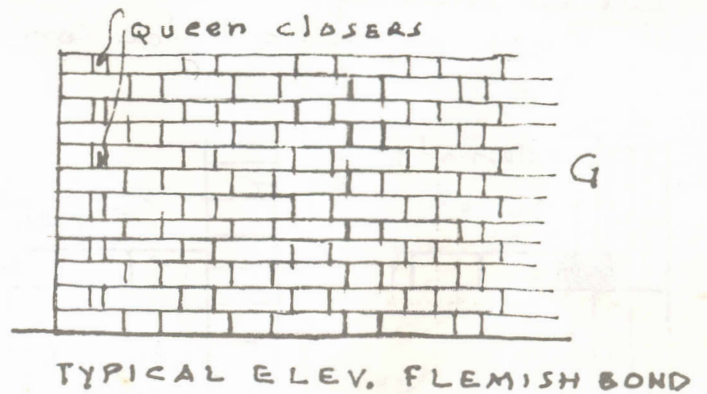
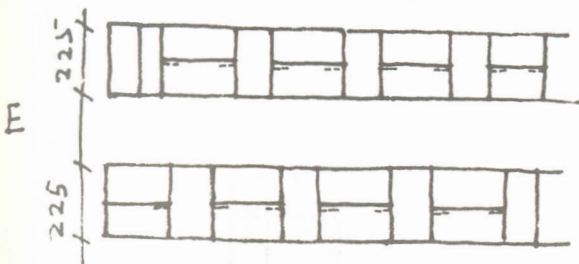
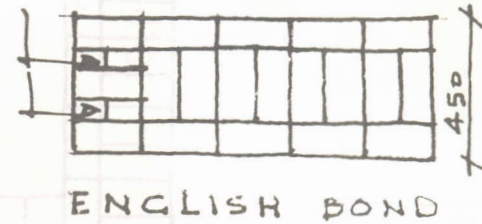
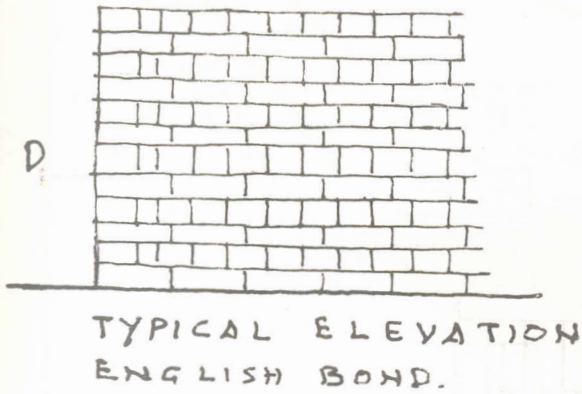
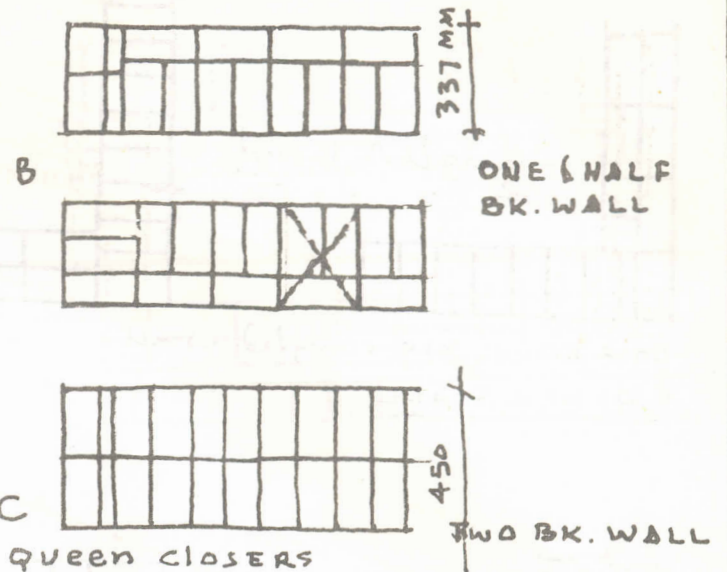
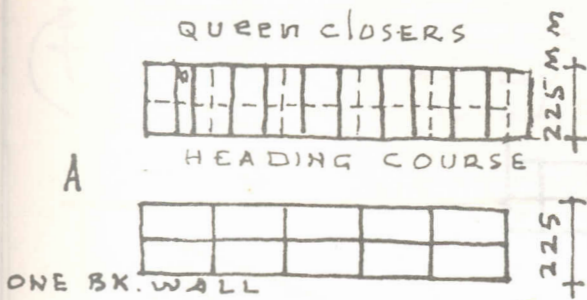
KING CLOSER



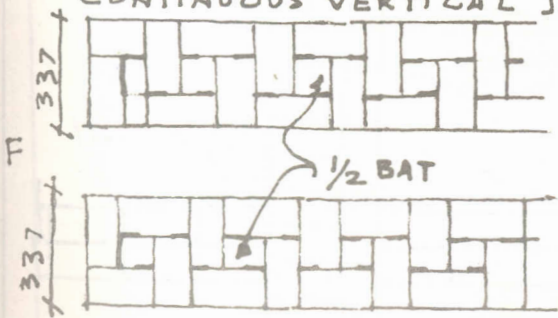
BULL NOSE

SHEET No 1

IMPORTANT TERMS OF BRICK



FLEMISH BOND  
DARK LINES INDICATE CONTINUOUS VERTICAL JOINTS



FLEMISH BOND

ENGLISH

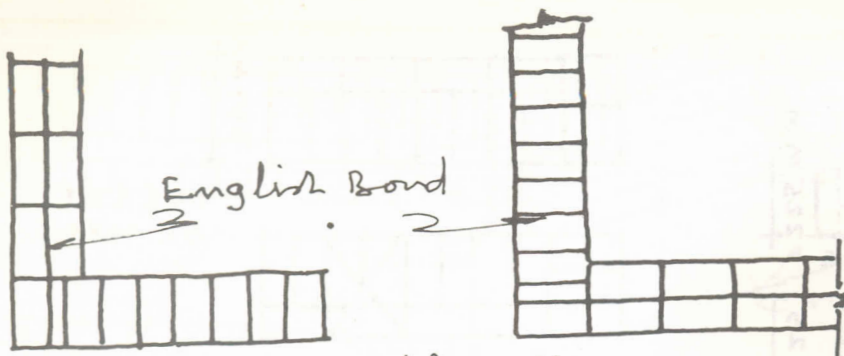
CONTINUOUS VERTICAL JOINT

FLEMISH

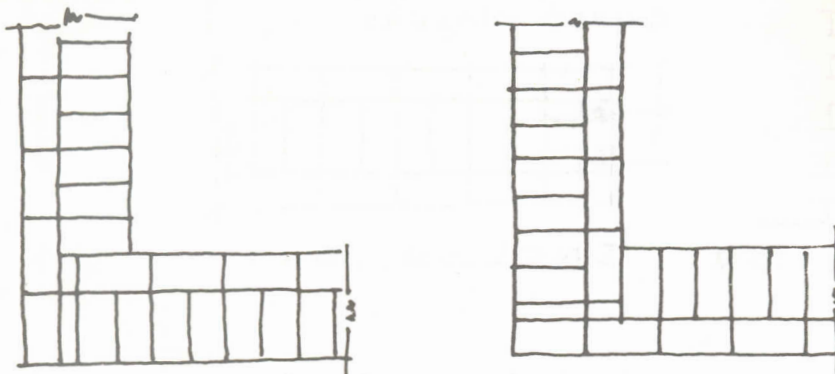
WEAKNESS OF SINGLE FLEMISH BOND

COMPARATIVE STRENGTH.

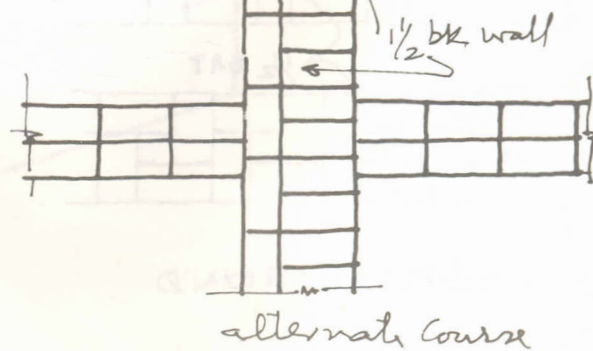
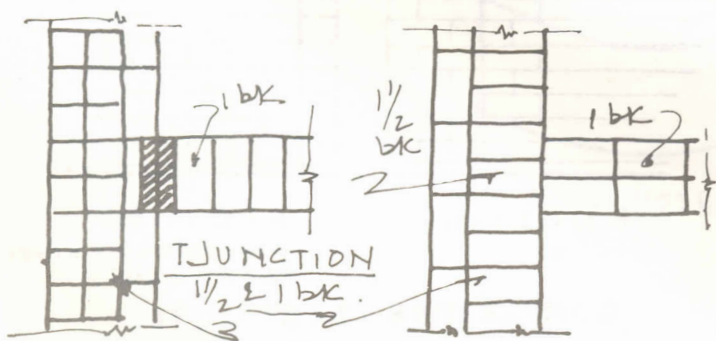
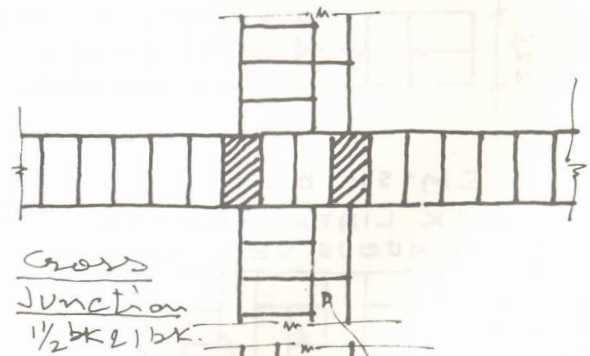
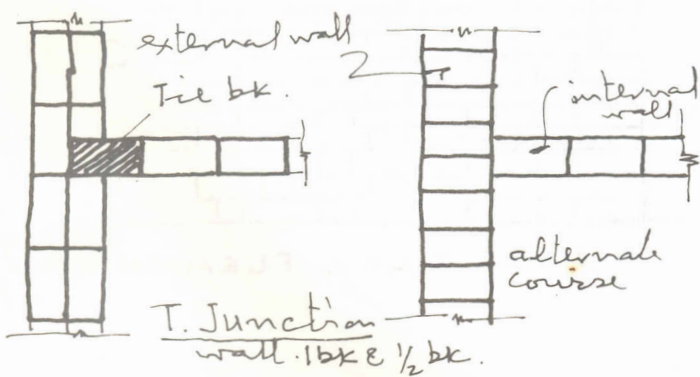
SHEET No 2. DETAILS OF BRICK BOND IN WALLS.



one brick right angled wall  
CORNER WALL

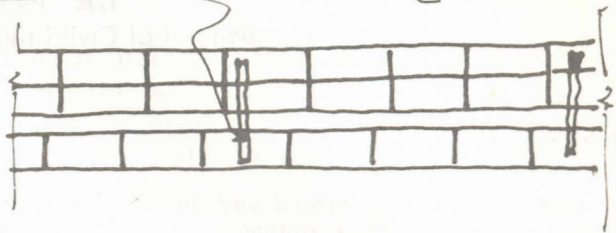
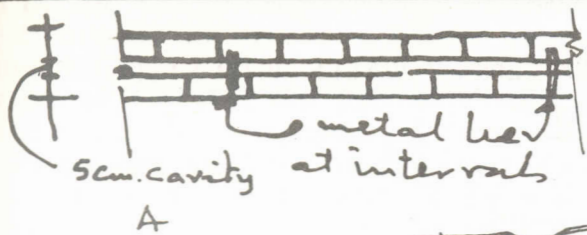


One & half brick thick corner wall

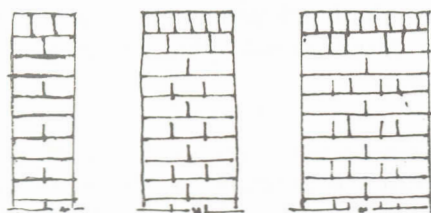


SHEET NO 3

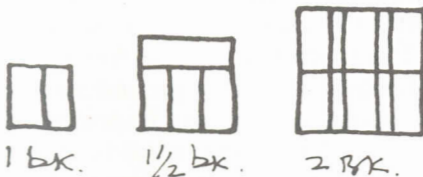
BRICK WALLS



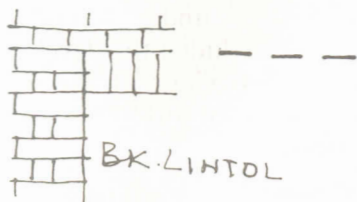
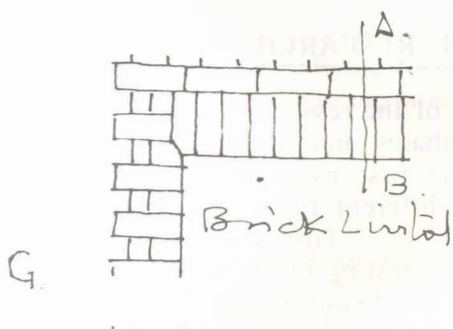
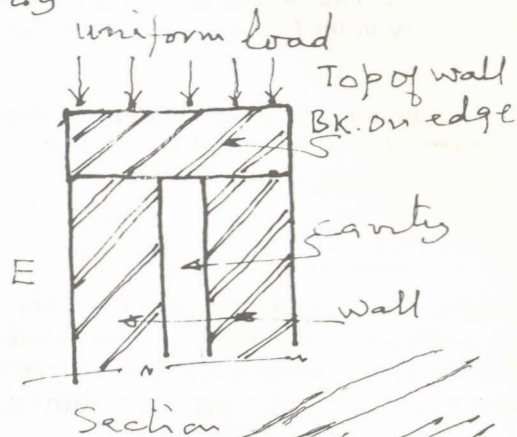
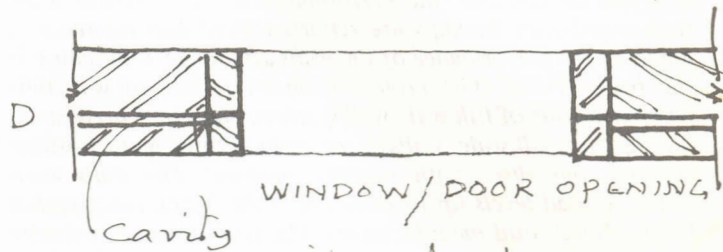
CAVITY WALL



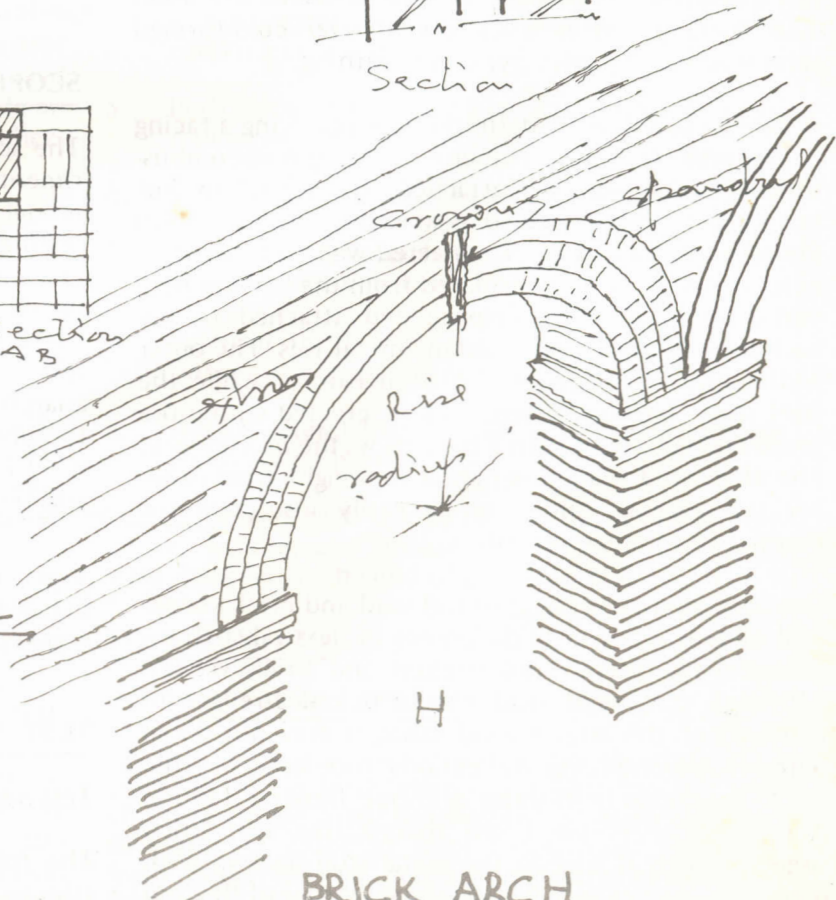
F elevations



COLUMN Plan.



BRICK LINTOL



BRICK ARCH.

## THE POST CRACKING BEHAVIOR OF BRICK VENEER WALLS WITH STEEL STUD BACKUP

By

DR. JOSEPH O. ARUMALA

Department of Civil Engineering, University of Port-Harcourt.

### ABSTRACT

*The results of an experimental and analytical programme designed to evaluate the performance of brick veneer walls with metal stud backups are reported. Particular reference is made to the performance of the walls after a crack develops in the brick veneer. The project included testing of wall ties, flexural testing of full-scale wall systems, and water permeance testing. Six full-scale walls were tested, three with positive pressure and three with negative pressure. The walls were tested to load levels up to three times the load recommended by the Metal Stud manufacturers. The lateral load test results are reported in the form of deflection profiles at various load levels.*

*Test results show that a large proportion of the lateral load is transferred to the metal stud backup after a crack develops in the brick veneer.*

### INTRODUCTION

Recently, a new exterior brick-masonry wall system has come on the market and has been widely used. The wall system is brick veneer over cold-formed steel stud backup with gypsum sheathing.

A veneered wall is by definition a wall having a facing of masonry units or weather-resisting non-combustible materials securely attached to the backup, but not bonded or attached so as to exert common action under axial load. A brick veneered wall consists of an exterior wythe of brick isolated from the backup by a minimum of 25 mm airspace and attached to the backup with corrosion resistant metal ties. The outer wythe gives the appearance of masonry, while the steel stud backup system may be erected with more speed and economy than a backup wythe of masonry. The steel stud system is lighter in weight than other backup systems, and may be easily insulated for thermal and sound control.

One area of concern of the steel stud and brick veneer wall system is the large difference in flexural stiffness between the metal stud backup and brick veneer. Although the metal stud has sufficient strength to carry all of the lateral wind loads, it may not do so without experiencing deflections too large for the brick veneer to withstand without flexural failure. According to simple beam theory, the stiff brick veneer, which is tied to the metal stud backup with metal ties, carries substantial lateral load until flexural

tensile cracks form. Only after flexural failure of the brick wythe will a significant load be transferred to the metal stud backup. The consequences of flexural failure of the brick veneer are water permeance or, in extreme cases, catastrophic structural failure of the wall system.

Most members of the Metal Lath/Steel Framing Association recommend a design criteria for brick veneer walls supported by metal studs in which the stud alone acting as a simple beam resists all lateral load without exceeding a midspan deflection of  $L/360$ . The Brick Institute of America, however, does not feel that this design procedure assures sufficient stiffness of the wall system to prevent cracking of the brick veneer. An experimental research was therefore co-sponsored by these two Associations to determine whether or not wall systems designed according to Metal Lath/Steel Framing Association criteria would perform adequately.

### SCOPE OF RESEARCH

The scope of the research project included two experimental phases and development of an analytical model. The first experimental phase involved the testing of different types of metal ties, for effective axial stiffness. The second experimental phase involved the testing of six simple span brick veneer walls with metal stud backup to measure their deflection characteristics under lateral load. And the analytical aspect included the development of models to simulate the behaviour of the wall system under wind pressures and for different boundary conditions and tie stiffnesses.

The subject of this paper is concentrated on the behaviour of the walls in which the brick veneers cracked during the tests.

### TEST PROGRAMME

#### Test Specimens

The full-scale lateral load test specimens were constructed according to details shown in Fig. 1.

Both the dry wall (backup wall) and the masonry were constructed by contractors familiar with such construction. The walls were constructed and tested in groups of three. The first three were tested with positive pressure (i.e. compressed air), the next three, negative pressure (vacuum). The first group of three walls, both the backup dry wall and the masonry veneer, were constructed at the same time. Upon completion of testing of this group of walls, it was observed that the dry wall was still in excellent condition. The test data also indicated very little residual deflections resulting from positive pressure tests. Therefore, the same three dry walls were re-used in the second phase of testing. That is, the veneer was sawed into pieces and removed, the wire portion of the ties replaced, and new brick veneer constructed. The primary purpose for re-using the dry wall was to eliminate as many variables in the testing program as possible. Re-using the dry wall was the best way to assure that the stiffness of the backup system did not vary between the positive pressure and negative pressure tests.

## TEST PROCEDURE

### Lateral Load Tests

Lateral load testing was accomplished using a plywood frame equipped with an electric vacuum cleaner motor and impeller. The chamber was constructed so that it completely surrounded the top and sides of the brick veneer wall with an airspace of approximately 25 mm. In order to seal this air gap, thus minimizing air leaks during tests, a rubber tube was placed between the perimeter of the brick veneer and the inside wall of the test chamber. Before load testing the walls, the tube was inflated to provide an air seal without significantly restraining lateral deflection of the brick veneer.

### Water Permeance Tests

The tests for Water Permeance were an adaption of "Water Permeance of Masonry." ASTM E 514 - 79. However, since the back side of the brick wall was not accessible, it was necessary to modify several of the techniques. The test chamber was clamped to the wall at a distance of approximately 750 mm from the base. This position was chosen so that the region of the wall that was subjected to high flexural stresses would also be exposed to the water permeance chamber. However, the large volume of masonry below the water permeance test chamber absorbed water that would ordinarily collect in the flashing in a standard E 514 Test. Thus, collection of water in the flashing was not as meaningful as in the standard E 514 test.

The water for the water permeance test was a closed-loop system. Water was collected at the base of the water permeance chamber and returned to the drum from which the water was pumped. In practice, however, it was not possible to seal the perimeter

of the water permeance chamber completely. Although every attempt was made to ensure a closed system, leaks were inevitable.

## Instrumentation

The brick veneer and dry wall panels were instrumented with mechanical dial gages accurate to within 0.025 mm. A sufficient number of dial gages were attached in order to obtain a complete deflection profile of both walls. Gages were located at approximately the height of the wall ties. It was, therefore, possible to determine the difference in wall deflection at the tie location. A total of 20 dial gages were used on each wall.

Lateral load was monitored by a manometer mounted on the lateral loading chamber. The manometer was accurate to within (0.5 mm) resulting in pressure readings accurate to within  $5 \text{ N/m}^2$

## Test Sequence

Each wall was tested according to the following procedure.

1. Pre-condition for water permeance, 24 hours.
2. Allow wall to dry, 24 hours.
3. Perform first water permeance tests, 3 hours, remove water permeance chamber.
4. Attach lateral load chamber, load test wall to one time design load, unload, remove chamber, attach water permeance chamber, seal with caulking compound.
5. Perform second water permeance test, 3 hours, remove water permeance chamber.
6. Attach lateral load chamber, load test wall to two times design load, unload, remove lateral load chamber, attach water permeance chamber, seal with caulking compound.
7. Perform third water permeance test, 3 hours, remove water permeance chamber.
8. Attach lateral load chamber, load test to three times design pressure.

Dial gages were read at load increments at 240 N both during loading and unloading. Residual deflections were recorded at the end of each load test.

## TEST RESULTS

### Results of Lateral Load Tests

Of the six walls tested, one experienced flexural cracking of the brick veneer at slightly greater than one time design load; three at twice design load; and two did not crack at three times design load. The walls subjected to positive pressure experienced flexural cracking at  $2.5 \text{ kN/m}^2$ ,  $1.25 \text{ kN/m}^2$ ,  $1.5 \text{ kN/m}^2$



respectively. Only one of the walls subjected to suction cracked at  $2.75\text{kN/m}^2$ . The other two withstood three times design load without cracking.

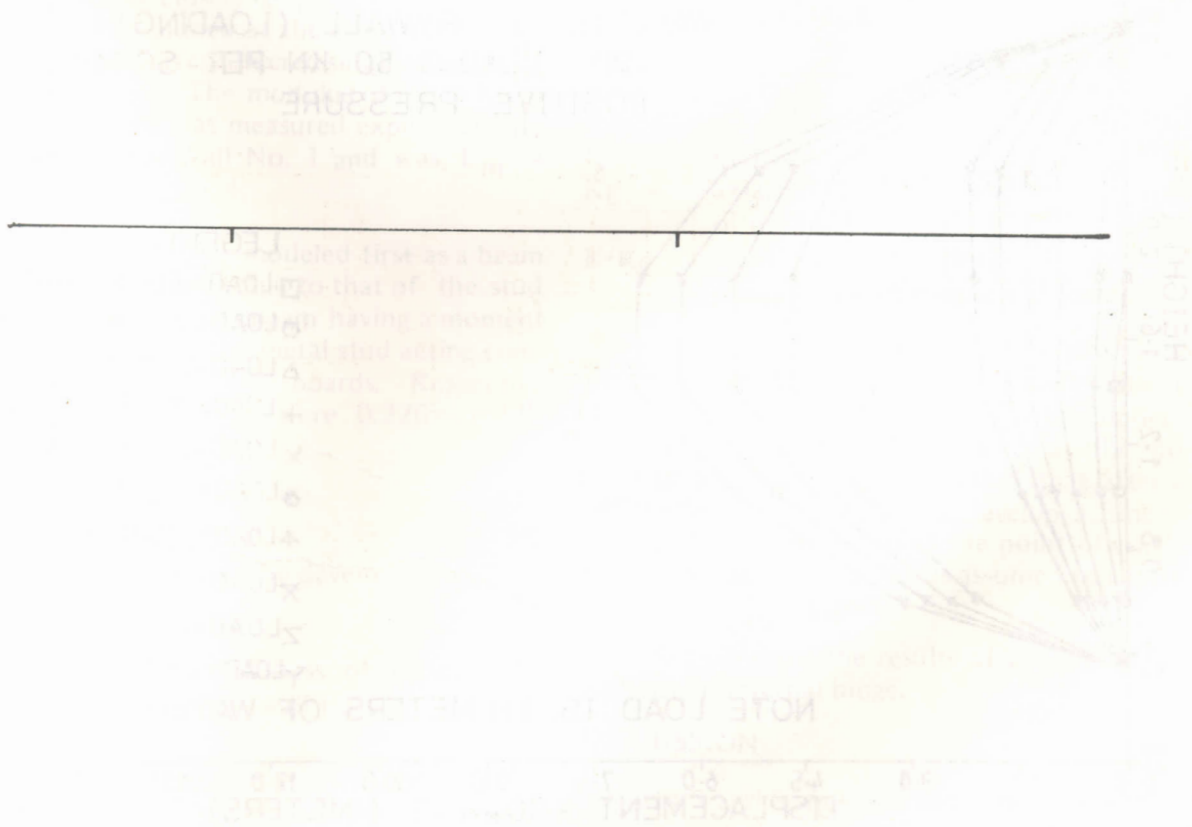
The best representation of lateral load test results are deflection profile graphs at increasing load levels. Figures 2 and 3 illustrate typical results where the brick veneer cracked during the tests. These figures include deflection profiles of both brick veneer wall and dry wall.

The behaviour shown in Fig. 2 was generally characteristic of three of the walls tested (Wall Nos. 1,3, and 5.). That is, the deflected shape was a continuous smooth curve up to a lateral load level between  $2.5\text{kN/m}^2$  and  $2.75\text{kN/m}^2$  after which a flexural tensile crack formed in the brick veneer which completely altered the deflection profile and magnitude. Figure 3 shows the corresponding dry wall deflection. Although it remained a smooth continuous curve, the dry wall deflection increased markedly at the load level corresponding to cracking of the brick veneer. Figure 2 also illustrates how the top of the brick veneer moves laterally due to the absence of a positive lateral support. Figure 1, Detail A, illustrates that the top of the brick veneer is supported elastically by a neoprene pad, friction fit between the top of the brick veneer and the bottom of the shelf angle above. The magnitude of the top end deflection increased in

proportion to the load up to a value of approximately 2.5 mm before cracking. After cracking, no appreciable top deflection was observed with increased loading.

### Results of Water Permeance Tests

The results of the water permeance tests are summarized in Table 1. Some practical problems were encountered while conducting the water permeance tests. The tooled joints made it difficult to obtain a water-tight joint around the periphery of the water permeance chamber. Once a leak started, it was difficult to stop because the silicone caulking will not adhere to wet surfaces. It was also difficult to quantify the amount of water lost from the leaks, since a portion of it spilled on the ground and was lost and the rest collected at the flashing. This meant that water collected at the flashing was more than the amount of water that flowed through the wall in some cases. For example, on Wall No. 2, the amount of water collected at the flashing on the second day of water permeance testing, was much higher than the other two days of tests, because there were leaks that were difficult to stop. In view of these difficulties, the water permeance test results for those specimens in which leaks in the seals were observed are to be regarded with caution.



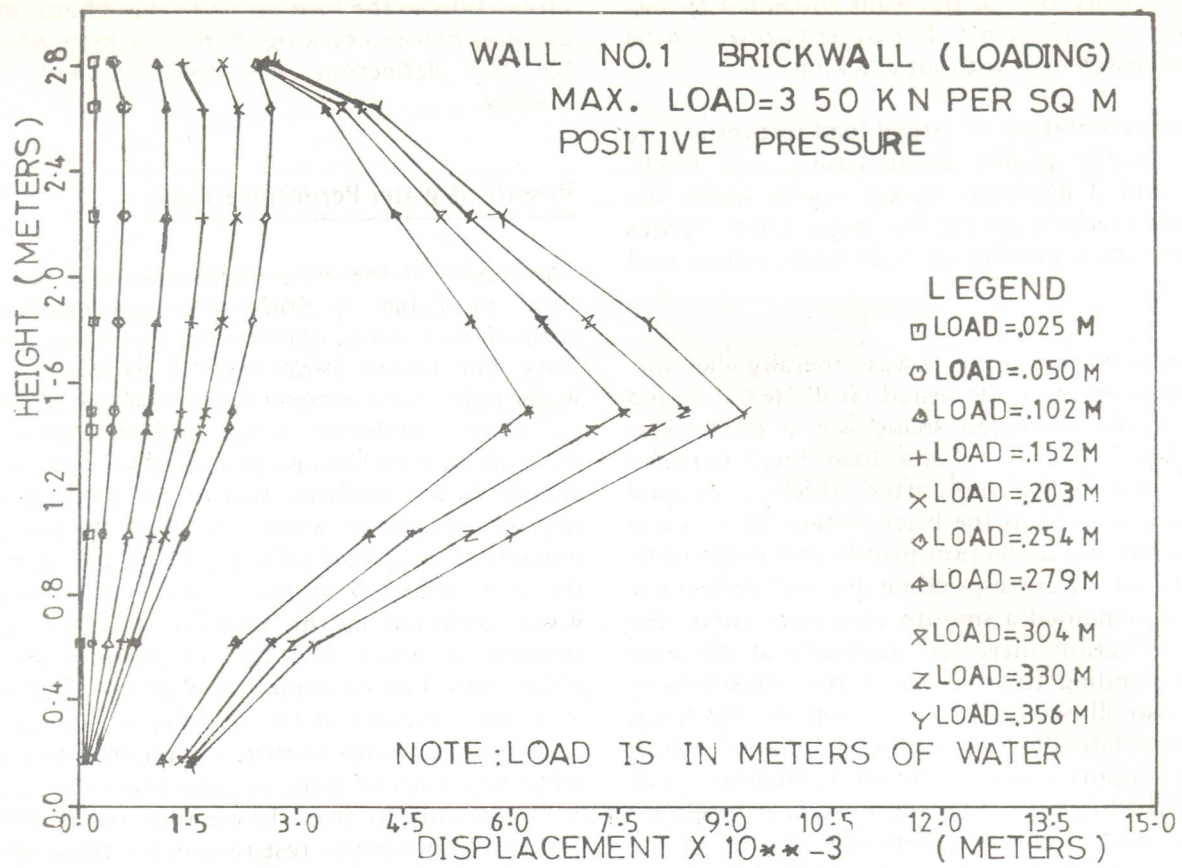


Fig.2 Brick Wall Displacement Profile to 3 Times Design Load for Wall No.. 1 .

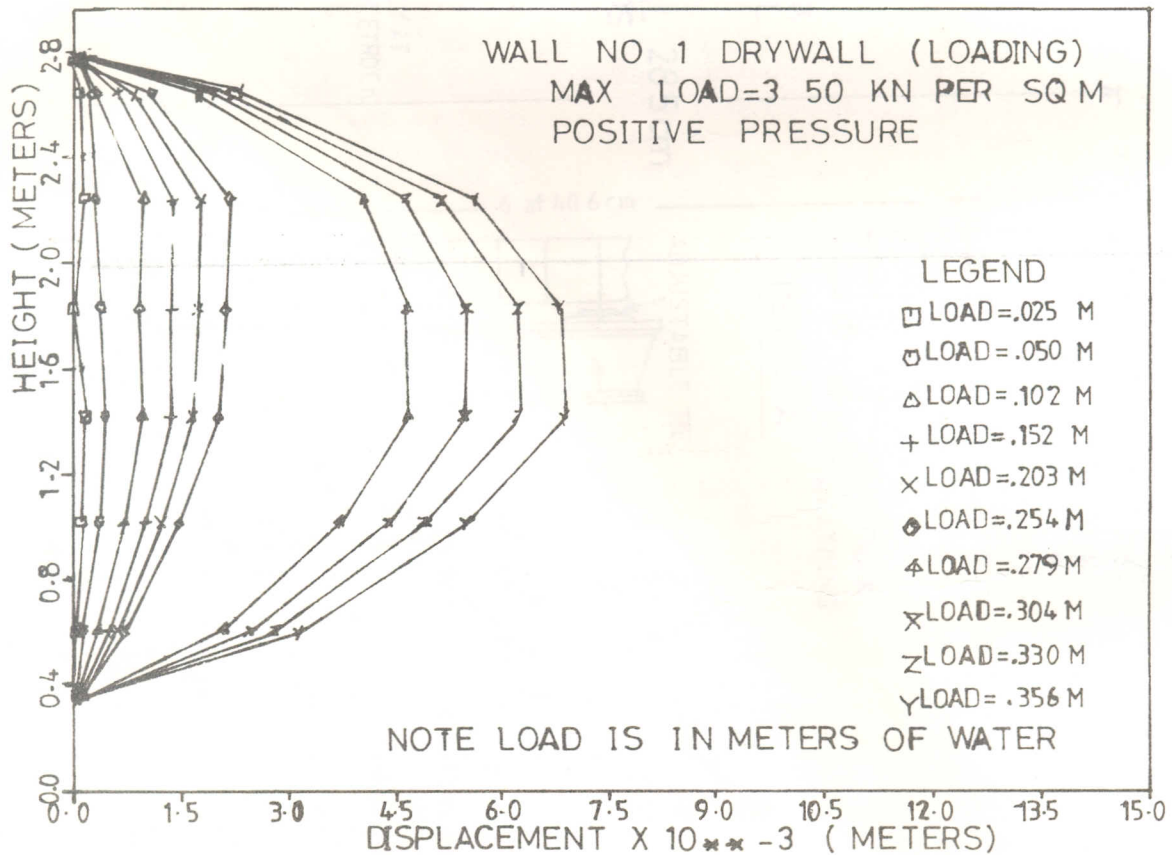


Fig.3 Drywall Displacement Profile to 3 Times Design Load for Wall No.1.

**TABLE 1**  
**WATER PERMEANCE TEST RESULTS**

Wall N.	Loss of Water – System (liters)			Water Collected on Flashing (liters)		
	1 day	2 day	3 days	1 day	2nd day	3 day
1.	1.3	1.6	2.0	0	0	0
2.	2.3	3.9 <sup>a</sup>	1.9	0.28	0.57	0.03
3.	1.0	1.0	0.7	0	0	0
4.	0.5	0.8	0.9	0	0	0
5.	1.8	2.0	3.0 <sup>a</sup>	0.66	0.15	1.23
6.	0.5	0.5	0.5	0	0	0

<sup>a</sup>Leaks occurred during the test

### DEVELOPMENT OF MATHEMATICAL MODEL

A mathematical model was developed using simple beam theory in which the two walls were treated as vertical beams connected by linear springs. Boundary conditions of the beams were chosen to match the conditions of tests as closely as possible. The brick veneer was treated as pinned at the base, and free at the top. The dry wall was considered simply-supported at the base and the top. The modulus of elasticity of the masonry in flexure was measured experimentally from a beam cut from Wall No. 1 and was,  $E_m = 6.125 \text{ kN/mm}^2$ . See Figure 4.

The metal stud dry wall was modeled first as a beam having a moment of inertia equal to that of the stud alone, then, as a transformed beam having a moment of inertia corresponding to the metal stud acting compositely with the gypsum wall boards. Respective values of moment of inertia were  $0.226 \text{ mm}^4$ , and  $.583 \text{ lmm}^4$ .

#### Model Notation

Several terms were defined in the development of the mathematical model:

$A =$  relative flexural stiffness of masonry to axial stiffness of one wall tie.  
 $= \frac{E_m I_m}{KL^3_m}$

where  $E_m =$  modulus of elasticity of masonry (ranges from  $6.125 - 21 \text{ KN/mm}^2$ ).

$I_m =$  moment of inertia of a strip of masonry having a width equal to the horizontal stud spacing,  $35.9 \text{ mm}^4$ , for 88 mm brick thickness and 600 mm stud spacing.

$K =$  axial stiffness of a single wall tie.

$L_m =$  height of brick veneer.

$B =$  relative flexural stiffness of brick veneer to flexural stiffness of backup dryway.

$$= \frac{E_m I_m}{E_s I_s}$$

where  $E_s =$  modulus of elasticity of steel =  $206.5 \text{ KN/mm}^2$ .

$I_s =$  moment of inertia of backup system.

$K_E =$  axial stiffness of elastic support at the top of the brick veneer.

$K/K_E =$  ratio of axial stiffness of interior ties to elastic support at the top of wall.

The mathematical model was capable of modification which permitted the placement of an internal hinge in the brick veneer. The hinge in the model which simulated the crack was located at the point of maximum moment. It is assumed that after a crack forms, the brick veneer will develop a hinge, which cannot transfer moment, at the point of crack. After the brick wall cracked, it was assumed to rotate about the crack as a rigid body.

Figures 5–7 show the results of the model with and without an internal hinge.

### DISCUSSION

Figures 5 and 6 show the deflection plots in the brick veneer and the dry wall steel stud backup, respectively, before and after a crack develops in the brick veneer for  $K/K_E =$  infinity, that is, when the top of the brick wall is free. These agree with the shapes obtained from the lateral wall tests before and after the brick veneer cracked, see Figures 2 and 3.

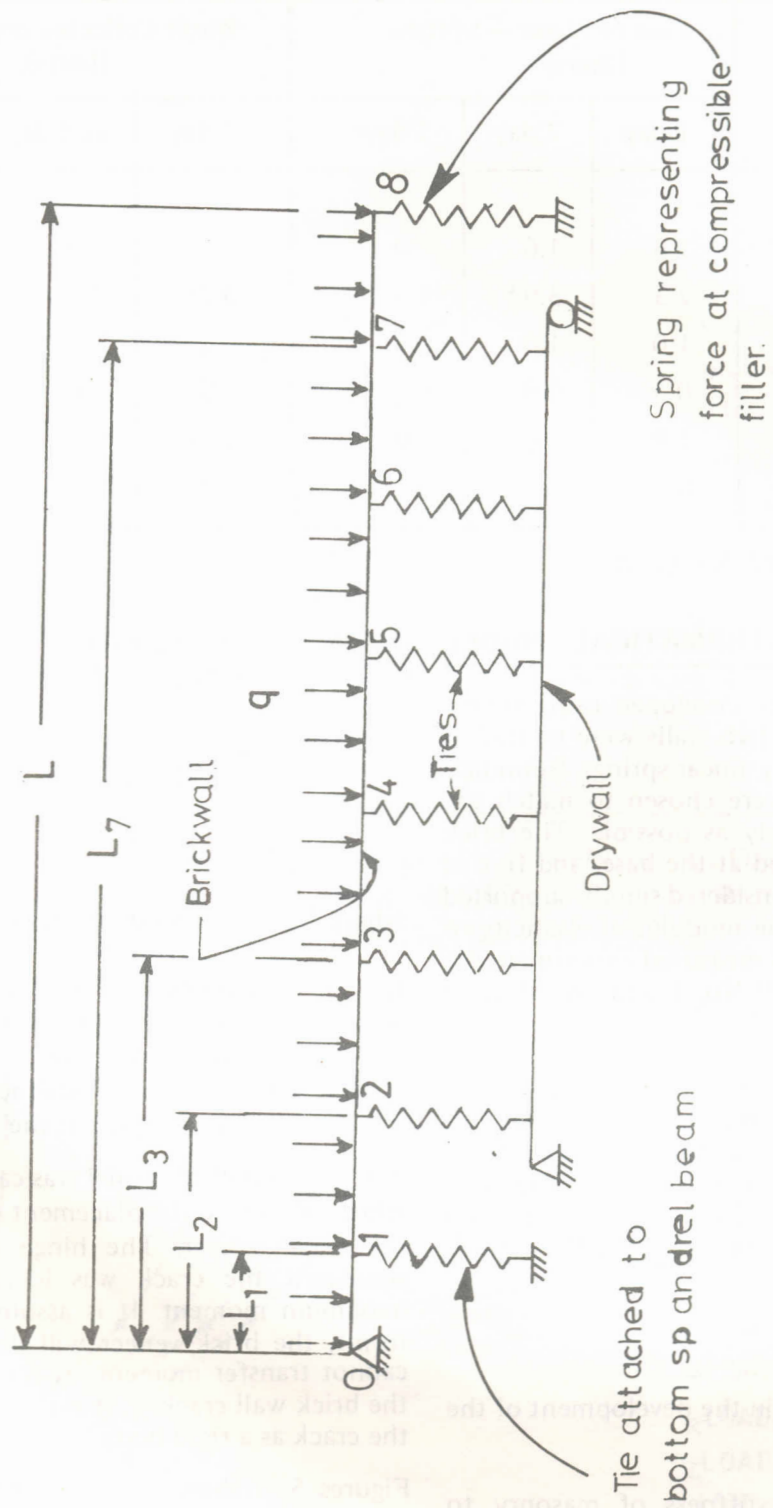


Figure 4 Mathematical Model for Wall System

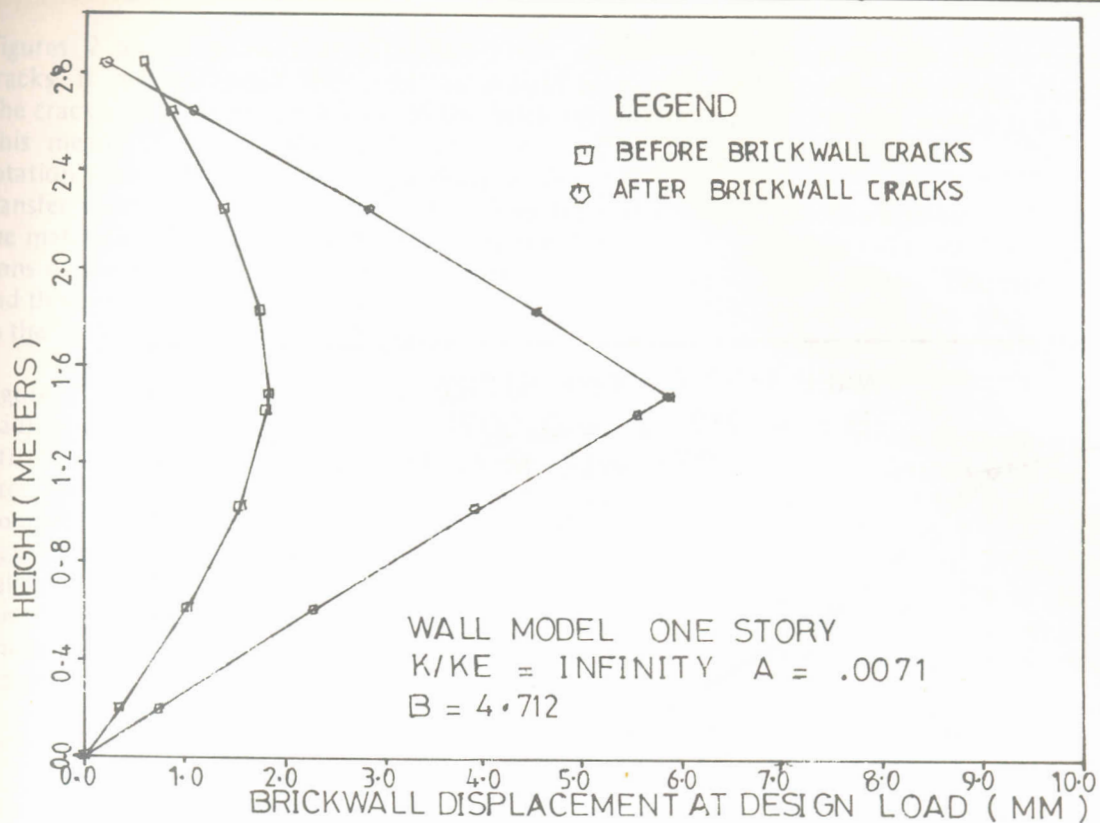


Fig. 5 Computed Displacement Profile of Brick Veneer at Design Load ( $0.17\text{N/mm}^2$ ) Before and After Cracking.

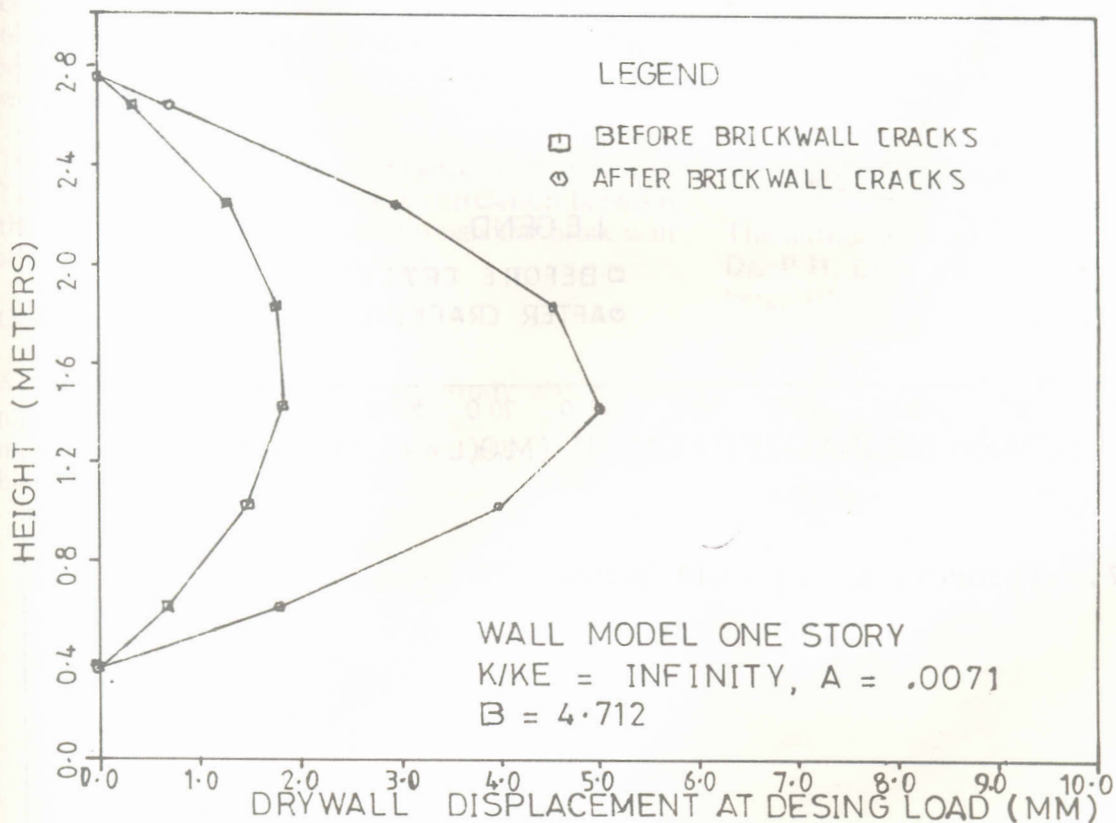


Fig.6 Computed Displacement Profile of Drywall at Design Load ( $0.17\text{N/mm}^2$ ) Before and After Cracking of the Brick Veneer.

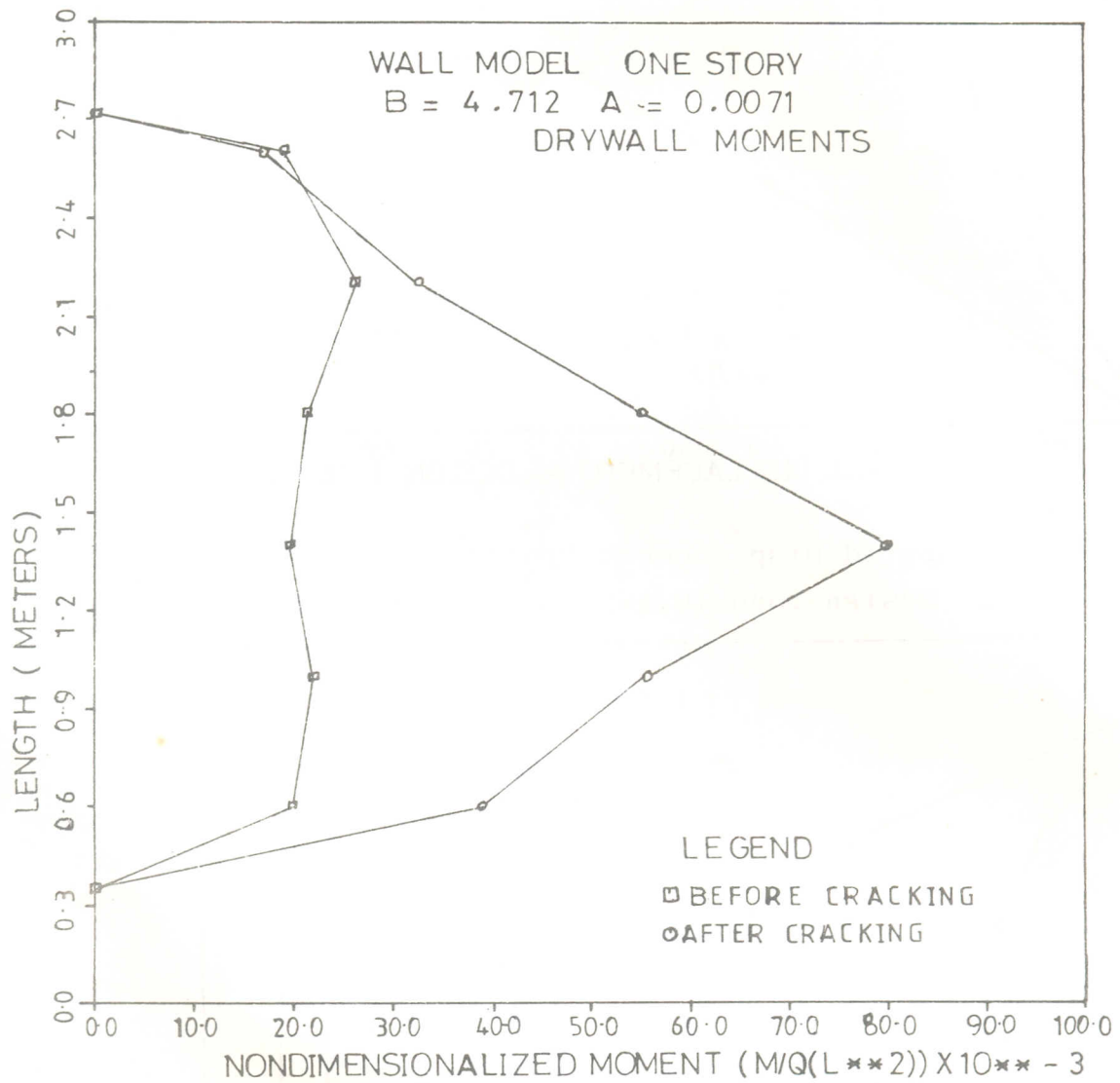


Figure 7. Theoretical Drywall Moment Plots

Figures 2 and 5 show that after the brick veneer cracks, it rotates about the crack as a rigid body. The crack also reduces the stresses in the brick veneer. This means that after the brick veneer cracks, its rotation about the crack as a rigid body allows it to transfer more load to the steel stud backup through the metal ties. Figures 3 and 6 show that the deflections of the steel stud backup wall increase markedly and this confirms the fact that more load is transferred to the backup wall after a crack develops.

Figure 7 shows the moment variation (at the same load) in the drywall before and after the crack was introduced. The maximum moment in the drywall after the crack was about three times the maximum moment before the crack. This transfer of load suggests that it may become necessary for the backup wall to resist all the applied lateral load under certain conditions. Therefore, the current design practice in which the steel studs are designed to resist the full design load is quite in order.

The only wall that experienced a flexural crack prior to a water permeance test is Wall No. 2. This wall showed more water leakage before loading than it did after the flexural crack occurred. That is, contrary to what was expected, a flexural crack did not cause a substantial increase in leakage. This may not generally be true. In this test, the forces that produced the crack were not present during the water permeance test. The crack was able to close up under the self-weight of the wall, in the absence of other forces that would tend to prevent a re-closing.

The results of the water permeance tests shown in Table 1 do not show any direct correlation between the amount of water passing through the brick wall and the magnitude of applied load.

## CONCLUSION

An experimental and analytical study was performed on brick walls with metal stud backup. A mathematical model was developed which was capable of predicting the inelastic behaviour of the wall

system. Based on the test results and the computer model, the following conclusions were reached concerning the post-cracking behaviour of the wall system.

1. The brick veneer will resist some of the applied lateral load until the stress in the veneer exceeds that which corresponds to the modulus of rupture of the masonry. At this state, a crack will form at the point of maximum moment in the brick veneer.
2. The stresses in the brick veneer will be released and on further loading, the brick veneer will rotate about the crack.
3. More load is transferred to the metal stud backup after the crack in the brick veneer. The load transferred may be as much as three times that transferred before the crack occurs.
4. Although the results of the water permeance tests do not show any direct correlation between the amount of water passing through the brick wall and the magnitude of applied load, and whereas the development of crack did not influence much the quantity of water passing through the brick veneer, it is expected that in real walls, cracks in the brick veneer can be avenues through which water can pass through the wall. The water passing through may then subject the metal ties and studs to corrosion.

## ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance of Dr. R.H. Brown, John Ralph Bryan, Kenneth Halseberg, Rhett Whitlock, Tommy Consins and Barry Palm. The cooperation of the staff of the Rural Housing Research Unit is especially appreciated.

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## LATERITIC SOILS AS MASONRY UNITS – PERFORMANCE CHARACTERISTICS

by

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### ABSTRACT

*Lateritic soils being locally available materials have attracted investigations by researchers in the recent times. Lateritic soils have been used as mud walls, mortars, components of structural elements, and masonry units. This paper presents the summary of the results of studies by the authors and others on the utilization of lateritic soils in the building and allied industries. The results show that masonry units from lateritic soils can be satisfactorily used for buildings both in the urban and rural areas. Considerable savings can be made when used without stabilisation with cement but special attention must be provided for weather protection.*

### INTRODUCTION

The building construction industry in Nigeria is at present at cross-roads. There is an acute shortfall in the provision of adequate housing in all parts of the country both in urban and rural areas<sup>10</sup>. The problems besetting the construction industry are numerous but the most important is the unavailability with the resultant increase in the cost of construction materials<sup>7</sup>. Other problems include:

- (1) Massive construction programmes and post-civil war reconstruction principally by the public sector. This made it impossible for local production of inputs such as cement to meet the sudden upshot in demand<sup>8</sup>
- (2) Lack of reliable data on the properties of locally available materials which results in reduction in the utilisation of those materials.
- (3) Improper funding of research efforts on locally available construction materials.

Lateritic soils have been one of the major building materials in Nigeria for a long time. Walls of the large percentage of residential homes in rural areas have been built and continue to be built with "worked" lateritic soils, in different forms with or without cement stabilisation. Their usefulness (as landcrete blocks) has been virtually replaced by sandcrete blocks in modern building technology especially in urban housing. Therefore any means or ways by which properties of lateritic soils could be investigated and the results made available will be beneficial. This will create an awareness in the public about the usefulness of these cheap and locally available materials thereby reducing the cost of construction materials.

This paper is a summary of the results of studies by the authors and others on adoption of lateritic soils as building materials or as component of structural elements and masonry units.

### Definition of Lateritic Soils

Providing a full-proof definition for lateritic soils has not always been easy. Lateritic soils are essentially products of tropical or sub-tropical weathering usually found in areas where natural drainage is impeded. Generally, ratios of silica to sesquioxide represented by  $S_1 O_2 / (Fe_2O_3 + Al_2O_3)$  which are less than 1.33 are indicative of laterites, those between 1.33 and 2.00 of lateritic soils and those greater than 2.00 of non-lateritic types. Because this definition is not convenient from an engineering point of view, particularly where there is a lack of adequate laboratory facilities, Ola<sup>12</sup> has adopted local terminology which regards as lateritic soils all products of tropical weathering with red, reddish brown or dark brown colour, with or without nodules or concretions and generally (but not exclusively) found below hardened ferruginous crusts or hard pan.

### Lateritic Soils as Building Materials

For a very long time, laterite has featured in building construction works in Nigeria. This is evident from the fact that the majority of houses in rural areas in use today were built from lateritic soils (rammed earth). The practice varies depending on the location and related local problems and physical properties of the lateritic soils. In recent times, investigations have been carried out as part of the efforts to determine the usefulness of lateritic soils in building and allied industries and some useful results have been obtained. The rate and ease of mixing of lateritic soils are influenced by: the degree of finess of the specimen, density, particle shape, stickiness, chemical stability, and chemical composition<sup>3,9</sup>. The mineralogical properties of some residual soils have been studied by Ola<sup>11</sup> as they relate to building problems. He found out that all the three criteria of mineralogy, climatic conditions and land use jointly influence the geotechnical behaviour of soils and are each of significant importance. He also found out that stabilization of lateritic soils with cement, lime, bitumen, etc. are the effective means of improving engineering properties of lateritic soils both for road construction and for low cost housing.

## Bunt Bricks From Lateritic Soils

The properties of burnt bricks have been found to be improved by addition of cement. In order to achieve optimal strength conditions, the soil-cement bricks require much less hard firing than plain bricks<sup>2</sup>. Depending on the firing temperature and the quantity of cement used, the addition of cement could result in brick strengths of up to four times those without cement at the same temperature and at least two and half times the maximum strength with plain bricks at any firing temperature. This is shown in Figure 1.

The strength characteristics of mud blocks at ambient temperatures made from lateritic soil and reinforced with pieces of a rope material (i.e. fibre reinforcement), also locally produced and available, was studied by Akinmusuru and Adebayo<sup>1</sup>. An optimum strength condition was achieved with 2.5 percent by weight of fibres and the compressive strength was improved by up to 50 percent over that of unreinforced blocks. However, rope fibre-reinforced blocks would be unsuitable for the manufacture of bricks due to expected disintegration of the rope material under excessive heat.

## Masonry Units

In recent times, the use of masonry units has been getting popular and a lot of research efforts are being directed along this trend but without any form of coordination. For use as masonry unit in building construction, approximately 10% of cement will be needed to stabilize lateritic soils to produce blocks of the same order of compressive strength as for sandcrete blocks. This fact was reported by Lasisi<sup>5</sup>. Ola<sup>12</sup>, has also reported on the successful use of soils around Zaria with a minimum compressive strength of 4.14 MN/m<sup>2</sup> after drying to constant weight. Figure 2 shows the variation of unconfined strength of cement stabilized specimens at different levels of cement content.

## Strength Characteristics of Lateritic Soils as Affected by Grain-Size

The strength characteristics of stabilized and unstabilized lateritic soils are affected by the grain-size range. The following conclusions have been reached by Lasisi and Ogunjide<sup>7</sup> from their studies on the strength characteristics of Ifewara laterites:

- (i) The finer the grains the greater the compressive strength of the specimen tested.
- (ii) At, and below 3:1 laterite/cement mix proportion, cubes made from any particular grain size range would gain strength with age.
- (iii) Cubes made from specific grain size range using 1:1 and 3:1 laterite/cement mix propor-

tion are best capable of being utilized in the building industry but may be expensive.

- (iv) The laterite/cement mix ratio of 1:1 will be satisfactory for damp-proof course. Losses of strength have been shown by the more economical laterite/cement mixes of 5:1 and above. Figures 3 and 4 show the effect of mix proportion, age and grain-size ranges for the stabilized specimens.

Lasisi and Osunade<sup>6</sup> have shown from their studies on unstabilized lateritic soils that improvement in the compressive strength characteristics could be obtained. The cost of separation of lateritic soils to different grain-size ranges may be too much to justify effective utilization. Figure 5 shows the effect of grain-size ranges on unstabilized specimens made from lateritic soils.

## Mechanical Equipment for Unit Production

In the execution of the construction of building walls, no matter how small, the number of blocks required may be large. This calls for the need to standardise the size and make the quality control more effective in a semi-factory production situation. To achieve this objective, the method employed is the use of moulds into which the soil is "rammed" by hand and the units are allowed to cure before being used in building. In preparation for making of the units, sometimes the soil is "worked" by adding water gradually and squeezing with legs or mortar to improve consistency.

As a means of improving the specimens and easing the rigour involved in making these units, manually operated machines have also been employed. A simple machine developed and fabricated by Oloro was tested by Lasisi<sup>13</sup>. The machine is a double-action type that compacts the unit to desired dimensions resulting in highly compacted units with minimum effort. Block units from tiles (15mm thick) to the largest size of 150mm have been produced using this equipment. Figure 6 shows the comparison of the strength characteristics of the products with those from hand moulding.

## Durability

For the overall performance of blocks made of lateritic soils, the weather resistance properties of lateritic soil-units is an important parameter to be investigated. This parameter is investigated by carrying out durability test. Fitzmaurice<sup>4</sup> has recommended a minimum value of about 5 percent loss of weight for minimum durability after 12 cycles of wetting and drying for permanent buildings in urban areas with more than 508mm of annual rainfall. Preliminary studies by Lasisi<sup>5</sup> have shown large losses of particulate material,

especially at low cement contents. Ola<sup>12</sup> has found that at 5% cement content, most soils with small clay content will satisfy the minimum 5 percent weight loss.

Moisture migration and thermal expansion due to variation in temperature of the atmosphere have also been found to be problems. The moisture movement for well compacted units varies from 0.03 to 0.12 percent as compared to a maximum of 0.05% for burnt bricks. Thermal expansion of  $4.0$  and  $6.0 \times 10^{-6}$  m/m/°F have been recorded which is lower than the dimensional changes associated with shrinkage and moisture content, Ramson<sup>14</sup>

To alleviate the associated problems of expansion and weight loss, the followings are the recommended practice:

- (i) Limiting the length of walls built with stabilized walls by the provision of expansion joints.

- (ii) Rendering of walls with soil-cement mortar of a mix of 3:1 soil-cement ratio.

- (iii) When the units are machine produced, the rendering can be omitted.

- (iv) Roofs must always be provided with at least 0.75 metre overhanging eaves to shield the walls from excessive moisture from rainfall.

#### Conclusion

Results presented in this paper are meant to show that research efforts have been directed to the study of the properties and performance characteristics of lateritic soils with a view to recommending it to the building industry as a substitute for sand in sandcrete or as a building material. However, it is evident from the foregoing that a lot remains to be investigated.

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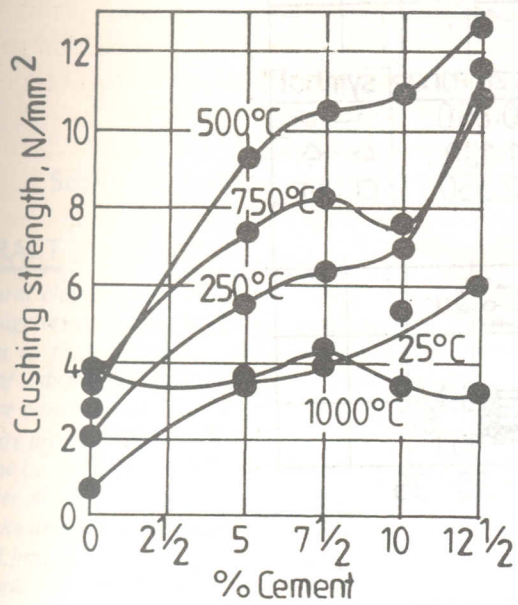


Figure 1: Effect of cement on crushing strength of plan soil-cement bricks.

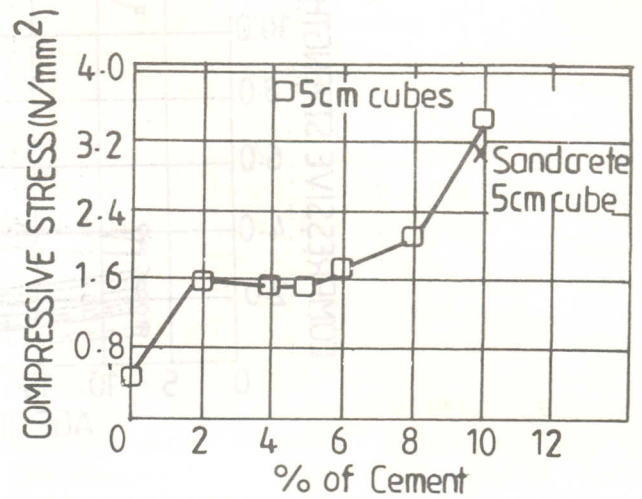


Figure 2: Strength Properties for specimens.

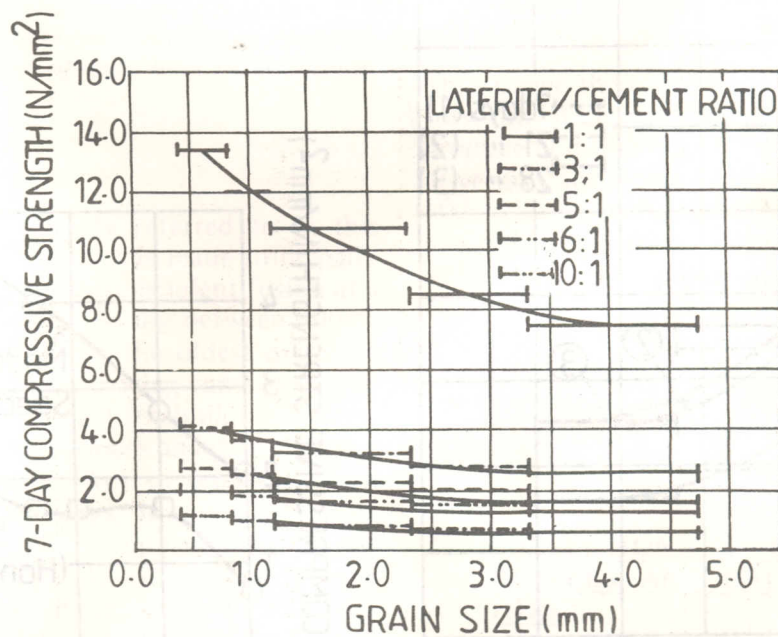


Figure 3: 7-Day compressive strength as a function of grain size ranges.

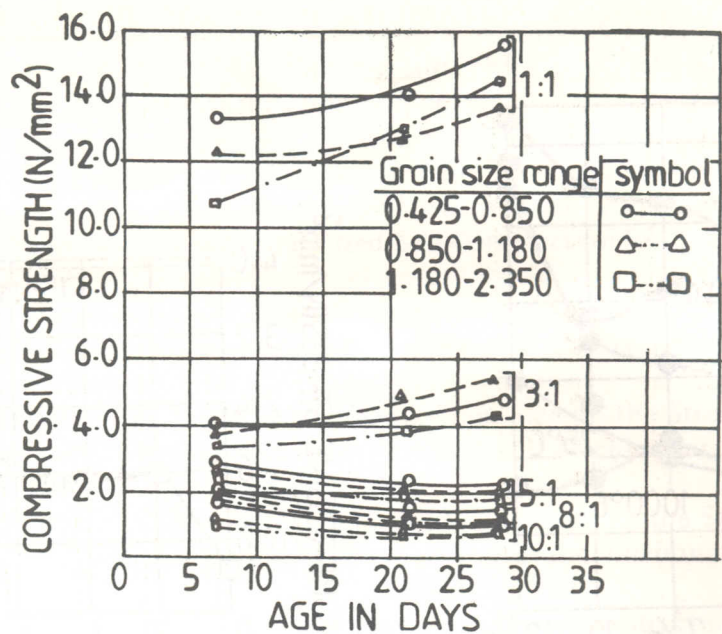


Figure 4: Strength development with age for different laterite/cement ratios

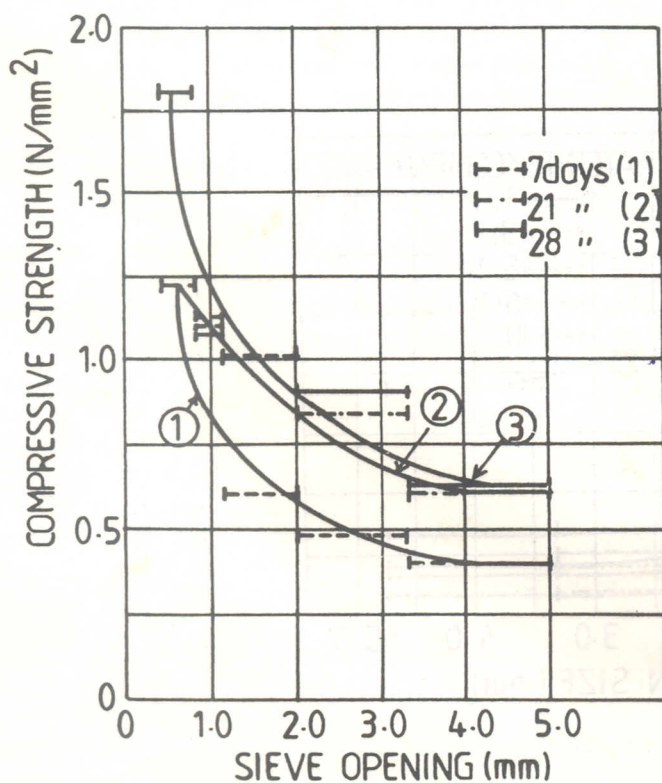


Figure 5:

Grain size effect on specimens (Unstabilized)

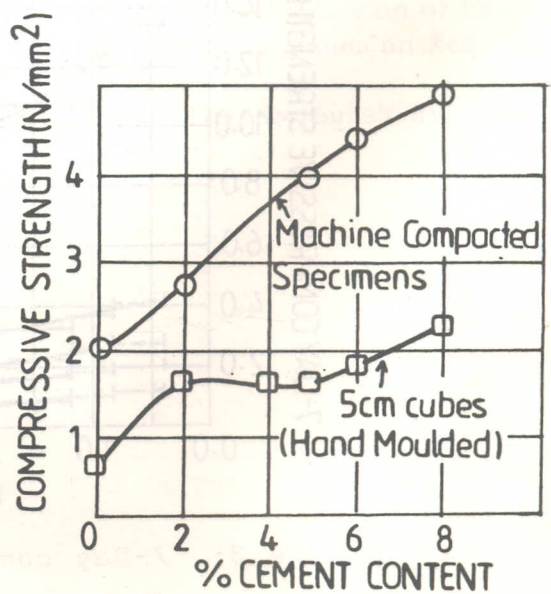


Figure 6:

Strength Characteristics at 4 weeks

## INVESTIGATION OF SUITABILITY OF "MADE-IN-NIGERIA" SOLID BURNT CLAY BRICKS FOR PEDESTRIAN AND LIGHT VEHICULAR TRAFFIC PAVEMENTS

By

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### ABSTRACT

*Solid burnt clay bricks, which are produced by many companies in Nigeria are currently grossly underutilized. This study is an effort to find alternative suitable uses for the bricks. The results of laboratory investigations of the suitability of the bricks for construction of pedestrian and light vehicular traffic pavements are reported in this paper. Tests were conducted to determine compressive and flexural strengths, abrasive resistance, water absorption, efflorescence and amount of warpage and cracks under pressure of bricks manufactured by LACON Nigeria Limited, Ikorodu; Chanchaga Clay Products Limited, Chanchaga; and Nigeria Brick and Clay Products Limited, Jos. A comparison of test results with specifications for paving bricks indicate that both Chanchaga and Jos produced bricks may be suitable for pavement purposes.*

*Results of tests performed on bricks produced in the laboratory show that the level of suitability of burnt clay bricks for construction of pavements can be significantly increased by introducing a compactive effort of between 3 and 5.0N/mm<sup>2</sup>, water of formation slightly less than optimum moisture content of available clay material and burning temperature of between 900 and 950°C. Additional evaluation of suitability of bricks through construction of a test brick pavement is in progress.*

### 1. INTRODUCTION

Solid burnt clay bricks, simply referred to in this paper as burnt bricks are materials made principally from clay and which are fired to incipient fusion at a very high temperature ranging usually between 900°C and 1200°C. They are one of the oldest materials used for building and civil engineering construction in the world. They have been used for building houses, factory floors, sewers, bridge floors and piers, and for paving walkways and driveways in urban areas in many countries. On such ways, the solid standard bricks form the wearing course under which one or more layers of base materials are provided. Such structures built hundreds of years ago in countries like United States of America, Britain, India and Holland still exist today.

Unfortunately, despite the establishment of about twenty brick manufacturing plants in different parts of Nigeria since 1976 and the relatively low cost of locally produced bricks, their application in the building and civil engineering construction industry has not gained much popularity in the country. Many brick plants have either closed down or reduced their level of production considerably due to lack of

sufficient demand for bricks. There is therefore an urgent need to determine the various suitable local applications of bricks in order to ensure the survival of the industry and increase the cost-effectiveness of civil engineering structures in the country. One area in which bricks have been applied successfully in other countries, is the construction of pedestrian walkways, vehicular driveways and related structures in urban areas. At present in Nigeria, many of these ways are either unpaved or inadequately paved in most of the urban areas mainly because of high cost of paving with traditional material and/or lack of equipments and other related reasons. There is no doubt that, if locally produced bricks can be proved suitable for pedestrian and light vehicular traffic pavements, quality of urban transportation will likely increase as brick pavements can be easily and cheaply constructed in many residential and other areas. Also maintenance services and costs will be reduced as brick pavements are known to last for several years with little or no maintenance.

This paper therefore reports the findings of laboratory investigations into the suitability of locally produced burnt bricks for paving pedestrian walkways, driveways and other roads which carry not more than 100 vehicles per day in Nigerian urban areas. The investigation involves laboratory tests and comparison of the test results with applicable standards.

Due to difficulties experienced in obtaining samples from factories, burnt bricks from only three brick manufacturing companies in different parts of Nigeria have been tested. These samples have been supplemented by others made in the laboratory for testing.

### 2. COLLECTION OF BURNT SOLID BRICK SAMPLES AND BACKGROUND INFORMATION

Several solid burnt bricks, raw materials and information on water of formation (water content of mixture), production process and period, burning temperature and other relevant information were obtained through site visits and discussions with officials of three brick manufacturing companies; LACON Nigerian Limited, Ikorodu; Chanchaga Clay Products Limited, Chanchaga near Minna and Nigeria Brick and Clay Products Limited, Jos between 1982 and 1983. The summary of all the information obtained is

shown in Table 1.

Engineering requirements which must be met by bricks for pedestrian and light vehicular traffic pavements were then compiled from ASTM book of standards (1), and specifications and experiences of the Brick Institute of America (2) and National Paving Brick Manufacturers Association of America (4). The summary of the relevant requirements is shown in Table 2.

### 3. LABORATORY INVESTIGATIONS

#### 3.1. (TESTING OF FACTORY-PRODUCED BRICKS)

Compressive and flexural strengths, abrasion resistance, water absorption, warpage, efflorescence and alternating soaking and drying tests were performed on the bricks collected from the three factories. The tests were conducted as specified for paving bricks in ASTM C (5).

A specially adapted apparatus consisting of two 25 mm diameter bearing cylinder rods, two 64 mm diameter bearing cylinder rockers, a 6 mm thick steel bearing plate and a compression testing machine was used for the flexural test and abrasion resistance was measured by the abrasion index given in ASTM (5) as: -

$$\text{Abrasion index} = \frac{100 \times 24\text{-hr absorption}}{\text{compressive strength (psi)}} \quad \text{--(1)}$$

##### 3.1.1. Discussion of Results

Results of the tests performed on the burnt bricks are shown in Tables 3 to 11. The results in Table 3 show that both Chanchaga and Jos made burnt bricks have compressive strengths which are higher than 20.7 N/mm<sup>2</sup> recommended by ASTM as the minimum compressive strength for pedestrian and light traffic paving bricks.

The results of flexural strength tests in Table 4 show that, although there are no ASTM or other specified standard for paving bricks (since flexural strength may only be important when bricks are subjected to severe loading), the flexural strengths of 1.39, 0.53 and 0.41 N/mm<sup>2</sup> for Chanchaga, Jos and Ikorodu bricks respectively seem to be on the low side if they are compared with possible flexural stresses of 1.97, 4.18 and 1.95 N/mm<sup>2</sup> on Chanchaga, Jos and Ikorodu bricks respectively (assuming the standard laboratory conditions of the flexural test prevail on a brick pavement). Such results coupled with warpage values of between 1.2 mm and 4.4 mm shown in Table 5 indicate that the bricks may not be able to withstand high bending stresses. The water absorption results in Table 6 indicate again that only Chanchaga and Jos produced bricks absorb less than 14% water on the average as specified in (4) although Ikorodu

bricks also meet part of the specification as the maximum absorption is less than 17%.

Similarly the abrasion indices of 0.31, 0.40 and 0.56 for Chanchaga, Jos and Ikorodu bricks respectively shown in Table 7 are within the ASTM specified maximum of between 0.11 and 0.50.

Results shown in Table 8 indicate that all the bricks have highly durable resistance to compressive stresses with just average durability of resistance to abrasion. Finally, the results of the alternating soaking and drying and effervescence in Tables 9 and 10 show that all the bricks are not affected structurally or in appearance by full or partial soaking in water.

#### 3.2. TESTING OF LABORATORY PRODUCED BURNT BRICKS.

In order to identify ways of improving pavement related qualities of burnt bricks produced in the factories, series of tests were conducted on raw materials and bricks produced with different characteristics in the laboratory. The tests were conducted in preliminary and detailed stages as follows,

##### 3.2.1. Preliminary Tests

The purpose of preliminary tests was to identify the most important factors that affect properties of burnt bricks. Initially, samples of raw materials collected from each of the brick manufacturing companies, were subjected to Atterberg and wet sieve analysis tests in the laboratory. From the results of these tests, summarized in Table 12, particle size distribution of material (proportion of sand and clay) was identified as one of the major factors. To identify other factors, samples of clay and sand were collected from around Ilorin and mixed in different proportions to form five different mixes as shown in Table 13. Each of the mixes was then used at different moisture contents (water of formation) to mould bricks by the stiff mud extrusion method, similar to what is practiced in the factories.\* The bricks were later burnt in an oven at different temperatures ranging from 950 to 1050°C. Flexure, abrasion resistance, absorption and efflorescence tests as described earlier were performed. From the results, summarized in Table 14, burning temperature, water of formation, density and other major factors that affect the pavement-related qualities of burnt bricks were identified.

##### 3.2.2. Detailed Tests

After identifying major factors that affect brick properties, efforts were made in this stage to determine the combination of these factors, which will result in brick with the best results. For this purpose, 15 sets of bricks, each set of different material mixes, water of formation and/or compactive effort were prepared

\* - The method involves pouring clay and sand mixed in their required proportion with water and allowed to form a homogeneous material into 225mm x 112mm x 77mm wooden moulds and extruded before drying and burning in the oven.

as shown in Table 15. The compactive effort was introduced by a dry pressed method, in order to increase the density and reduce the water of formation of the bricks. Bricks prepared from each of these mixes were then burnt at a temperature of between 900°C and 1050°C and thereafter tested for their pavement related qualities as described earlier for factory-produced bricks.

### 3.2.3 Discussion of Results

Results of the tests conducted are summarized in Tables 16 and 17. Results in Table 16 show clearly that bricks produced in the laboratory through the mud extrusion process are below standards. This is because of the relatively low densities obtainable by this process. It is however significant to note that the results show that the best temperature for burning bricks for pavements is between 900°C and 950°C because bricks burnt at these temperatures were consistently superior to the bricks burnt at higher temperatures.

Results in Table 17 show that the dry-pressed extrusion process produces high quality bricks. The quality of the bricks is much higher than the quality of bricks produced by the mud extrusion process mainly because of relatively higher densities together with lower water of formation of the dry-pressed extrusion mixes. Further examination of the results show that the quality of the dry-pressed bricks depend mainly upon material characteristics (proportion of clay and sand in mix), water of formation and compactive effort. The effect of burning temperature was eliminated by burning all the bricks at 900°C. Results for types B and C show that addition of 17.5% sand caused a reduction in strength, increase in absorption and reduction in abrasion resistance in type B compared to type C which had no sand. This is probably because the sand in type B did not allow compaction to be as effective in increasing density as in type C. Also, the results for the pairs of types B and G and D and I show that a reduction of water of formation from 15% to 13% per unit caused an improvement in the pavement-related qualities of the bricks. The increase seems to be due to the fact that at 15% water of formation, which is greater than the optimum moisture content of 13% for the constituent clay, water had actually replaced a portion of the soil solids thereby reducing the strength and quality of other proportions. It can also be seen from results for types B, D and E that at water of formation of 15 per cent for a mix containing 82.5 per cent clay and 17.5 per cent sand, an increase of compactive effort from 1.0 to 2.5 N/mm<sup>2</sup> caused an improvement while an increase from 2.5 to 6.2 N/mm<sup>2</sup> compactive effort caused a reduction in quality of the bricks. This is probably because the compactive effort of 6.2 N/mm<sup>2</sup> was higher than the optimum compactive effort for the soil and as such caused some deformation of the soil grains with a subsequent reduction in strength and other qualities. Results for types I to L indicate that the optimum compactive effort for the

constituent clay is between 3.3 and 5.0 N/mm<sup>2</sup>.

It is further shown that with the clay available (liquid limit 53, plastic limit 25, optimum moisture content of 13.2 per cent), bricks with the best pavement-related properties are obtained with a mix of 100 per cent clay, water of formation between 12 and 13 per cent and a compactive effort of between 3.3 and 5.0 N/mm<sup>2</sup>.

Finally, the results clearly show that the quality of brick types H to L is higher than the quality of all factory-produced bricks tested. This is expected since the maximum density and minimum water of formation for factory-produced bricks are 1930 kg/m<sup>3</sup> and 20 per cent respectively compared with 2322 kg/m<sup>3</sup> and 12 per cent for maximum density and minimum water of formation respectively for dry-pressed-extruded bricks produced in the laboratory.

## 4. CONCLUSIONS

Based on the results of tests carried out, it can be concluded that majority of locally produced burnt bricks meet the major requirements and may be suitable for paving pedestrian and light vehicular traffic pavements. The most suitable for construction of pavements seems to be burnt bricks produced in Chanchaga followed by Jos produced bricks. The bricks are strong in compression (in most cases stronger than concrete with 28 day strength of 20.7 N/mm<sup>2</sup>), and are resistance to water and abrasive forces. Their only major weakness is their relatively low flexural strengths. The degree of suitability of the factory produced bricks seem to be dependent mainly on the particle size distribution of the brick raw material. Burnt bricks produced in Ikorodu seem the least suitable mainly because it contained the highest proportion of fine-grained material with very little percentage of sand.

It has however been shown that the effect of the use of sand in the material mix can be eliminated and the overall pavement-construction qualities of the burnt bricks can be significantly improved by using a dry-pressed extrusion instead of stiff mud extrusion method used in the factories. Also, bricks with very good qualities for pavement construction will also result by using a water of formation slightly less than optimum water content of the available clay material and a compactive effort not more than 5.0 N/mm<sup>2</sup>.

Finally, although the test results indicate suitability of locally-made bricks for pavement construction, a test brick pavement is being built and evaluated at the University of Ilorin. It is believed that the construction and evaluation of a test brick pavement will provide clues as to the effects of environmental, traffic repetition, user behaviour, type of base and joint materials and other important elements on the performance of brick road pavements.

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**TABLE 1: SUMMARY OF BACKGROUND INFORMATION ON FACTORY-  
PRODUCED SOLID BRICKS**

	Type of Raw Material	Dimensions of Brick			Brick Production Process
		Length (mm)	Breadth (mm)	Depth (mm)	
LACON, Ikorodu	Mostly Clay	180	254	75	Stiff Mud Process, Bricks deaired, extruded dried and burnt. Water of formation about 20%. Maximum Burning temperature between 950°C and 1010°C
Chanchaga Clay Products	A fairly even mixture of clay and sand	180	254	75	
Nigeria Brick and Clay Products Limited Jos	Clay with some sand	170	240	64	

**TABLE 2: ENGINEERING REQUIREMENTS OF BRICKS FOR PAVING  
PEDESTRIAN AND LIGHT TRAFFIC (MAXIMUM = 100 VEH/DAY) ROADS**

PERFORMANCE PARAMETER	ASTM SPECIFICATIONS	OTHER SPECIFICATION**
COMPRESSIVE STRENGTH (MINIMUM)	17.2 N/mm <sup>2</sup> for individual brick 20.7 N/mm <sup>2</sup> for average of 5 bricks	31.1 N/mm <sup>2</sup>
FLEXURAL STRENGTH	NONE*	0.78
SATURATION COEFFICIENT (MAXIMUM)	NO LIMIT	0.78
COLD WATER ABSORPTION (MAXIMUM, %)	17 for individual brick 14 for average of 5 ricks	8
ABRASION INDEX (MAXIMUM)	0.11 – 0.50	
WARPAGE (MAXIMUM)	1.6 mm	
EFFLORESCENCE (MAXIMUM)	Slightly Effloresced	
VISUAL APPEARANCE	Free of Cracks	

\* TYPICAL VALUES RANGE BETWEEN 4 AND 5.5 N/mm<sup>2</sup>

\*\* –BRICK INSTITUTE OF AMERICA

**TABLE 3: COMPRESSIVE STRENGTH OF FACTORY-MADE BRICKS**

SOURCE OF SPECIMEN	SPECIMEN NUMBER	AREA (mm <sup>2</sup> )	CRUSHING LOAD (kN)	COMPRESSIVE STRENGTH (N/mm <sup>2</sup> )
Ikorodu:	1	14450	300	20.8
	2	13924	270	19.4
	3	15381	240	15.6
	4	14514	260	17.9
	5	14760	300	20.3
	AVERAGE	—	—	18.8
Chanchaga:	1	15424	386	25.0
	2	14340	390	27.2
	3	14040	302	21.5
	4	15000	416	27.7
	5	14340	386	26.9
	AVERAGE	—	—	25.7
Jos:	1	12141	272	22.4
	2	14260	354	24.8
	3	12938	252	19.5
	4	14094	246	17.5
	5	11860	240	20.2
	AVERAGE	—	—	20.9

TABLE 4: FLEXURAL STRENGTHS OF FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	FAILURE LOAD (NEWTONS)	DIMENSION OF SPECIMEN			FLEXURAL STRENGTH $R = \frac{3WL}{2bd^2} \text{ N/mm}^2$
			LENGTH (mm)	BREADTH (mm)	DEPTH (mm)	
Ikorodu:	1	2000	180	253	75	0.36
	2	2500	180	254	75	0.47
	3	2000	180	254	74	0.39
	AVERAGE	—	—	—	—	0.41 =====
Chanchaga:	1	8000	180	253	75	1.52
	2	7000	180	254	75	1.32
	3	7000	180	284	75	1.32
	AVERAGE	—	—	—	—	1.39 =====
Jos:	1	1500	170	240	64	0.39
	2	2500	170	239	64	0.65
	3	2000	170	239	63	0.54
	AVERAGE	—	—	—	—	0.53 =====

TABLE 5: WARPAGE OF FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	MAXIMUM CONCAVE WARPAGE (mm)	MAXIMUM CONVEX WARPAGE (mm)
Ikorodu:	1	3.0	4.5
	2	3.0	5.0
	3	2.5	4.0
	4	3.0	4.5
	5	3.0	4.0
	AVERAGE	3.0 ===	4.4 ===
Chanchaga:	1	2.0	3.0
	2	2.0	2.5
	3	1.5	2.5
	4	2.5	3.0
	5	2.0	3.0
	AVERAGE	2.0 ===	2.8 ===
Jos	1	1.5	2.0
	2	0.5	1.5
	3	1.0	2.0
	4	1.0	2.0
	5	2.0	2.5
	AVERAGE	1.2 ===	2.0 ===

**TABLE 6: 24 HOUR COLD WATER ABSORPTION OF FACTORY-  
MADE BRICKS**

SOURCE OF SPECIMEN	SPECIMEN NUMBER	DRY WEIGHT OF SPECIMEN (Wd) (g)	SATURATED WEIGHT AFTER 24 HR SUBMERSION IN COLD WATER (Ws) (g)	SATURATED WEIGHT AFTER 5 HR SUBMERSION IN BOILING WATER (Wb) (g)	ABSORPTION % = 100 (Ws-Wd)	SATURATION COEFFICIENT (Ws-Wd)
					Wd	(Wb-Wd)
Ikorodu	1	1763.5	2041.0	2083.0	15.7	0.86
	2	2184.5	2506.0	2557.5	14.7	0.86
	3	1869.0	2152.0	2195.5	15.1	0.86
	4	1826.0	2094.5	2141.0	14.7	0.85
	5	2018.5	2325.5	2346.0	15.2	0.86
	AVERAGE	—	—	—	15.1 =====	0.86 =====
Chanchaga:	1	2039.5	2284.0	2358.0	12.0	0.77
	2	2348.0	2635.0	2719.0	12.2	0.77
	3	2223.0	2487.0	2572.5	11.9	0.76
	4	2167.5	2423.0	2504.0	11.8	0.76
	5	2264.0	2533.5	2618.0	11.9	0.76
	AVERAGE	—	—	—	12.0 =====	0.76 =====
Jos	1	1837.0	2114.5	2178.0	15.1	0.81
	2	1809.0	1983.5	2069.0	9.7	0.67
	3	1622.0	1807.0	1880.0	11.4	0.72
	4	1636.0	1824.0	1897.0	11.5	0.72
	5	1733.0	1934.0	2012.0	11.6	0.72
	AVERAGE	—	—	—	11.9 =====	0.73 =====

TABLE 7: ABRASION RESISTANCE OF FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	ABSORPTION, %	COMPRESSIVE STRENGTH (N/mm <sup>2</sup> )	COMPRESSIVE STRENGTH (psi)	ABRASION INDEX
Ikorodu:	1	15.7	20.8	3015	0.52
	2	14.7	19.4	2812	0.52
	3	15.1	15.6	2261	0.67
	4	14.1	17.9	2594	0.57
	5	15.2	20.3	2942	0.52
	AVERAGE	—	—	—	0.56 =====
Chanchaga:	1	12.0	30.0	4348	0.28
	2	12.2	28.8	4174	0.29
	3	11.9	23.0	3333	0.36
	4	11.8	25.0	3623	0.33
	5	11.9	27.2	3942	0.30
	AVERAGE	—	—	—	0.31
Jos	1	15.1	22.4	3246	0.47
	2	9.7	24.8	3594	0.27
	3	11.4	19.5	2826	0.40
	4	11.5	17.5	2536	0.45
	5	11.6	20.2	2928	0.40
	AVERAGE	—	—	—	0.40

TABLE 8: EFFECT OF SOAKING ON COMPRESSIVE STRENGTH AND ABRASION  
RESISTANCE OF FACTORY - MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN REFERENCE NUMBER	DRY WEIGHT (g)	1 DAY SATURATED WEIGHT (g)	7 DAYS SATURATED WEIGHT (g)	WATER ABSORBED	ABSORPTION %	CRUSHING LOAD (kN)	AREA (mm <sup>2</sup> )	COMPRESSIVE STRENGTH		ABRASION INDEX
									N/mm <sup>2</sup>	Psi	
Ikorodu	1/1 Day	1736.5	2000.5	—	264	15.2	224	12591	17.7	2567	0.59
	2/1 Day	2147.0	2476.5	—	329.5	15.3	292	15840	18.4	2668	0.57
	3/1 Day	2333.0	2681.0	—	348	14.9	348	16850	20.7	3002	0.50
	AVERAGE	—	—	—	—	15.1	—	—	18.9	2746	0.55
						=====			=====	=====	
Ikorodu	4/7 Days	2122.0	—	2451.0	329.0	15.5	304	15684	19.4	2813	0.55
	5/7 Days	1927.5	—	2233.5	306.0	15.9	260	13801	18.8	2726	0.58
	6/7 Days	1738.0	—	2006.5	268.5	15.4	204	12667	16.1	2335	0.66
	AVERAGE	—	—	—	—	15.6	—	—	18.1	2625	0.60
						=====			=====	=====	
Chanchaga	1/1 Day	2107	2365	—	258	12.2	352	14642	24.0	3480	0.35
	2/1 Day	2072	2317.5	—	245.5	11.8	328	13680	24.0	3480	0.34
	3/1 Day	2350	2627.0	—	277.0	11.8	396	15660	25.3	3669	0.32
	AVERAGE	—	—	—	—	11.9	—	—	24.4	3543	0.34
						=====			=====	=====	
Chanchaga	4/7 Days	2241.5	—	2533	291.5	13.0	372	15545	23.9	3466	0.38
	5/7 Days	2320	—	2623	303.0	13.1	396	15788	25.1	3640	0.36
	6/7 Days	2081	—	2348	267.0	12.8	376	14760	25.5	3698	0.35
	AVERAGE	—	—	—	—	13.0	—	—	24.8	3601	0.36
						=====			=====	=====	
Jos	1/1 Day	1622	1800.5	—	178.5	11.0	348	13737	25.3	3669	0.30
	2/1 Day	1544	1759	—	215	13.9	260	12614	20.6	2987	0.47
	3/1 Day	1756.5	2004	—	247.5	14.1	348	15035	23.1	3350	0.42
	AVERAGE	—	—	—	—	13.0	—	—	23.0	3335	0.40
						=====			=====	=====	
Jos	4/7 Days	1559	—	1737	178	11.4	296	12654	23.4	3393	0.34
	5/7 Days	1722	—	1972.5	250.5	14.5	292	14287	20.4	2958	0.49
	6/7 Days	1422.5	—	1630	207.5	14.6	256	11950	21.4	3103	0.47
	AVERAGE	—	—	—	—	13.5	—	—	21.7	3151	0.43
						=====			=====	=====	

TABLE 9: EFFECT OF ALTERNATING SOAKING AND DRYING ON  
FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	DRY WEIGHT (g)	OVEN-DRIED WEIGHT AFTER 7 DAYS (g)	COMMENTS ON FINAL APPEARANCE
Ikorodu	1	4360	4360	Whitish surfaces developed on all bricks. However, bricks remain structurally sound. No cracks
	2	4217	4216.5	
	3	3993	3992	
Chanchaga	1	4416	4415	No change in appearance, brick remained structurally sound. No cracks.
	2	4403	4403	
	3	4364	4364	
Jos	1	3460	3460	Bricks still sound but minor cracks developed on surfaces
	2	3429	3429	
	3	3268	3268	

TABLE 10: EFFLORESCENCE OF FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	DRY WEIGHT (g)	OVEN-DRIED WEIGHT AFTER 7 DAYS (g)	APPEARANCE AND RATING
Ikorodu	1	4450	4449	Bricks remained fairly sound. Slightly effloresced.
	2	3985	3985	
	3	4370	4369.5	
Chanchaga	1	4422.5	4422.5	Bricks remain very sound. No efflorescence.
	2	4381	4378	
	3	4412	4412.5	
Jos	1	3448	3446	Bricks were still structurally sound but developed Green coloration (mucor) on the surface. Slightly effloresced.
	2	3294	3292	
	3	3289	3289	

TABLE 11: DENSITY OF FACTORY-MADE BRICKS

SOURCE OF SPECIMEN	SPECIMEN NUMBER	DRY WEIGHT (kg)	VOLUME (X10 <sup>-3</sup> m <sup>3</sup> )	DENSITY (kg/m <sup>3</sup> )
Ikorodu	1	4.2315	2.243	1886.6
	2	4.3250	2.311	1871.3
	3	4.4500	2.331	1908.7
	4	3.9725	2.154	1843.9
	5	4.0360	2.154	1873.4
	AVERAGE	—	—	—
Chanchaga	1	4.4170	2.267	1948.4
	2	4.4310	2.307	1920.7
	3	4.4015	2.277	1933.0
	4	4.4000	2.296	1916.4
	5	4.3710	2.277	1927.6
	AVERAGE	—	—	—
Jos	1	3.4480	1.830	1888.8
	2	3.2940	1.700	1940.7
	3	3.2810	1.710	1921.5
	4	3.5820	1.920	1867.8
	5	3.6490	1.910	1910.5
	AVERAGE	—	—	—

TABLE 12: SUMMARY OF RESULTS OF TESTS ON RAW MATERIALS  
COLLECTED FROM BRICK MANUFACTURERS

LABORATORY TEST	RESULTS		
	IKORODU	CHANGHAGA	JOS
LIQUID LIMIT (%)	45.7	45	46.5
PLASTIC LIMIT (%)	24.1	25.0	21.0
PLASTICITY INDEX	21.6	9.0	25.5
PARTICLE SIZE DISTRIBUTION (RELATIVE)	FINEST; (MOSTLY CLAY) WELL-GRADED; GREATER THAN 74% PASSING 75 MICRON SIEVE	COARSEST; WELL GRADED; ONLY 42% PASSING 75 MICRONS SIEVE	NOT VERY COARSE; WELL GRADED; ABOUT 62% PASSING 75 MICRONS SIEVE

TABLE 13: MATERIAL MIXES FOR PRELIMINARY TESTS

MIX NUMBER	% BY WEIGHT OF CLAY MATERIAL	% BY WEIGHT OF SAND PASSING 1.18 mm BUT RETAINED ON 600 MICRONS SIEVE	% BY WEIGHT OF WHITE SAND
1	100	-	-
2	82.5	6.5	11
3	70	-	30
4	70	11.2	18.8
5	57.5	15.8	26.7

**TABLE 14: SUMMARY OF RESULTS OF PRELIMINARY TESTS  
ON LABORATORY-MADE BRICKS**

MIX NUMBER	1		2		3		4	5
Total % of Sand	—		17.5		30.0		30.0	42.5
Liquid Limit of Mix (%)	66.4		62.4		57.8		51.5	44.9
Plastic Limit of Mix (%)	29.6		26.9		25.7		24.3	22.3
Plasticity Index	36.8		35.5		32.1		27.2	22.6
Water of Formation (%)	42.9		36.3		34.7		29.3	26.8
Dry Shrinkage (%)	8.8		8.8		7.0		5.3	5.3
Burning Temperature (°C)	1050	950	1050	950	1050	950	1050	1050
Firing Shrinkage (%)	9.6	8.8	8.8	8.8	9.6	8.8	7.0	6.1
Compressive Strength (N/mm <sup>2</sup> )	1.4	3.7	2.9	5.7	5.5	8.2	3.6	5.3
Absorption (%)	12.1	12.9	11.5	11.6	11.1	11.1	12.0	12.2
Abrasion Index	5.96	2.40	2.73	1.40	1.39	0.93	2.3	1.59
Density (kg/m <sup>3</sup> )	1765	1792	1839	1809	1856	1827	1888	1917

**TABLE 15: CHARACTERISTICS OF BRICKS COMPONENTS  
USED FOR DETAILED TESTS**

IDENTIFICATION OF MIX	% BY WEIGHT OF CLAY PASSING 5mm SIEVE	% BY WEIGHT OF SAND	WATER OF FORMATION (%)	COMPACTIVE EFFORT APPLIED (N/mm <sup>2</sup> )	COMMENTS	
1	75	25	20.4	—	BRICKS MADE BY MUD-EXTRUSION PROCESS	
2	66	34	30.7	—		
3	75	25	25.3	—		
A	75	25	14.0	0.83		
B	82.5	17.5	15.0	1.0		
C	100.0	—	15.0	1.0		
D	82.5	17.5	15.0	2.5		
E	82.5	17.5	15.0	6.2		
F	100.0	—	13.0	0.5		BRICKS MADE BY DRY-PRESSED-EXTRUSION PROCESS
G	100.0	—	13.0	1.0		
H	100.0	—	13.0	1.7		
I	100.0	—	13.0	2.5		
J	100.0	—	10.0	5.0		
K	100.0	—	12.0	3.3		
L	100.00 (3.36mm Sieve)	—	12.0	2.1		

**TABLE 16: SUMMARY OF PROPERTIES OF BRICKS MADE IN THE  
LABORATORY BY MUD EXTRUSION PROCESS**

MIX	1			2			3		
% Clay	75			66			75		
% Sand	25			34			25		
Water of Formation	20.4			30.4			25.3		
Burning Temperature (°C)	900	950	1000	900	950	1000	900	950	1000
Density Kg/m <sup>3</sup>	1777	1772	1770	1864	1848	1846	2280	1886	1760
Shrinkage	4.0	4.7	5.6	8.7	9.0	9.2	5.0	5.5	6.0
Absorption %	12.8	12.6	12.6	11.4	6.1	6.1	16.6	12.3	12.3
Saturation Coefficient	0.71	0.72	0.72	1.73	0.63	0.63	0.75	0.72	0.72
Compressive Strength N/mm <sup>2</sup>	5.2	4.6	4.4	4.9	4.0	3.8	9.2	6.1	3.6
Abrasion Index	1.7	1.9	2.0	1.6	1.1	1.1	1.3	1.4	2.4

TABLE 17: SUMMARY OF PROPERTIES OF BRICKS MADE IN THE LABORATORY  
BY THE DRY-PRESSED EXTRUSION PROCESS

	A	B	C	D	E	F	G	H	I	J	K	L
MIX 1		82.5	100	82.5	82.5	100	100	75	82.5	100	100	100
% Clay	75	17.5	-	17.5	17.5	-	-	25	17.5	-	-	-
% Sand	25											
Water of Formation (%)	14	15	15	15	15	13	13	13	13	10	12	12
Grain Size of Clay Less Than (mm)	5	5	5	5	5	5	5	5	5	5	5	3.36
Compactive Effort (N/mm <sup>2</sup> )	0.83	1.0	1.0	2.5	6.2	0.5	1.0	1.7	2.5	5.0	3.3	2.1
Density (kg/m <sup>3</sup> )	1506	1630	1780	1740	1764	1800	1918	1927	1964	23.22	2322	1953
Linear Shrinkage	2.2	4.2	6.0	6.4	5.6	3.3	4.4	3.5	4.7	4.2	3.5	4.0
Saturation Coefficient	0.81	0.89	0.89	0.89	0.90	0.87	0.76	0.84	0.76	0.72	0.78	0.65
Absorption %	14.5	24.0	20.7	16.3	15.7	14.0	12.7	12.5	9.6	12.84	9.6	11.00
Compressive Strength (N/mm <sup>2</sup> )	13.6	18.1	22.0	27.3	15.5	10.0	16.10	16.9	32.4	31.3	42.5	35.4
Abrasion Index	0.73	0.91	0.65	0.41	0.70	0.97	0.79	0.32	0.20	0.20	0.16	0.21
Flexural Strength									1.51	1.50	1.72	1.52

## CONSTRUCTION OF SOILCRETE PARABOLIC ARCHED STRUCTURE

By

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### ABSTRACT

*The paper appears to confirm that soilcrete hollow blocks may be used not only for walls but as structural materials for construction of some curved structural forms. The example of such a structure is the parabolic arched structure built at the Ahmadu Bello University, Zaria. The construction of such a structure is highlighted in the paper.*

### 1. INTRODUCTION

Early arches were made of a number of wedge-shaped blocks of masonry which were usually set in a jointing material of mortar, although this is not essential to their stability at that time. The behaviour of such a structure has, on account of its antiquity, been the subject of considerable speculation. Such structure when carrying its normal working load is essentially a redundant structure and experiments have shown that elastic theory is rightly applicable for its analysis/1, 2/.

The Civil Engineering Department, Ahmadu Bello University (ABU), Zaria in collaboration with Nigerian Building and Road Research Institute Lagos carried out researches on soilcrete hollow blocks, its production and use in building structures. These were used in constructing the parabolic arch structure which is located between the Civil Engineering Department, Kashim Ibrahim Library and Department of Architecture in ABU. The soilcrete hollow block as produced industrially is of 150mm x 400mm in plan section and 150mm high. It has two rectangular hollows each of 150mm by 94mm in plan. These blocks were produced by Ocidental Construction Company, Zaria.

The assumptions governing analysis, design, method of construction and observations of the behaviours of the structure form the basis for this paper.

### 2. DESIGN OF THE STRUCTURE

The design of the arched structure recognizes the fact that failure may occur due to any of the following/1, 2/

- (a) Development of excessive tensile stress in the jointing material.

- (b) Development of excessive compressive stress in the material.  
 (c) Sliding of one block over another  
 (d) Spreading of the abutments  
 (e) Elastic buckling.

The arch (funicular curve) is of a parabolic shape and has the following dimensions.

Span of arch	=	10000mm
Length of arch	=	10000mm
Arch Rise	=	3,000mm
Thickness of arch = block width = 150mm.		

The walling units are of soilcrete hollow blocks with dimensions 150 x 400 x 150mm. The block has an average weight of 8.88kg with average wet compressive strength of 1.65N/mm<sup>2</sup> after 1 day of soaking /3, 4/. The average dry compressive strength after 7-days of curing by spraying of water and covering with cellophane material is about 3.0N/mm<sup>2</sup> /3,4/. The mortar used for the block laying were of two type of mixes. The first mix (1:2 of cement: sand) was used for the first twenty courses of the parabolic arch on each side while the second mix (1:3 of cement: sand) was used for the rest higher courses up to the crown. Mortar cubes (70.7 x 70.7 x 70.7mm) cast from the same batch of first mix has an average compressive strength of 40.0N/mm<sup>2</sup> after 25-days of ageing. Compressive strength of 16 N/mm<sup>2</sup> was obtained from mortar cubes of the second mix which was used for the upper courses. The age at which the mortar cubes for upper courses were tested was 22-days.

The foundation assumed is that of deep strip foundation on 400mm footing to ensure uniform transfer of loads to the bedrock. The foundation is along the length of the arch and under 50° to the ground level. The dimensions of the foundation are as follows

Depth of foundation	=	1,200mm
Breadth of strip footing	=	700mm
Depth of footing	=	400mm.

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Concrete cubes cast from the same batch of that used for the foundation has the following average compressive strength.

$$\begin{aligned} \text{After 7-days of age} &= 15.0\text{N/mm}^2 \\ \text{After 32-days of age} &= 20.0\text{N/mm}^2 \end{aligned}$$

To ensure good connection between the foundation and the arch, two types of connections were used. The connections were between the upper part of foundation (just above ground level) and the first two courses of the block wall. The right hand side foundation was connected to the wall by means of steel bars of diameter 12mm with total length of 300mm including hooks. The first course of the hollow blocks was filled with concrete while the proceeding second course of hollow blocks was also filled with concrete but alternatively. The left hand side of the foundation was filled exactly the same way with concrete but *no steel bars* were used between the foundation and the block wall.

At the crown, concrete were used and the concrete cube made from the same batch of concrete has an average compressive strength of  $16.5\text{ N/mm}^2$  after 22-days of age. The shape and dimensions of the parabolic arch structure is as shown in Figures 1 and 2.

The total load on the parabolic arch structure is as below:

- (a) Wind or imposed load =  $0.75\text{ kN/m}^2$
  - (b) Roof covering by water proof or plastic Insulation =  $0.25\text{ kN/m}^2$
  - (c) Rendering  $-(2 \times 0.020\text{m} \times 16.0\text{ kN/m}^2) = 0.64\text{ kN/m}^2$
  - (d) Self weight of hollow blocks =  $1.45\text{ kN/m}^2$
- Total =  $3.09\text{ kN/m}^2$

Load transmitted to the strip foundation is as follows.

$$\begin{aligned} \text{Horizontal force} = H &= \frac{qL^2}{8f} = \frac{3.09 (10.10)^2}{8 \times 2.975} \\ &= 13.24\text{ kN/m} \end{aligned}$$

$$H = 13.24\text{ kN/m length of arch.}$$

$$\text{Vertical force} = V = \frac{3.09 \times 10.10}{2} = 15.60\text{ kN/m}$$

Axial thrust along the arch wall = R.

$$\begin{aligned} R &= \sqrt{(13.24)^2 + (15.60)^2} = 20.46\text{ kN/m} \\ R &= \frac{20.46}{20.5\text{ kN/m}} \end{aligned}$$

$$\text{Compression in the parabolic arch structure (soilcrete block)} = 20.5$$

$$\frac{20.5}{0.15 \times 1.0} = 136.2\text{ kN/m}^2$$

$$f(\text{block}) = 0.14\text{ N/mm}^2$$

$$\text{Pressure on the soil (excluding selfweight of foundation)} f_s = \frac{20.5}{0.7 \times 1.0} = 29.23\text{ kN/m}^2$$

$$f_s = 0.03\text{ N/mm}^2$$

The existing stresses are below permissible ones.

### 3. CONSTRUCTION OF PARABOLIC ARCH STRUCTURE

#### (a) Schedule of Work

Before the work started on site, a lot of planning was done to know the extent of the job. The amount of materials needed and the time and cost of construction were carefully detailed prior to the commencement of work. The schedule of work is principally concerned with the time taken to do each aspect of the construction. Fig. 3 shows critical path and the corresponding work progress Bar Chart is as shown in Figure 4.

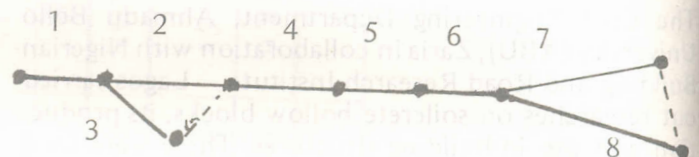


Figure 3: Critical Path for Construction of the Arch Structure.

Weeks	1	2	3	4	5	6	7	8	9
1. Making of formwork (centering)									
2. Foundation Trench									
3. Concreting									
4. Erection of centering									
5. Block laying									
6. Removal of centering									
7. Levelling and clearing									

Figure 4. Work progress Bar Chart for the arch structure

With the above chart, it is apparent that the construction will be finished at the end of the nine weeks. Actually, the removal of centering was done after six weeks of commencing work on site.

### (b) Formwork (Centering)

All the centering were constructed by the Civil Engineering Department Technical staff. To obtain the shape of the parabolic arch, a rope is held at a distance equal to the span of the arch. The rope is allowed to drop on its own weight to a fall equal to the rise of the arch. Measurements were then taken along the fall of the rope and transferred to a flat floor in Civil Engineering laboratory. The points on the curve are then known and the curve is neatly drawn on the flat floor.

Each centering is of three parts. The rib which forms the curve, the struts which act as columns and the base. To get the shape of the rib, templates are spread over the curve and the shape cut out. The parts that form the rib are labelled A, B, C, D and E. Using the cut out templates with the above label, the shapes are cut out of full-board (hardwood measuring 300mm wide by 25mm thick and 3600mm long). The hardwood is of Black Afara. The struts are cut into shape from the fullboard. Each strut consists of two boards measuring 150mm wide by 25mm thick and cut to the required height along the arch curve. The base for each centering consist of two fullboards enclosing the struts. The assembled centering is as shown in Fig. 5.

Altogether seven centerings were constructed.

### (c) Block Laying

The panel of the foundation is just few millimetres above the ground level and the block laying starts from this point. Before laying, the seven centerings were arranged along the length of the arch at a distance of 1.7 metres. The bracing of the centerings were done by shores in the direction perpendicular to the plane of the centering. Each centering is well positioned to ensure verticality before being braced. Special wedges were hammered into position underneath the base of each centering to facilitate removal of centerings after completion of laying and hardening of the structure. The arrangement of the centerings are as shown in Plate I.

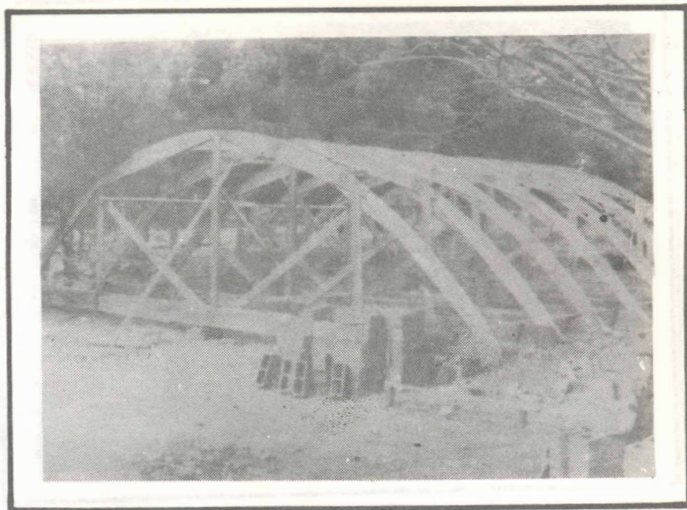


PLATE I — ARRANGEMENT OF CENTERINGS

In laying the soilcrete blocks along the arch curve, two lines are used. One of the line is along the side while the other is on the top of the course. The lines are positioned to ensure that the blocks are in straight line and also follow the curvature very accurately. Another important thing used in the laying of the blocks is called ledger. Ledgers are hardwood of thickness 25mm and breadth 50mm (for this construction). The ledgers are placed on the centering at a distance equal to the height of the block. The aim of the ledgers is to facilitate chalking along the course of the block. The blocks are laid in an edge-way. This is because the ledger placed in an edge-way resist more bending moment than when laid in a flat-way. In laying the blocks, both sides of the arch are being laid simultaneously with two courses on each side every day. It is then left for another one day before laying the same number of courses on each side. This was done to minimise some eccentricities and settlement of centering that could occur. In each course, the blocks are laid before chalking to ensure the course is straight and that it follows the curvature. Plates II and III show the different stages of laying. The laying of blocks was completed three weeks after commencement of construction.

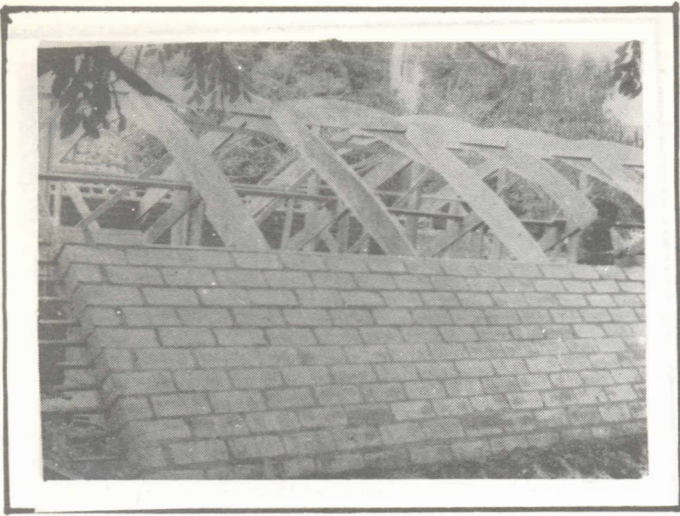


PLATE II: FIRST 8 – COURSES OF LAYING



PLATE III – LAYING CLOSE TO CROWN

#### 4. OBSERVATION

After about twenty five courses of the blocks for the structure have been laid on each side of the arch, it was observed that there was a longitudinal crack between the first and second courses of blocks above the top of the foundation. The crack went through the entire length of the arch and were on both sides. The crack lies on the same position on each side. It was observed that the cracks opened more in the mornings and evenings and closes in the afternoon when it is hot. However no damage was done. Plate IV shows the longitudinal crack.

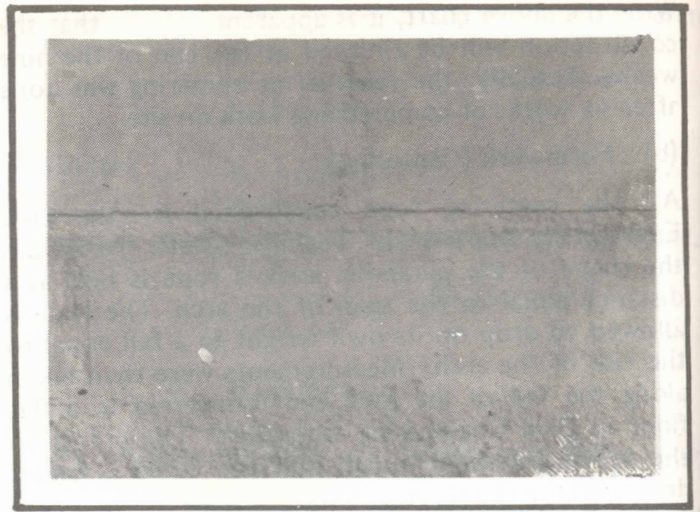


PLATE IV – LONGTITUDINAL CRACK

On removing the centering after block-laying and hardening for 21-days, the cracks closed themselves. These cracks may be caused by shrinkage (high strength cement mortar was used) and probably by some eccentricities in the curvature.

Another observation was vertical hair cracks along the curvature of the arch. This occurred close to half-length of the arch structure. Demec measuring guage points were installed and measured for some weeks but no changes were observed. These cracks also opens more in the mornings and evenings and closes in the afternoon. Plate V shows the vertical hair cracks.

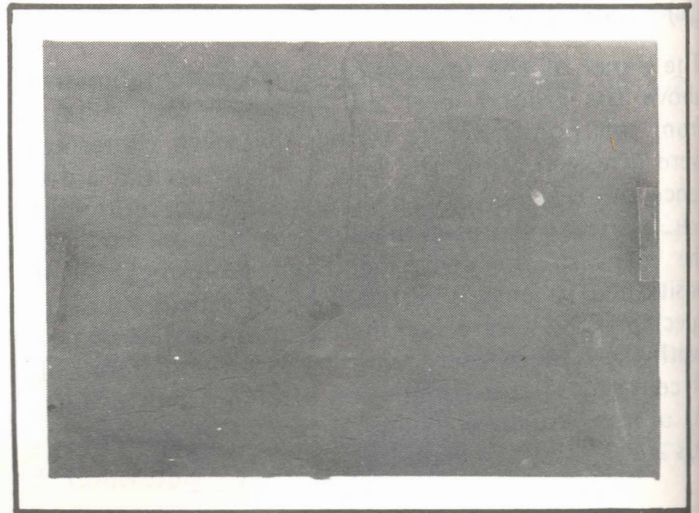


PLATE V – VERTICAL HAIR CRACKS

Cracks also closed themselves after removal of the centering. The crack might probably be caused by differential settlement of the structure.

Plates VI and VII show when the centerings were being removed and when it has been completely removed. All cracks closed when the arch was standing on its own.



PLATE VI – CENTERINGS BEING REMOVED



PLATE VII – ARCH STRUCTURE STANDING ON ITS OWN

## 5. COST OF CONSTRUCTION

For any construction, the cost must be taken seriously to determine the suitability of such structure. The breakdown of the cost is as shown in table 1.

TABLE 1 – COST OF CONSTRUCTION

S/No	Materials	Cost	
		₦	K
1.	Soilcrete blocks	1,031	25
2.	Black Afara (25 x 300 x 3600mm)	1,250	00
3.	Cement	720	00
4.	Sand	120	00
5.	19.05 mm aggregate	495	00
6.	Labour	1,080	00
1	Total	4,696.	25

The actual cost is about four thousand, six hundred and ninety six naira, twenty five kobo (₦4,696.25) which is small when compared to the cost of using reinforced concrete.

## 6. CONCLUSION

From the observation and construction of the arched structure, the following conclusions can be derived:

1. Soilcrete hollow blocks can be used to construct small to medium parabolic arched structures.

2. Soilcrete hollow blocks can withstand all the forces generated as a result of this type of structural shape.
3. It is cheaper when soilcrete hollow blocks are used than reinforced concrete to construct such structures.
4. Soilcrete hollow blocks can withstand all the climatic conditions of Nigeria if well rendered.
5. The inside of the structure is cooler than the inside of any other building around since soilcrete is a bad heat conductor. It is therefore suitable for use in building for the Zaria climate.
6. This type of structure is very useful for warehouses, parking lots, snack-spots and other useful recreational facilities if environmental factors are well taken care of.
7. More research should be done on the use of soilcrete hollow blocks especially in areas of long span arched structures.

## 7. ACKNOWLEDGEMENT

The concept of studying soilcrete hollow blocks for durability using arched structures was initiated by Professor S. Oleszkiewics, former Head of Civil Engineering Department of Ahmadu Bello University. The authors are grateful to him for his pioneering efforts in practical research. This research is being sponsored by the Nigerian Building and Road Research Institute, Lagos.

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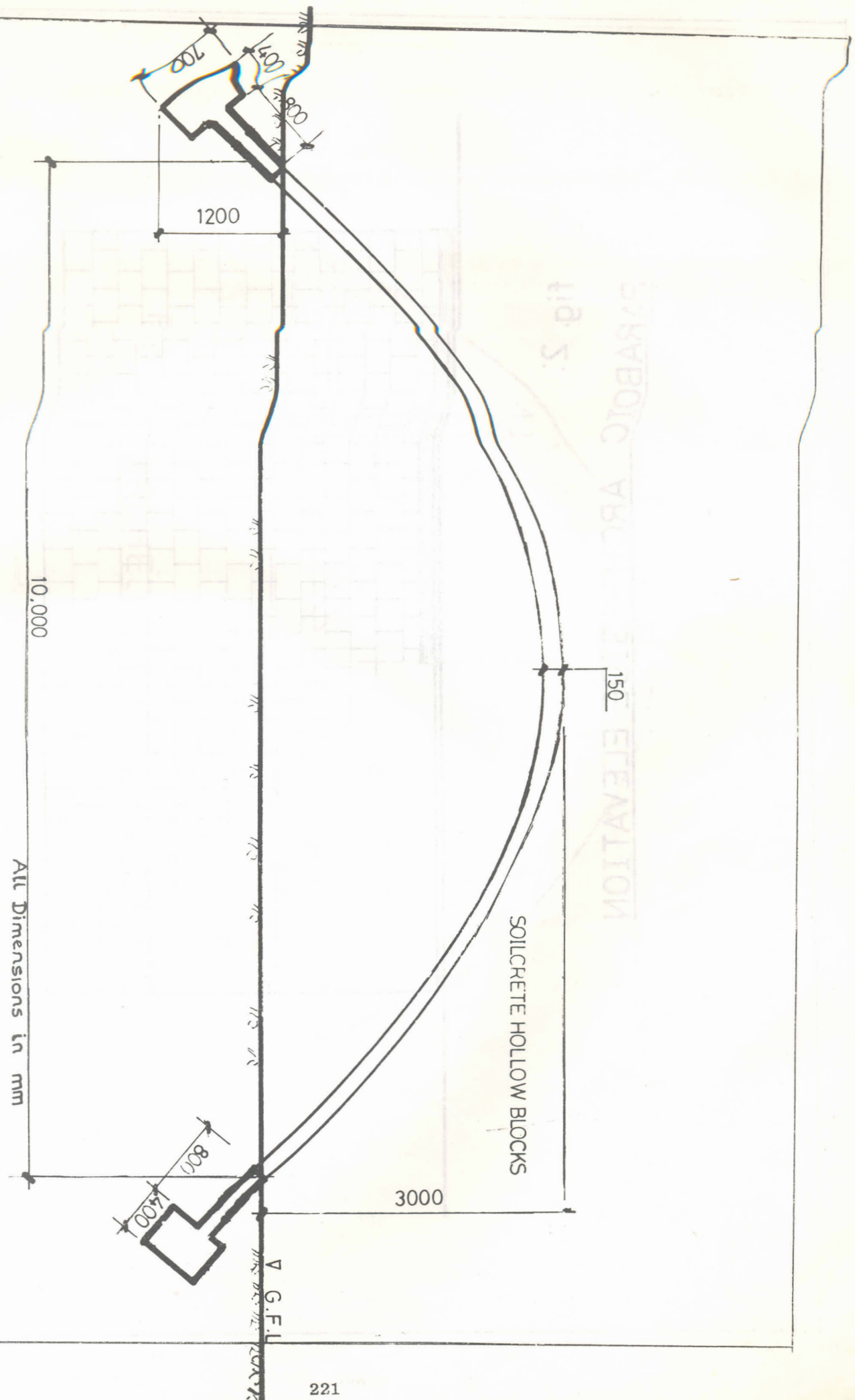


Fig. 1 CROSS SECTION OF STRUCTURE

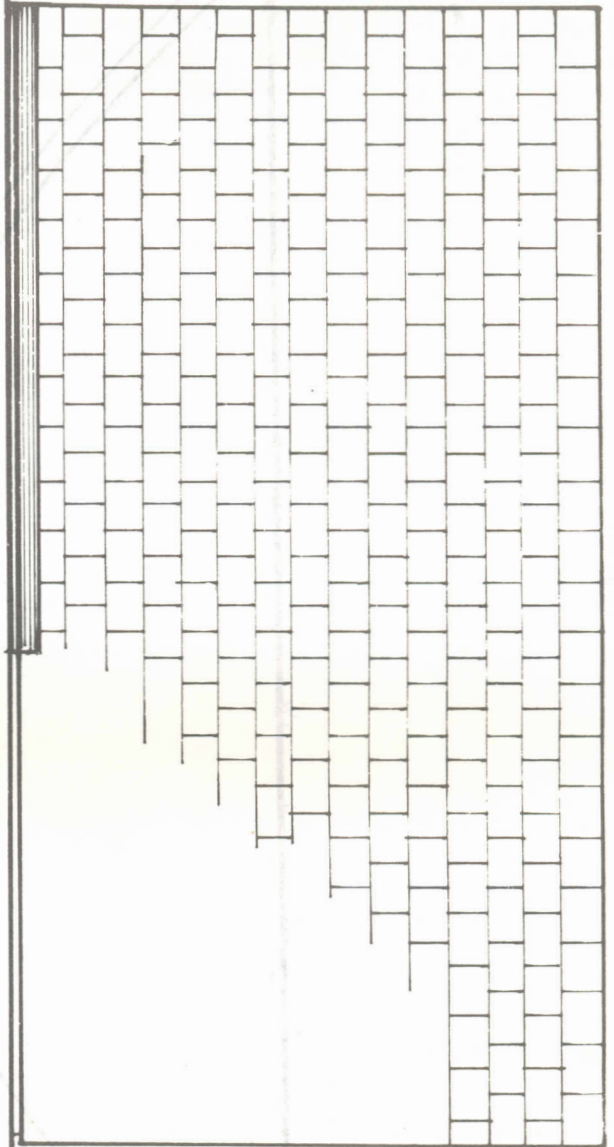


fig. 2:

PARABOLIC ARCH - SIDE ELEVATION



ON S. TABRA

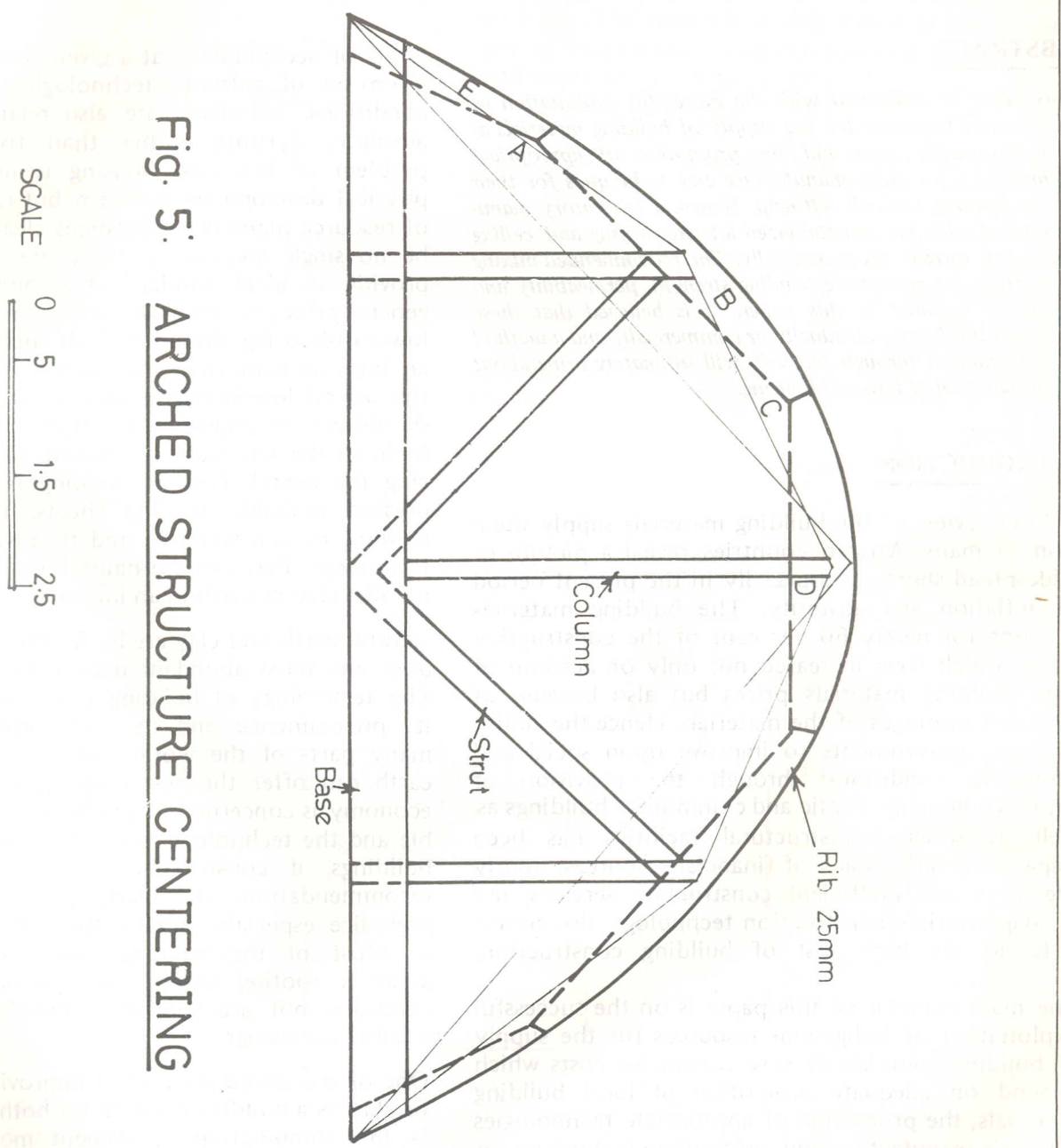


Fig. 5: ARCHED STRUCTURE CENTERING

SCALE 0 0.5 1.5 2.5

## LOW COST INNOVATIONS IN BUILDING MATERIALS WITH RAFFIA/CEMENT STABILIZED LATERITE FOR ROOFING AND CEILING SHEETS.

By

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### ABSTRACT

*This paper is concerned with the successful exploitation of indigeneous resources for the supply of building materials at very reasonable costs and the promotion of appropriate technologies for their manufacture and techniques for their use in housing through self-help. Hence, a laboratory manufacture of raffia/cement stabilized laterite roofing and ceiling sheets was carried out successfully. The recommended mixing proportion for reasonable bending strength, permeability and weight is outlined in this paper. It is believed that these materials produced individually or commercially and a method of construction through self-help will ultimately bring about the production of low-cost housing.*

### INTRODUCTION

A brief review of the building materials supply situation in many African countries reveal a picture of widespread shortages especially in the present period of inflation and austerity. The building materials account for nearly 60 per cent of the construction costs, which have increased not only on account of high building materials prices but also because of frequent shortages of the materials. Hence the ability of many governments to improve upon social and economic conditions through the provision of improved housing, public and community buildings as well as other infrastructural facilities has been impaired greatly. Lack of financial resources, poorly organized and inefficient construction services, use of inappropriate construction technology also contribute to the high cost of building construction.

The main concern of this paper is on the successful exploitation of indigenous resources for the supply of building materials at very reasonable costs which depend on adequate promotion of local building materials; the promotion of appropriate technologies for their manufacture and appropriate techniques for their use in housing and building. It is believed that such materials and method of construction through self-help will ultimately bring about the production of low-cost housing.

There has been a problem of defining a "low-cost housing" and especially the standards to use since these vary widely from country to country by region, in urban and rural areas, by stages of development and urbanization. They also vary with climate and culture. Standards can be defined as measures of

levels of acceptability at a given time and place in a given set of cultural, technological and economic conditions. Standards are also relative rather than absolute, dynamic rather than fixed. Since the problem of low cost housing is not essentially a physical development problem but rather a problem of resource planning, it becomes clear that there can be no single solution as there are no resources to provide an ideal standard of accommodation. As a general principle, the basic minimum standard set for low-cost-housing should be high enough to represent an improvement over the current level of living of the several low-income groups in any country and it should not, of course, be too high to be attainable by them in the relative near future. One way of reducing the overall cost of building is to look at the present available roofing sheets, their costs and method of construction, and to advance a self-help technology that can use natural and abundant material like clay or earth in an improved form.

Natural earth and clay are by far the most commonly used and most abundant natural building materials. The technology of building with earth has retained its pre-eminence and its perfection increasing. In many parts of the world and especially in Africa, earth can offer the best building material as far as economy is concerned. It can be cheap, readily available and the technology is simple to build with. Earth buildings, if constructed by adhering to research recommendations for many years can remove its prejudice especially among the elites to build with it. Most of the buildings with concrete blocks, asbestos roofing sheets, etc. provide good living condition but are generally costly for an average small-house owner.

One of the tested method of improving lateritic clay or clay as a building material for both walls and roof is the combination of cement mortar and raffia fibres. Raffia like sisal fibre increases the strength of concrete and reduces its brittleness in a manner similar to that obtained with fibrillated polypropylene film. Raffia is believed to be superior to polypropylene fibres with regard to strength and also give flexural strength similar to those of short sisal fibres. Raffia fibres when carefully sliced into strips of very tiny diameter and reinforced with cement and clay for roofing sheets are similar to sisal fibre which have been tried and tested widely in many buildings in Kenya and recently in other countries as shown in the Table 1 below.

BUILDINGS	LOCATION
Trial Structures at Kenyetta University College Appropriate Centre.	Nairobi – Kenya
Kenya Asbestos Cement Co.	Mombossa-Kenya
Nasal Rural Training Centre	Sinya–Kenya
Karen Village Technology Unit	Karen–Kenya
Building Research Unit Testing Unit	Tanzania
Intermediate Technology Development Group	U. K.
Community Hall Built by University College Nairobi and Kenya Government for Regional Training	Nairobi–Kenya
Large Silo by F.A.O. Regional Rural Structure Programme.	Kabita Campus of University of Nairobi.

Table 1: Selected Buildings Using Sisal Stabilized Clay Roofing Sheets.

This paper presents the results of an investigation on the characteristics of raffia-cement stabilized clay/laterite roofing and ceiling sheets for low-cost buildings. That technology utilises simple self-help method of production of materials and construction of buildings. The research is also aimed at the production of earth-quake resistant low-cost buildings for both urban and rural areas.

#### PRODUCTION PROCESS FOR ROOFING SHEETS

The earth used for the research is Alawusa laterite from Lagos State. It should be noted that laterites abound in most parts of the country, whereas a truly clay deposit is not very common. The Alawusa laterite as used in the laboratory experiment was crushed and sieved to obtain the clay fraction. The average clay content in Alawusa laterite is 48.4%.

TABLE II: OPTIMAL WORKING MIXES OF CEMENT-STABILISED CLAY SOIL

Alawusa Laterite/Cement Ratio	Optimum Water/Cement Ratio	Compressive Cube Strength in KPa			
		3 Days	7 Days	14 Days	28 Days
1:5	0.225	9,521.7	12,465.0	16,753.3	19,303.0
1:3	0.250	9,582.0	13,486.6	19,693.3	20,516.7
1:1	0.450	8,577.0	13,080.0	15,541.7	17,866.7
3:1	0.750	4,500.0	6,376.7	9,226.7	10,830.0
5:1	1.050	3,380.0	4,903.3	6,943.3	9,591.7
8:1	2.100	3,747.0	4,823.3	5,610.0	8,866.7
10:1	2.300	3,277.0	3,873.3	4,921.7	7,070.0

From Table II, the difference between the compressive strengths after 28 days of the laterite/cement ratio 1:5 (19,303.0 KPa) and 1:3 (20,516.7 KPa) on one hand compared to 1:1 ratio (17,866.7 KPa) is very small. This is the basis for the take-off of the laboratory experiment for the roofing and ceiling sheets.

One metre square sheet made in polythene envelope on a flat plywood board is the first step in the form-

work preparation. Then follows the fixing of moulding strips which form the three sides of a thin flat mould. The fourth moulding strips is a stick over which the polythene forming the moulding is passed and fixed. The proportion of mixture of various materials used for the casting of one roofing sheet is shown in Table III. These represent cement/laterite ratio of 2:1 and 1:1 respectively.

**TABLE III: PROPORTION OF MATERIAL MIXTURE**

	Cement	Laterite/Clay	Raffia Fibres		Water
			Chopped	Non-Chopped	
Type A	9. kg	4.5 kg	250 gr	150 gr	4.5 kg
Type B	7. kg	7 kg	250 gr	150 gr	5 kg

The 400 gramme of raffia is made up of 150 gramme of raffia chopped to 25 mm length and added to the mortar cement – laterite or clay and mortar. The remaining 250 grammes of about one metre long raffia were added during the actual process of manufacture on the form-work.

The casting of the roofing sheet begins by first laying a small amount of enough paste of the mixture on the flat plywood board with the polythene. A layer of half of the raffia fibres of 250 gramme of the one metre long is placed along and across the paste on the flat surface before covering it with another paste. Again another layer of the remaining metre long raffia fibres (125 gramme) is placed along and cross the paste. Finally the second layer of the fibres is covered with the last paste. The diameter (thickness) of the raffia fibre is 0.2 mm. The smaller the diameter of the raffia the better it is for use in the mixture. Soon after the flat sheet is made, it is slipped on to an asbestos sheet and pressed into corrugation with the aids of light plastic drainage pipes. After 24 hours, the sheet is removed from the polythene envelope

and cured in water for at least 3 weeks. A better result is got by longer curing to 4 weeks. Then it is allowed to dry and is ready for use. For the purpose of fixing the roofing sheets to the burlins or to the roof structure, holes are made on the corrugated sheet while it is in the plastic state before it is allowed to be cured properly.

**PRODUCTION PROCEEDURE FOR CEILING SHEETS**

Instead of the one metre square sheet, a 1.2 metre square made in polythene envelope on a flat plywood board is the first step. The board is equally divided into four equal parts to enable the casting of four ceiling sheets at a time. As in the setting up of the mould for the casting of the roofing sheets, the proceeedure is the same in casting the four ceiling sheets at a time on one board.

The following proportions are used for the production of each of the two types of ceiling boards.

**TABLE IV: CEILING SHEETS MIXING PROPORTIONS**

	Cement	Laterite	Raffia Fibres		Water
			Chopped	Non-Chopped	
Type A	5.4 kg	5.4 kg	120 gr	150 gr	Thick Enough for a Paste (4.8 kg)
Type B	10.8 kg	10.8 kg	240 gr	150 gr	(4.8 kg)

Both chopped raffia and non-chopped raffia fibres are used as in the preparation of corrugated roofing sheets. The casting and curing of the ceiling sheets are also carried out in the same manner as the roofing sheets except that the ceiling sheets are not corrugated and are not placed on asbestos for corrugation purposes.

For the purposes of the fixture of the ceiling sheets to a structure, holes are created in the sheets while they are still in plastic stage.

**DISCUSSION OF RESULTS**

Tests for thickness, bending strength and impermeability on sheet materials (flat and corrugated) using BS 4624 were carried out on the roofing and ceiling sheets to get the following results (Table. V).

Material	Weight (Kg)	Thickness	Failure Load	Impermeability
Roofing Sheet				
A	15.5	9.5mm	54.5 kg	Not permeable
B	17.0	10 mm	44.5 kg	Not permeable
Ceiling Sheets				
A	6.0	8 mm	45.3 kg	Not permeable
B	6.5	8.5 mm	47.6 kg	Not permeable

Table V: Results of the tests with two types each of the roofing and ceiling sheets.

Ordinary portland cements was used together with raffia that had been sliced into very tiny diameter of 0.2mm as stabilizing material. The water utilized in the laboratory investigation was the normal tap water for drinking. For the production of both the corrugated roofing and ceiling sheets, there were two types of cement: laterite: raffia ratios in order to compare their weights, thickness, bending strength and permeability as shown in table V.

In general, the maximum bending strength decreases with increasing laterite/cement ratio. This is expected because of the decreasing amount of stabilizing cement in the total mix. Also the weight increased with increase in laterite/cement ratio. The principal observation was that the optimum water/cement ratio increased with increasing laterite/cement ratio and in a rather linear manner. The optimal bending strength for a given laterite/cement mix decreases with increasing optimal water/cement ratio.

## CONCLUSION

With this innovation in building materials, an entire building can be built by self-help labour and the ultimate realization of low-cost and yet decent durable buildings can be built in both our rural and urban areas. In an earlier paper by this author, where explanations were given as to how to make raffia stabilized load bearing walls and "fancy-blocks" or screen walls, most of the debate on what yardstick to use for low-cost buildings has partially if not wholly been solved. The relationship of cost to minimum standard for low cost housing is basic. A typical home may cost as much as ten or fifteen times an ordinary worker's annual income.

Since clay or laterite and raffia occur abundantly in most of our urban and rural towns, and with the amount of cement in use for a building greatly reduced by this new innovation, it is certain that decent buildings through self-help is now possible. It is possible to determine the cost of the basic minimum standards by taking reasonable low income bracket, and multiplying that by the reasonable cost/income ratio.

The investigation shows that laterite/cement/fibre mixes have the potential for use on both load and non-load bearing sheets provided the laterite/cement ratio is not more than 10:1. Earthquake-resistant low-cost housing could be built in relatively short-time.

Project designed and executed on the self-help Architectural and constructional plans should be of four basic criteria aimed at:

- (a) standardizing construction components to minimize the house of such components required.
- (b) simplifying dimensional aspects through the use of a standardized unit of measurement.
- (c) prefabricating light components to be produced, handled and utilized by self-help builders.
- (d) improving design to produce plans orientated towards industrial production but easy to understand for those participating in the project.

On the whole this new innovation's advantages are (1) it reduces cost (2) most of the materials used are available locally. (3) it increases permeance of structures and (4) increases earthquake resistance.

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## SMALL SCALE PRODUCTION OF FIRED AND STABILISED BRICKS FROM KANO SOILS

By

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### ABSTRACT:

*The paper describes a small scale production of soil-cement block and burnt bricks from Kano soils. Details of the manufacturing processes and test results on the bricks are given. The addition of 4% cement to soil produces bricks of adequate strength when moulded under a nominal compactive pressure of  $1 \text{ N/mm}^2$ . Burnt bricks were produced by using the clamp kiln method with firewood as fuel.*

*Field trial experiments were also carried out in co-operation with Kano State Housing Corporation at Kano. Two structures – one with 4% cement stabilized soil bricks and the other burnt bricks were built to obtain data on environmental effects. The post evaluation study indicates a general satisfaction with the structures at the end of one year.*

### INTRODUCTION:

Soil is the most readily available building material known for ages and it occurs abundantly in Nigeria. The origin and occurrence of different types of soils dictate the soil properties. When soils are employed for construction purposes, these properties such as the compressive strength, shrinkage/swelling ratio etc are often improved upon by various methods for better performance. Some of these methods include cement stabilization and firing. Fired bricks were in use in Nigeria in the past. Old buildings in Lagos and other parts of the country testify to this. The advent of cement production resulted in the gradual and eventual replacement of bricks with sandcrete blocks to the extent that cement had to be imported en masse to supplement local production level. In order to ease this dependence on cement, it is necessary to make use of abundant soil. To this end the Federal Government set up seven semi-mechanised brick plants in the country which produce fired bricks of various sizes. This effort is further complemented by the establishment of other brick factories by some state governments and private entrepreneurs. Despite this, the use of fired brick in building construction in Nigeria remain unpopular.

To popularize the use of bricks in building construction, an easy method of moulding and firing on a cottage level needs immediate attention. The Nigerian Building and Road Research Institute has therefore, embarked upon a programme of research to produce fired bricks as well as stabilized bricks from soils found in different parts of Nigeria on small scale level. The present investigation deals with the Kano soil.

### TRADITIONAL METHOD OF BRICK MAKING AROUND KANO:

Sun dried soil blocks of various sizes have been the traditional walling materials in Kano in the past and are still being used in some villages and towns today. These are made around ponds due to water scarcity (Fig. 1). Block making in Kano State is not a well co-ordinated industry and the blocks made are irregular in shape and size, although these are adequately strong. Blocks made in such ways showed a compressive strength of  $0.37-0.5 \text{ N/mm}^2$ .

For its preparation, soil is dug from a place close to water pond and is generously mixed with water for easy workability. Reeds and grasses are mixed at this stage to check shrinkage cracks and improve durability. The mass is then placed into the wooden mould where compaction is achieved by hand. The mould is lifted leaving behind the brick on the ground. The mould is dipped into water and the adhering mud cleaned off before filling the mould with mud for the next block. The blocks are shifted the following day to an open place for sun drying. About 100 blocks per day is made by one person.

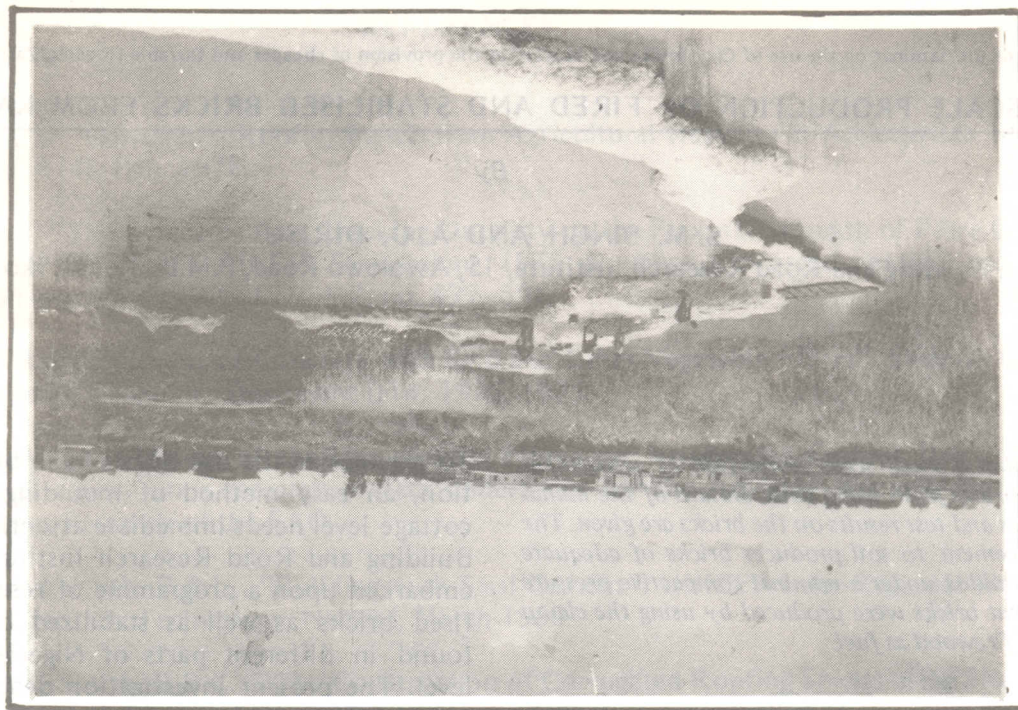


FIG 1 – TRADITIONAL METHOD OF MAKING SOIL BLOCKS

**PHYSICAL AND CHEMICAL PROPERTIES OF SOIL USED:**

Two types of clay samples were used for the laboratory investigation. The grey and the yellowish grey clay were both collected from burrow pits at Bagauda near Kano. The samples were subjected to physical and chemical tests. The Atterberg limits, grain size analysis and other physical test results are shown in Table 2. Clay-silt and sand content (fig. 2) were determined by pipette method (1). The X-ray diffraction analysis were carried out and the diffractograms are shown in figure 3.

The chemical composition of the clays were carried out. Silica content was determined by dissolution method using hydrofluoric acid. Oxides of magnesium and calcium were determined by flame atomic absorption technique after complete dissolution. Sodium and potassium were determined by flame emission photometric method. Total oxides of aluminium and iron were determined using EDTA by back titration technique and correction made for CaO and MgO.

Iron oxide was determined by colorimetric thiocyanate method and  $Al_2O_3$  was obtained by difference (13). The result of the chemical analysis is presented in Table 1.

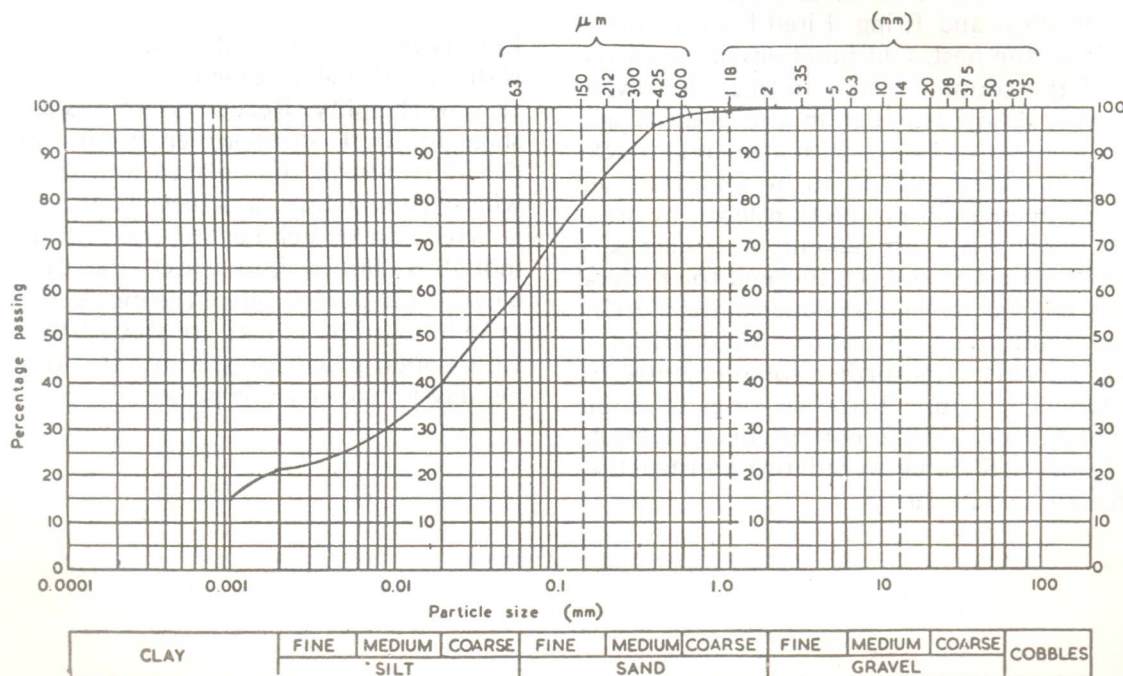


Fig. 2 – Grain size analysis of Kano soil used

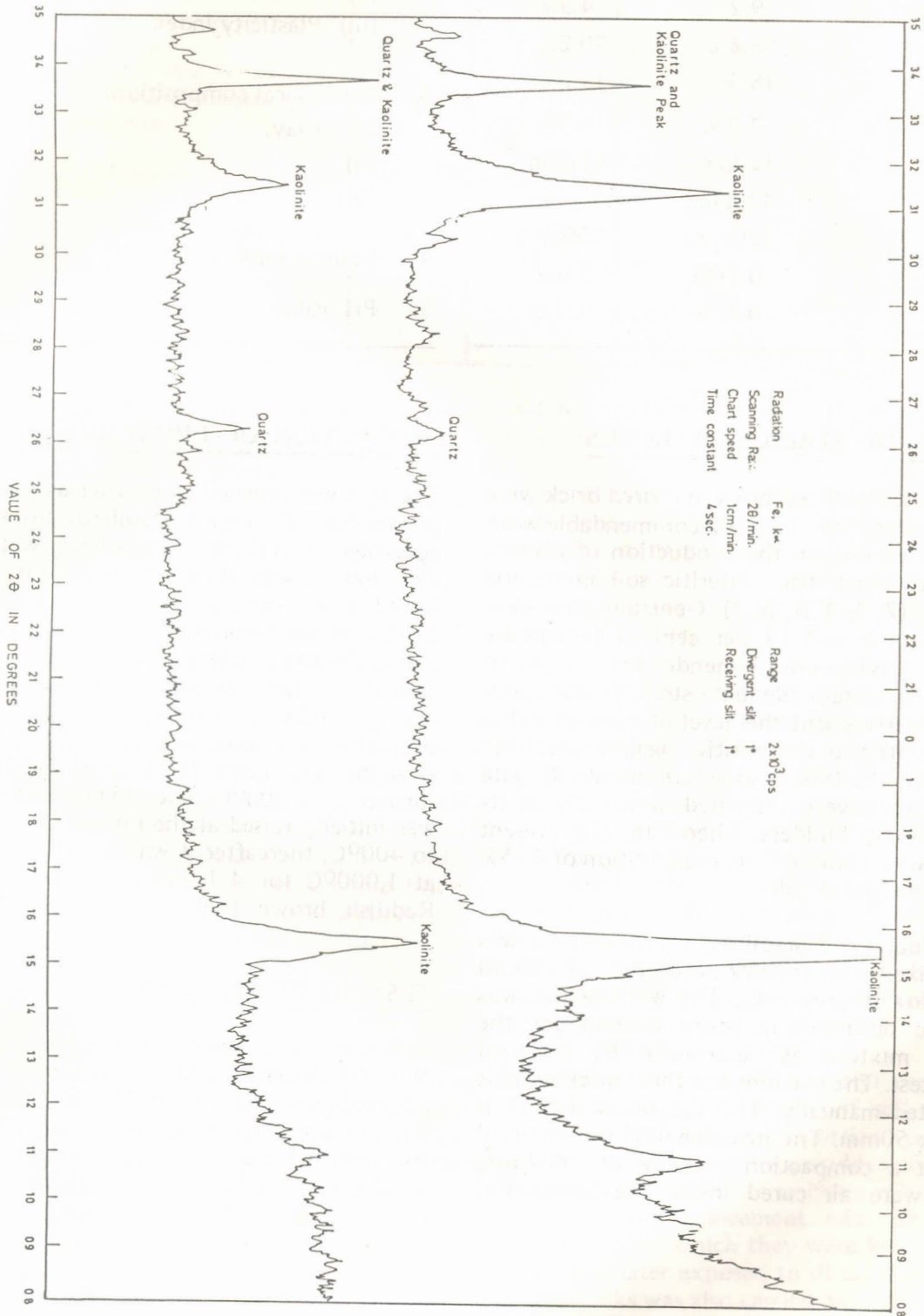


Fig. 3. — X-ray distribution Curve of the Soils

**Table 1: Chemical Analysis of the Soils**

	Greyish Yellow Clay	Grey Clay
1. Loss on ignition	9.2%	4.9%
2. SiO <sub>2</sub>	68.3%	70.2%
3. Fe <sub>2</sub> O <sub>3</sub>	18.3%	15.0%
4. Al <sub>2</sub> O <sub>3</sub>	5.9%	4.7%
5. TiO <sub>2</sub>	12ppm	17ppm
6. CaO	42ppm	46ppm
7. MgO	220ppm	250ppm
8. Na <sub>2</sub> O	0.74%	2.9%
9. K <sub>2</sub> O	0.41%	0.37%

**Table 2: Physical Properties of the Soil**

1. Specific gravity	2.6
2. Atterberg limits	
(i) Liquid limit,	32%
(ii) Plastic limit,	19%
(iii) Plasticity index	13%
3. Mechanical composition:	
(i) Clay,	28%
(ii) Silt	26%
(iii) Sand,	46%
4. Soluble salts	almost nil
5. PH. value	9.1

**PRODUCTION OF STABILIZED BRICKS:**

Portland cement stabilized brick and fired brick were made in the laboratory. In fact a commendable work had been carried out on the production of cement stabilized brick/block from lateritic soil in Nigeria and elsewhere (2, 3, 4, 5, 6, 7). Generally, the addition of between 8 and 12 per cent of cement by weight of soils has been recommended by majority of these workers to obtain adequate strength and water resistance properties. But this level of cement makes the stabilized brick uncompetitive against sandcrete blocks. Further, the lack of long term durability data and field studies have contributed immensely to its unacceptability by builders. Therefore, the present investigation was confined to the addition of 4–5% of cement by weight of soil.

For the production of stabilized bricks, cement was intimately mixed with the dry powdered soil (50:50 grey and yellowish grey soil). The water added was equal to the optimum moisture content for the soil cement mixture as determined by standard compaction test. The machine has three brick moulds and is operated manually. The size of each brick is 230 x 110 x 50mm. The machine has been reported (5) to exert a compaction pressure of 1MN/m<sup>2</sup>. The bricks were air cured inside the laboratory.

**PRODUCTION OF FIRED BRICKS:**

The soil was crushed to powder as was done for the production of cement stabilized bricks. Water was generously sprinkled to completely wet the soil particles and it was then left overnight. The soil was kneaded and used in casting bricks which were left to dry in the laboratory. It was observed that a few bricks showed cracking tendency during drying. Addition of 5% sand by volume of the soil checked the drying cracks. This amount of sand is found to be optimum as it does not adversely reduce the brick strength. The dried bricks were fired in an electric furnace at 1,000°C. The temperature of the furnace was initially raised at the rate of 200°C per hour up to 400°C; thereafter it was raised to and maintained at 1,000°C for 4 hours and then allowed to cool. Reddish brown (red brick) bricks were obtained.

**TESTING OF THE BRICKS:**

Bulk density, compressive strength, water absorption and efflorescence tendency of the bricks were determined as per NIS 74 : 1976 U.D.C. 624, 012.8 specification for Burnt Clay Brick Unit. The test results are given in Table 3. It can be seen that Kano soil is satisfactory for the production of building bricks.

TABLE 3: TEST RESULTS ON BRICKS

Properties of Brick	Laboratory		Field	
	Fired	Stabilized	Fired	Stabilized
Bulk density, g/cm <sup>3</sup>	1.70	1.80	1.70	1.80
Compressive strength N/mm <sup>2</sup>	4.59	1.65	2.45-3.92	1.47-1.70
Water absorption, percent	14.0	13.0	14.0	18.0
Efflorescence tendency	Nil	Nil	Nil	Nil
Drying shrinkage per cent	4.3	4.0	—	—
Firing shrinkage per cent	5.0	—	—	—

**Field Trials at Kano:**

The laboratory investigations were extended to the field for a small scale brick production. The Kano State Housing Corporation (KSHC) Kano, provided a working space for the bricks production and the brick products were used to construct two experimental brick structures at the gate of its office.

Grey and yellowish grey clay soils were mixed at 50:50 ratio and was manually prepared for brick making. Big and hard clods of soil were crushed to powder. Five per cent of sand was uniformly mixed with the soil. Water was added just to wet the whole mass of the soil. It was then covered overnight and kneaded. The bricks were moulded using the brick making machine designed by the Institute. It was observed that three persons could make 800 – 1000 bricks working 6 to 7 hours a day on one brick making machine. A higher level of production was achieved as the moulders gained experience. In general, quality and output of the bricks improved with time. The moulded bricks were taken on wooden pallets and carried to a fairly open and levelled place and allowed to air-dry. The air temperature of the June weather was between 32 – 32°C with occasional breeze. After 48 hours of air-drying, the bricks were stacked in 8 to 10 layers of bricks (Fig. 4), leaving fairly good space in between the bricks to allow for free circulation of air. A gap of about one metre was left in between adjacent stacks so as to facilitate free movement of workers.

The dried bricks were fired in a clamp kiln (Fig. 5). A clamp kiln is an intermittent kiln which can be set up at any open place. It is intermittent in the sense that the fire burns for a period and then goes out, and the heat developed is lost. A clamp is a large pile of bricks stacked in a way as to leave spaces for the fuel

and for the distribution of the hot gases. Firewood was used as fuel.

Logs of wood were arranged with a radius of one metre over which was placed wood chips and straw to form a platform. The bricks were stacked on edge on the platform in a "Honey Comb" manner. The stacking was done in such a way that a circle opening was left at the centre.

There was alternation of bricks and wood layers. The layer of bricks was made up of three courses. As the height increased the amount of fuel (wood) decreased. The top of the kiln was covered loosely with fairly big lumps of clay. A wall was constructed round the stacked bricks and plastered. At the base of the kiln, four fire points were created. The central opening was partly filled with wood chips. The fuel was ignited and the fire was allowed to burn itself out. After four days, the bricks were removed from the kiln. It was found that about 75% of the total bricks were well fired and the remaining were either under-burnt or over-burnt.

For the production of portland cement stabilized bricks, hard and big lumps of soil were manually crushed to powder. 4% of portland cement and 10% sand by volume of soil were added to the dry soil in small batches to ensure uniform mixing. Water was added to the soil-cement mix. The bricks were moulded, after which they were kept in shade for 24 hours and later exposed to direct sunlight. Moulding of the bricks was also carried out in batches.

The fired as well as the stabilized bricks were tested for bulk density, water absorption, compressive strength and efflorescence tendencies and the test results are given Table 3.



Fig. 4: Drying of the Bricks in the Sun



Fig. 5: Firing Bricks in a Clamp Kiln.

#### DURABILITY TEST FOR CEMENT STABILIZED BRICK:

Wetting and drying tests were carried out to evaluate the durability of stabilized bricks. This gives an idea of the weather resistance properties. After 7 days air curing of the cement stabilized bricks in atmosphere, two bricks were dried at 70°C to constant weight and later immersed in water at room temperature for 5 hours. The bricks were then kept in an oven at 70°C

for 42 hours, after which they were weighed at room temperature. These bricks were brushed firmly all over with an iron brush and weighed again. The percentage loss by weight and water absorption were recorded. The test was repeated until the test specimens of brick had gone through 12 cycles of wetting and drying. The test results are given in Table 4. The recommended limit for minimum durability is not more than 5% loss by weight after 12 cycles of wetting and drying for permanent building for urban areas with more than 508mm of annual rainfall.

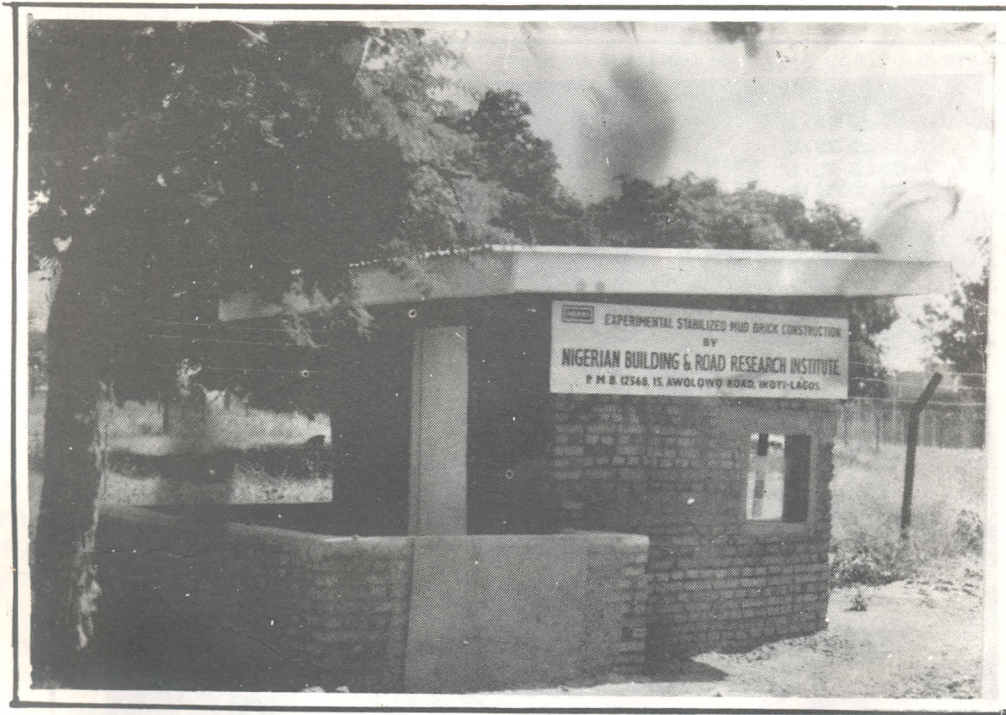
**TABLE 4: DURABILITY TEST RESULTS**

No. of Cycle Properties	1	2	3	4	5	6	7	8	9	10	11	12
Water absorption per cent	17.3	18.6	19.0	19.3	19.5	19.4	19.2	19.6	20.0	19.4	19.3	19.4
Percentage loss by weight	1.5	1.2	0.2	0.3	0.2	0.2	0.2	0.4	0.5	0.6	0.7	0.7

**CONSTRUCTION OF EXPERIMENTAL BRICK STRUCTURE:**

The construction of experimental brick structures with the cement stabilized and fired bricks produced were embarked upon for two reasons. The first is to study the environmental effects on these two types of clay products. The other is to demonstrate the employment of appropriate technology in the use of building bricks to the public. To achieve this, two

experimental brick structures (Fig. 6) one with stabilized bricks and the other with fired bricks, were constructed at the gate of the office of Kano State Housing Corporation at Kano. Local labour and masons were involved to carry out the construction in order to transfer the technology and stimulate the interest of the local populace. The exterior brick work was left unplastered. Simple mud mortar was used for stabilized brick whereas 1:6 cement-sand mortar was used for fired brick in the construction of walls.



**Fig. 6. Experimental Brick Structure for Security Guard.**

The masons had some initial difficulty in brick laying but this was overcome with time and experience. The major difficulty was in regard to the spacing in between two bricks, in plumbing and building a straight and vertical wall. Moreover, the masons used the habitual 3 to 4cm thick mortar in spite of the 1.0 to 1.5cm thick mortar emphasised. The progress of brick laying was therefore very slow most probably because of inexperience of the bricklayers. Normally,

the bricks are lighter than sandcrete blocks and their laying should be fast. The masons were disappointed to see that the four courses of brick could raise only 30cm of wall whereas four courses of sandcrete block raised more than 300cm wall. An alternative would be to increase the size of the brick and this is presently engaging the attention of the Institute, as moulds of larger sizes have been designed and fabricated for the brick making machine developed at the Institute.

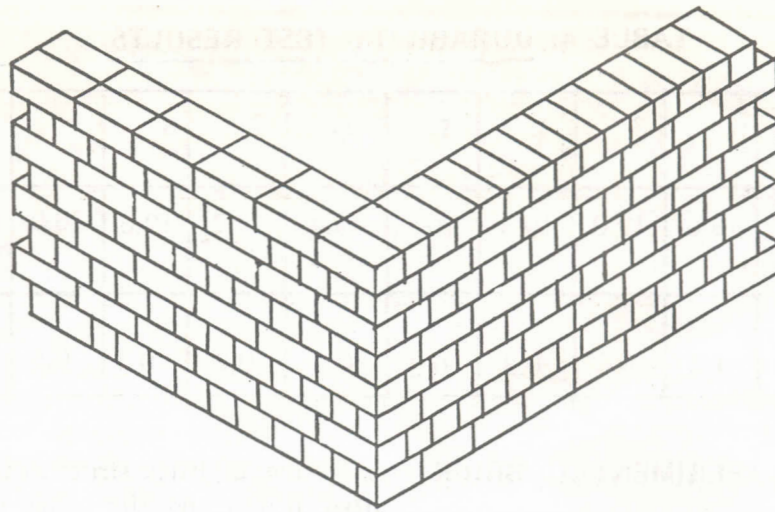


Fig. 7. Laying Pattern of Bricks

PREPARATION OF MUD MORTAR:

Mud mortar was prepared a day or two before use. Clay soil was used in its preparation because lateritic soils are not good mortars. Big lumps of clay were broken and made into a round shallow trough soaked

with water and left overnight. The soil was kneaded to obtain a good consistency (Fig. 8). The masons initially found it difficult to work with because of the stricky nature of the material but this was overcome with time.



Fig. 8: Preparation of Mud Mortar

DISCUSSION:

From the mechanical analysis of soil Fig. 2, it was observed that the percentage of clay, silt and sand was 28, 26 and 46 per cent respectively. The soil could be passed for brick making taking into consideration the total percentage of silt and clay which is 54 per cent.

X-ray analysis of the soil Fig. 3 shows the presence of Kaolinite, quartz and muscovite clay minerals. The high percentage of silica together with low percentage of aluminium (see Table 1) is an indication of free silica in the soil. The strength exhibited by the fired bricks may be due to the high percentage of oxides of iron.

The cracks developed during drying was effectively controlled by the addition of sand. There was loss in strength with the addition of more sand especially for fired bricks (Table 5) and 5% sand was found to be the optimum value. Addition of grog (fine calcined clay) also controlled cracking. The resultant bricks showed an appreciable increase in compressive strength. The stabilized bricks produced had little or no problem as far as shrinkage cracking is concerned.

Table 5: Effect of Sand on Compressive Strength of Fired Brick

Sl. No.	% of Sand	Compressive Strength, N/mm <sup>2</sup>
1	5	4.6
2.	10	4.0
3.	15	3.3
4.	20	2.6

The strength of fired bricks and cement stabilized bricks are 5.6N/mm<sup>2</sup> and 1.65N/mm<sup>2</sup> respectively. The strength of the fired brick progressively decreases 4.6N/mm<sup>2</sup> to 4, 3.3, 2.6 N/mm<sup>2</sup> as the additions of sand is progressively increased from 5 to 10, 15 and 20 per cent. Sand addition should, therefore, be kept minimum or should be avoided. The NIS 74: 1974 U.D.C. 624, O12.8 Specification for Burnt Clay Brick Unit recommends a minimum strength requirement of 2.5N/mm<sup>2</sup> which the fired brick attains at all additions of sand content.

A stronger brick can be achieved with better control of firing temperature and this can be made possible by using coal instead of firewood. An added advantage is that the desired temperature can be maintained for longer duration. Moreover, coal is cheaper than firewood particularly in the Northern states. The retail price of coal by the Nigerian Coal Corporation is ₦50.00 per tonne.

The strength of stabilized bricks with 4% cement is 1.65N/mm<sup>2</sup> (wet) which is low. The recommended minimum compressive strength requirements for stabilized bricks in India (9) and Ghana (10) are 1.76N/mm<sup>2</sup> (wet) and 1.39N/mm<sup>2</sup> (dry) respectively. Ola (5) considers 1.4N/mm<sup>2</sup> strength adequate for a stabilized brick for bungalows and one storey building. Fitzmaurice suggested that the 28 days strength requirements of soil cement for construction of low cost housing should be reduced to 0.69N/mm<sup>2</sup> in case of soils containing gravel to the extent of 70 per cent.

From the above, it may be concluded that the strength of 1.65N/mm<sup>2</sup> of brick with 4% cement stabilization is more than adequate for a single storey and bungalow type of building in the rural areas. Further if higher strength is desired, then bricks may be moulded under higher pressure (5). This factor assumes greater importance in the production of cement stabilized bricks in view of the increasing cost of cement.

The durability test results show that although the loss in weight after 12 cycles of wetting and drying is 6.7 per cent (Table 4) which is slightly more than the limit of 5% suggested by Fitzmaurice (12) for a permanent building in urban areas with more than 508mm of rainfall, the brick can be used for construction. The stabilised brick wall in rural areas could be treated with waterproof paints containing hydrophobic lime, cement and water-glass (1).

It has not been possible to calculate the cost of production of bricks as the moulding has been done with the assistance of laboratory technical staff.

#### POST-EVALUATION OF THE STRUCTURES:

After one year's use by two security men, a post-evaluation study indicated a general satisfaction with the structure. The feeling of stability and the permanent nature of the structure were greatly appreciated. One of the most desirable feature was its freedom from repair and maintenance. The structure looked new. In the stabilized brick structure, it was observed that in the absence of proper outlet for rain water in the backyard, slight settlement of the wall had taken place. This resulted in minor vertical cracks in the boundary wall.

#### CONCLUSION

Small scale production of stabilized blocks and burnt bricks was exhaustively discussed. The utilization of the brick making machine developed at NBRRJ facilitated the production of the stabilized and unstabilized bricks. Four percent cement stabilization was found to be adequate for the stabilized brick. The unstabilised brick was burnt in clamp kiln and the strength developed was found to be more than adequate for bungalows and one storey buildings.

This small scale production can be embarked upon on communal basis to provide for low cost housing in the rural areas and towns. This will go a long way in not only achieving the United Nation's resolution of housing for all by the year 2000 AD, it will also de-emphasise the heavy dependence on other building materials like cement most of which is imported.

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## DEVELOPMENT OF BRICK/BLOCK MAKING MACHINE

By

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### ABSTRACT:

*The paper describes the design and fabrication of a brick/block making machine for the production of sun-dried, cement-stabilized and fired clay bricks/blocks. Details of design and fabrication processes are given. Field trial experiments were carried out in collaboration with Kano State Housing Corporation. The present size of blocks was generally well received by the public. The machines are currently being used in executing a self-help project by the Kano State Government at Yakatsari Model Village.*

### INTRODUCTION:

Over the years, stabilized soils have been used in providing housing both in the urban and rural areas. Soil stabilization in the past is achieved using straws, chopped fibres etc. but nowadays lime, cement and other pozzolanic materials have been extensively used as the stabilizing agent. These stabilized soils are moulded into bricks/blocks of desired sizes, allowed to dry and are ready for use in construction.

In order to enhance the productivity of stabilized and fired bricks especially on a 'Self help' basis, the Nigerian Building and Road Research Institute developed a brick/block making machine which is capable of ensuring adequate compaction and producing high quality bricks. This machine is hand-operated and it is not too heavy as it can be easily moved to site.

The whole operation of soil mixing, moulding and compacting in the machine could be achieved by three operators and the production rate is six hundred to seven hundred blocks per machine per an 8 hour working day. The operational simplicity of the machine makes it a ready solution to the provision of low cost housing in Urban and/or Rural areas on a self - help or communal basis.

### TRADITIONAL CONSTRUCTION TECHNIQUES WITH SOILS

In Nigeria, three traditional methods of construction with soil existed and is still being practised in some rural areas. These are the Wattle and Daub, Cob and Adobe methods. The first two methods are labour intensive and construction is usually on a communal basis.

In the Cob method of construction, stiff mud is moulded into balls which are then piled up in thick layers to form a wall directly without the use of any kind of forms. The stiffness of the mud prevents slumping. The wall is constructed slowly so that each layer has enough time to harden before the commencement of a fresh layer of mud.

The Wattle and Daub construction method involves the erection of a vertical frame-work of post, reeds and poles. Branches are woven among the poles to form a bar for mud plaster which is applied to both-sides of the frame-work.

The Adobe block method is common amongst the affluent rural dwellers. Here, the finely ground soil is puddled into an almost liquid consistency by addition of water. Chopped fibres may be added to improve the workability but the amount must be controlled since excess fibres may reduce the strength of the finished product. The threaded soil is placed in a wooden mould whose inside is earlier wetted or slightly dusted with fine sand to prevent adhesion. The surplus mud is then struck off with a straight edge spatula. The mould is thereafter lifted and the moulded block is left at that spot for about 12 hours before being turned on edge to allow for adequate drying.

In all these traditional methods of construction with soils, sufficient compaction is not assured since the moulded soil blocks are at best tampered with hand or rammed with a wooden form. But it has been established by various researchers (Ola, Oguara etc) that higher compaction pressures during moulding gives rise to soil blocks of higher strength, greater density and better durability. Such compactive effort can be obtained by using a mechanical device and to this end different types of brick/block making machines have been developed in different countries to suit their environment.

## ADVANCEMENT OVER THE YEARS:

Concrete block making machines are unsuitable for making stabilized soil bricks/blocks. This is because concrete mixes are designed to have the right amount of workability for rapid compaction by tamping or vibration, whereas the correct amount of water needed for optimum compaction of a soil brick/block would result in an unworkable mix. This has led to the development of a number of simple presses over the past twenty years.

Some of the best known presses which are being used for housing construction in some third world countries are of two types, viz. constant pressure and constant volume presses. In the constant pressure type, the ram of the press exerts a constant pressure at every stroke while in the constant volume type, the ram moves over a fixed distance. Reducing the amount of soil fed into the constant pressure machine will result in a smaller block whereas in the constant volume type, under-compaction occurs, and this gives rise to low density soil block. In both cases, the amount of soil fed into the machine is important and should be controlled. Some of the known mechanical presses include the Cinva Ram, the Tek block and the Supertor types.

The Cinva Ram is the most common press and it consists of a metal mould in which a measured quantity of moist soil mix is compressed by an ascending piston connected via a toggle linkage to a lever. A hard pull on the lever arm provides the required compaction on the soil block. The compacting load is about  $2\text{N}/\text{mm}^2$  on a  $290 \times 140 \times 100\text{mm}$  soil block. When operated by two men, the machine is capable of producing about 300 blocks daily.

The Tek Block machine was designed by the University of Science and Technology in Kumasi Ghana. In this case, the lever arm is made of timber instead of the three piece metal arm used in Cinva-Ram. The number of operations required to press and eject a block is less than with Cinva-Ram because the top of the mould is fixed to the lever arm. After compaction of the soil, movement of the lever from one side of the mould to the other results in the top of the mould being removed and the block being ejected in one single operation. Size of block made by this machine is  $290 \times 215 \times 140\text{mm}$  with an output of 200 – 400 blocks per day.

The Supertor is an hydraulically powered soil-cement brick press which is being marketed in Brazil. It has four moulds and an output of 20,000 bricks per 8 hours working day. The brick sizes are  $230 \times 110 \times 50\text{mm}$  and/or  $200 \times 100 \times 50\text{mm}$ .

## DEVELOPMENT OF BRICK/BLOCK MAKING MACHINE

The brick/block making machine developed is based on the principle of attaining constant volume. Initially an attempt was made at designing a machine which can produce a through and through hollow block. This was aimed at improving the thermal conditions of houses built with such soil block. Bearing in mind the Nigerian Standard on building bricks which allows for 25% hollow, a mould was designed to produce bricks of  $220 \times 150 \times 50\text{mm}$  size. A machine incorporating two of such moulds was designed and fabricated. Unstabilised as well as fired bricks were made. Most of the fired bricks so produced were characterised by high shrinkage cracks.

The Nigerian Building and Road Research Institute considered that to effectively compete with sandcrete blocks, a block of almost the size of sandcrete would be desirable. To achieve this objective, various sizes of moulds were designed and these included:

	Length		Breadth		Height
(a)	230	x	138	x	62mm
(b)	230	x	110	x	50mm
(c)	240	x	158	x	110mm
(d)	290	x	140	x	100mm
(e)	220	x	100	x	60mm
(f)	290	x	150	x	70mm

Finally a mould of size  $290 \times 140 \times 100\text{mm}$  was adopted. In collaboration with the Mechanical Engineering Department of the University of Lagos, a prototype machine was designed and fabricated to incorporate three moulds. The design was such that the soil blocks produced had frogs to enhance bonding with mortar. Extraction of the moulded bricks was further enhanced by the provision of leg metal in the design. (See Fig. 1) The machine weighed 145kg and soil blocks produced were found satisfactory. In the laboratory condition, the output of a 3 - man team is 103 blocks in an 8 hour working day. The 3 - man team is comprised of two individuals mixing the soil, loading and unloading in and out of the machine, while the third individual operates the machine.

## FIELD TRIALS:

During laboratory investigation on which size of bricks is most suitable, machines with varying moulds were fabricated as mentioned earlier. A machine with mould size of  $230 \times 110 \times 50\text{mm}$  was taken for a field trial in Kano. The choice of Kano State was unique in the sense that the use of the Adobe method

of construction is quite common amongst the rural population, and as such the brick would be readily accepted. Moreover, the Kano State Housing Corporation gladly accepted the NBRRI proposal for the pilot project which was jointly managed.

The field trial was aimed at determining the weatherability and productivity of the bricks. For this, two types of bricks, stabilised and unstabilized were produced. From the exhaustive work done by Ola and others on stabilised soil, a 4% cement stabilization was adopted. The slow pace of construction which was due to small size of brick and lack of skilled labour (bricklayers) made it unacceptable. Consequently, larger moulds of blocks were designed and fabricated. The optimum mould size finally adopted was 290 x 140 x 100mm.

Another field trial was carried out this time in Yakatsari model village Project — in Kano. On Site, the rate of production was six to seven hundred bricks per 8 hour working day with three labourers maning the production. The production involved mobilizing the rural dwellers. The acceptability of the machine by the rural inhabitants was encouraging. To this end the NBRRI commissioned the production of ten brick making machines which have been produced. Most of these will be used at the site to produce blocks for the construction of models of the three types of houses designed by NBRRI for rural population. The three types were designed based on a survey carried out to determine the characteristics of Nigerian living pattern. The designs were such that construction could be done in stages.

#### CONCLUSION:

After a series of laboratory studies, fabrication of a prototype and field trials, a mechanical brick/block making machine was developed by NBRRI to produce both stabilized and fired bricks. The machine

is relatively light and can be easily transported to site and requires a 3 - man operation team. Successful field trials with the machine at the Yakatsari Model Village near Kano town shows that the machine can be gainfully employed in building low cost housing in rural and urban areas on a self-help or communal basis. All that is required is the initial induction as to the proper use of the machine.



FIG. 1 BRICK/BLOCK MAKING MACHINE  
DEVELOPED BY NBRRI

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## SOILCRETE HOLLOW BLOCK PRODUCTION MACHINE PRODUCED IN A. B. U:

By

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### ABSTRACT

*This paper discusses the essentials of the production of a simple soilcrete block making machine at Ahmadu Bello University, Zaria, Nigeria. The need for such a machine in fundamental research into the strength and durability of soilcrete blocks is stressed. The paper contains discussions on the effect of the variations of moisture content and compaction pressure on strength of soilcrete blocks. The prevailing frictional forces and their distribution during compaction and extraction are highlighted.*

### 1. INTRODUCTION

The use of soilcrete hollow blocks for low cost (cheap) and durable housing cannot be over-emphasized. There is therefore a need for a portable, simple block production sampling machine which is economically cheap and durable. The Occidental Construction Company, Zaria, which produces the soilcrete hollow blocks have not got enough measuring devices for analysing the samples. This is because the company's machine (TECMOR block making machine) has not got any means of measuring the compaction pressure used in producing the blocks.

A soilcrete hollow block machine is therefore produced at Ahmadu Bello University (A.B.U.) to take advantage of the quality of soil and help enhance other qualities that are lacking in the soil. The stabilized laterite (soilcrete) which is compacted into shape by this soilcrete machine is a highly resistant material after curing and drying. This material withstands a much higher stress than plain soil itself and offers a greater durability against the action of atmospheric agents. During this research, it was also found necessary to look into ways of producing machines with variable compaction pressures to determine the effect of such parameter on the final product. This paper discusses the basic production of such a machine and the problems encountered in its use.

### 2. AIMS OF THE SOILCRETE BLOCK MACHINE

Nearly all the soilcrete block samples used in the 'soilcrete research' at A.B.U. were produced by Occidental Construction Company using TECMOR block-making machine. This industrial machine does

not allow for preparation of samples required for analysis of samples under different factors affecting them. Tests carried out are therefore designed to fit the available samples. The TECMOR block making machine does not have means of measuring the compaction pressure and other properties necessary in research work. It was therefore necessary to develop a simple sampling machine which in the course of production can help achieve the following aims:

- (a) Measurement of variation of compaction pressures;
- (b) Three circular holes in a block in place of two rectangular holes but keeping the volume of holes the same with the soilcrete blocks produced by TECMOR machine. This is to check against the weakness at the web of samples produced by TECMOR;
- (c) Measurement of frictional force and its distribution during compaction and extraction of blocks;
- (d) Effect of variation of moisture content on strength qualities;
- (e) Obtaining the same size of blocks as produced by TECMOR but with circular holes;
- (f) Simplicity of the equipment. This is however the most important factor. Therefore, it was decided first to develop the forming part alone with manual feeding; the mixes being prepared beside in a pan mixer.

### 3. THE MACHINE

The forming part is essentially of die-box which is about twice the height of the block — that is 300mm. The plan section of the die-box is about 150mm by 400mm excluding the thickness of the steel plate which is 20mm. The inside of the die-box in contact with the soilcrete mix is well polished to reduce the frictional force. To create the circular holes, three cylindrical steel moulds closed at both ends are

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placed along the length of the die-box. The diameter of the cylindrical mould is 110mm including the thickness of the steel. The plan is as shown in Fig. 1.

The die-box is mounted at the middle of a steel frame, and compaction pistons are fixed below and above the die-box. The bottom piston is used for block extraction and therefore its stroke is 300mm. The upper piston is placed 200mm above the die-box table to allow for the removal of the extracted blocks. This piston may travel a distance of one half of the die-box, allowing for replacement. The top bearing plate can similarly be replaced. Figure 2 shows the top and bottom pistons.

To make the pistons effective, the top bearing plate is connected via a load cell to a hand operated universal hydraulic tool (single piston jacks and pump — 20 tons capacity). The bottom piston is by means of a PSC freyssinet machine which is connected to the bottom bearing plate via PSC freyssinet hydraulic jacks.

The photograph of the part of the machine is as shown in plate I.

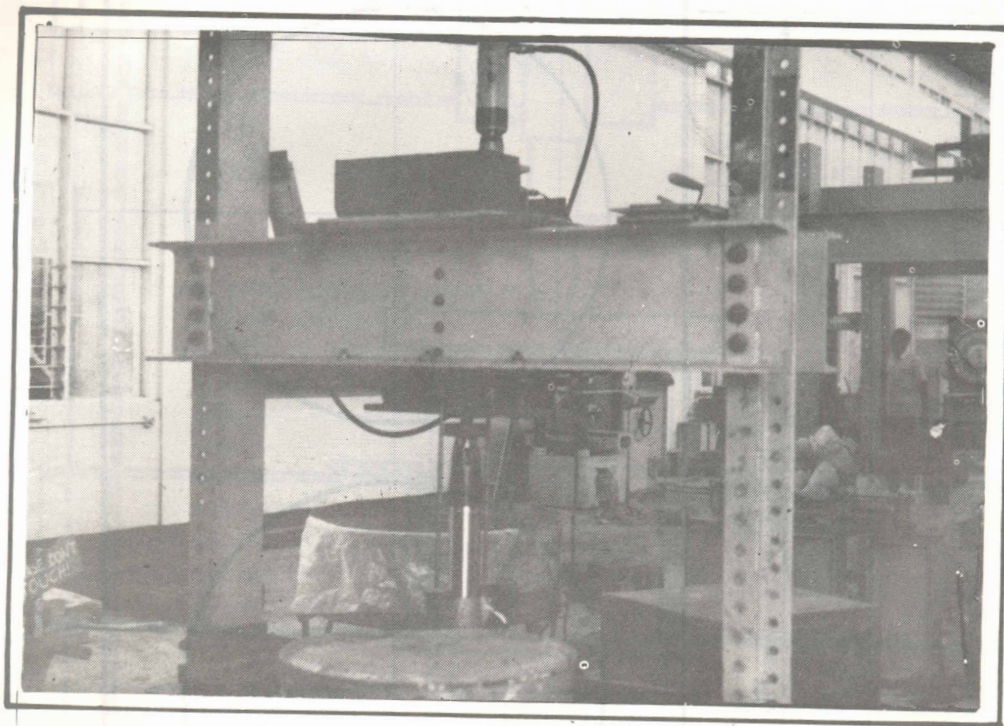


PLATE I — SOILCRETE BLOCK MAKING MACHINE.

#### 4.0 OPERATION

The machine needs two operators. First, the laterite is stabilized by mixing with cement in an open pan mixer. After mixing for about a minute, water is added and the mixing continued for another two minutes. The mould is then filled with the stabilized laterite and a top pressure is applied. This top pressure is applied by means of a hand operated universal hydraulic tool (single piston jacks and pump — 20 tons capacity) via a load cell. The load cell is connected to a metre strain gauge from where the strain is read and converted to a force by means of calibration graph. The bottom pressure is also applied by means of a PSC freyssinet machine. The pressure

which is transmitted to the freyssinet hydraulic jacks is applied by the operator on the key board of the L2D freyssinet machine in bars. Thus the block is compacted with a known top and bottom pressure. The top pressure is then released and the bearing plate moved up. The compacted block is pushed out by the operator applying the pressure at the bottom by means of the L2D freyssinet machine via the freyssinet hydraulic jacks. The moulded block measuring 400mm x 150mm in plan and 150mm in height is carefully removed to a place of curing. The output of the hand operated machine is about 15 blocks per hour during these initial trial stages. Efficiency can be improved with time.

Some of the soilcrete blocks produced by the machine are as shown in plate II.

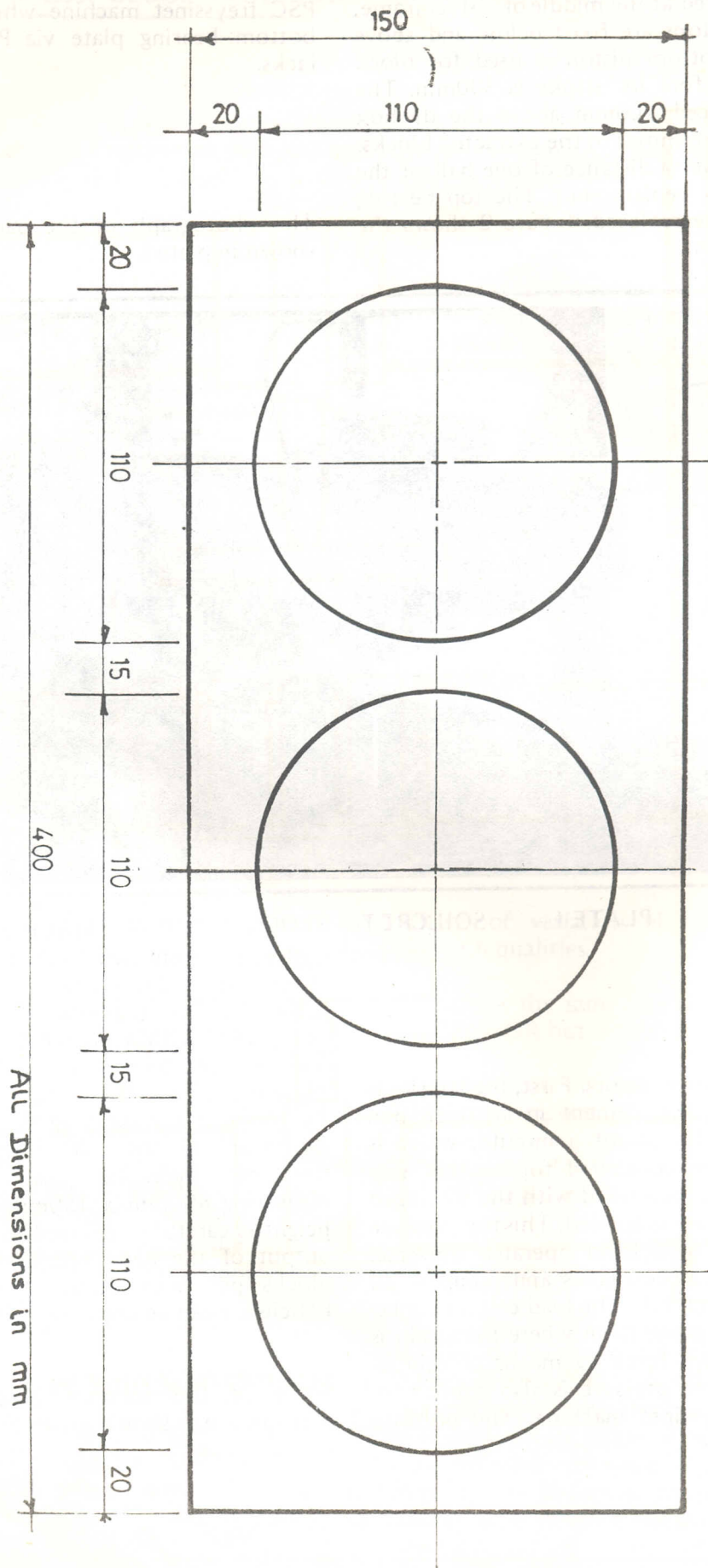


FIG. 1: PLAN SECTION OF DIE - BOX

All Dimensions in mm

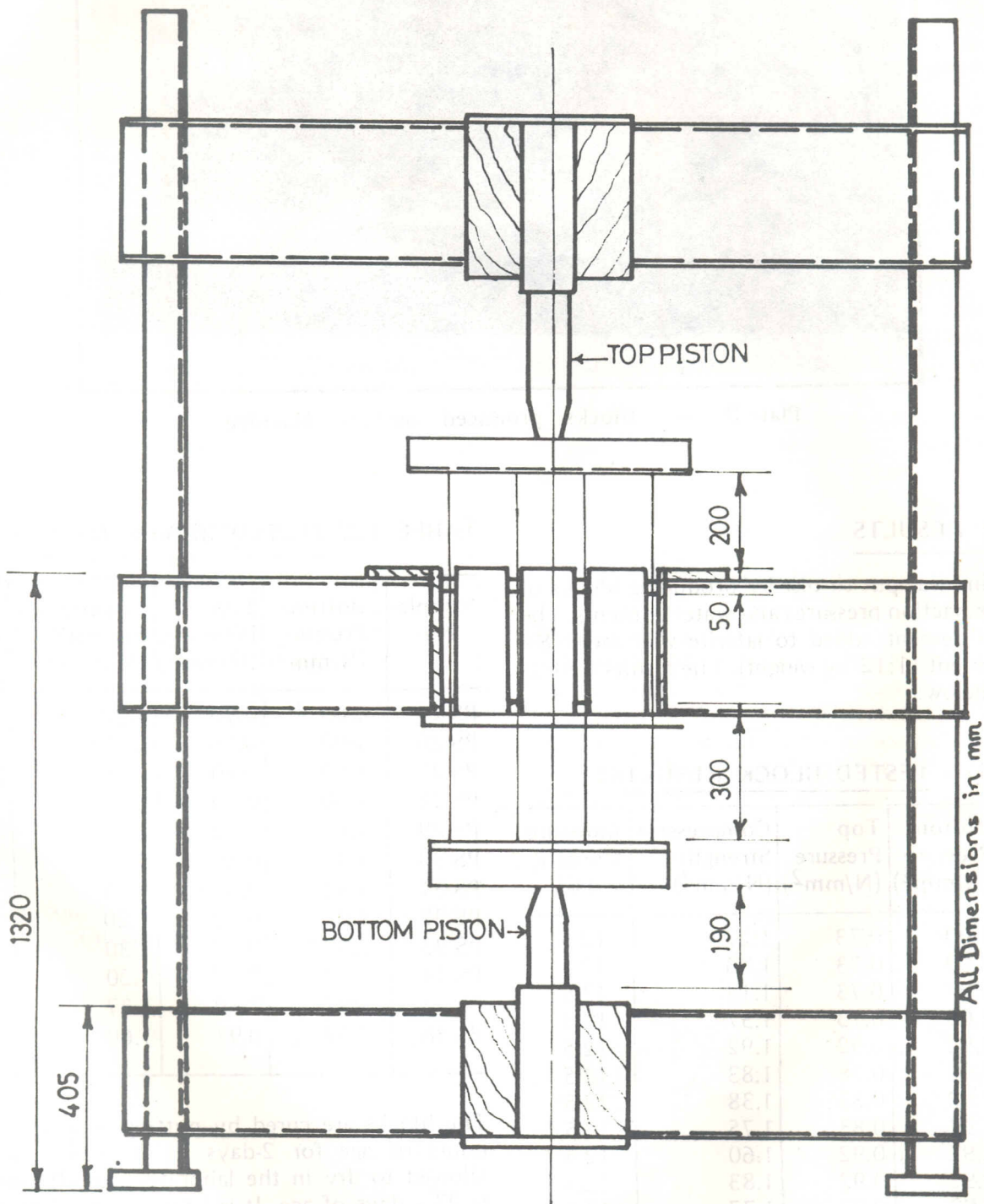


FIG. 2: SOILCRETE BLOCK-MAKING MACHINE IN A STEEL FRAME

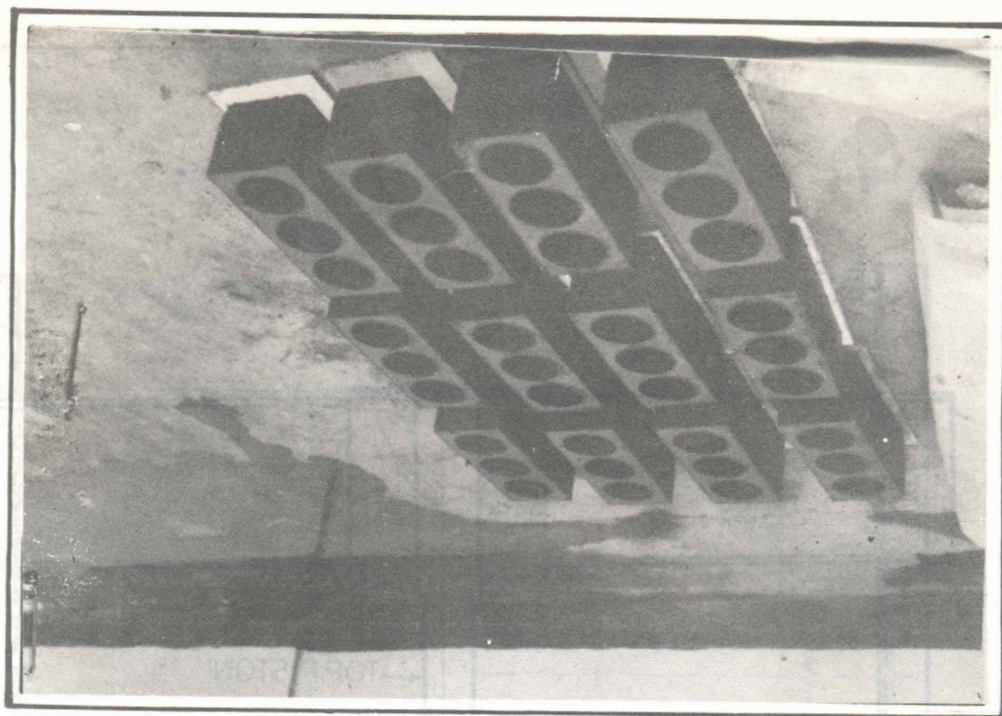


Plate II — Blocks produced by the Machine

## 5. TEST RESULTS

The machine was put to test by producing blocks of various compaction pressures and water contents. The amount of cement added to laterite was about 8% cement content (1:12 by weight). The results were as presented below:

TABLE 1.1 — TESTED BLOCK RESULTS

Sample No	Bottom Pressure (N/mm <sup>2</sup> )	Top Pressure (N/mm <sup>2</sup> )	Compressive Strength (N/mm <sup>2</sup> )	Moisture Content (%)
PS 13	1.00	0.73	1.27	12.5
PS 14	1.00	0.73	1.03	12.5
PS 15	1.00	0.73	1.13	12.5
PS 16	1.00	0.73	1.37	12.5
PS 17	1.92	0.92	1.92	12.5
PS 18	1.92	0.78	1.83	12.5
PS 19	1.92	0.83	1.38	12.5
PS 20	1.92	0.83	1.75	12.5
PS 21	2.92	0.92	1.60	12.5
PS 22	2.92	0.92	1.83	12.5
PS 23	2.92	0.92	1.77	12.5
PS 24	2.92	0.92	1.27	12.5

TABLE 1.2. TESTED BLOCK RESULTS

Sample No	Bottom Pressure (N/mm <sup>2</sup> )	Top Pressure (N/mm <sup>2</sup> )	Compressive Strength (N/mm <sup>2</sup> )	Moisture Content (%)
PS 25	1.00	0.70	1.20	15.0
PS 26	1.00	0.70	0.83	15.0
PS 27	1.00	0.70	0.68	15.0
PS 28	1.00	0.70	1.02	15.0
PS 29	1.92	0.80	1.17	15.0
PS 30	1.92	0.80	1.33	15.0
PS 31	1.92	0.80	1.25	15.0
PS 32	1.92	0.73	1.20	15.0
PS 33	2.92	0.87	1.30	15.0
PS 34	2.92	0.87	1.20	15.0
PS 35	2.92	0.80	1.37	15.0
PS 36	2.92	0.97	1.60	15.0

The blocks are cured by putting in water after 24-hours of age for 2-days. It is then removed and allowed to dry in the laboratory conditions until it is 27 - days of age. It is later re-soaked in water for another one-day and tested wet at the age of 28 days.

## 6. DISCUSSION

One observes that there are certain things that are unique about the soilcrete machine. The machine is purely used for soilcrete hollow blocks (stabilized laterite). The presence of the three circular steel moulds in the die-box and consequently circular hollows on the soilcrete block is also unique to the machine. The machine is simple and portable. This implies that it can easily be used on site. The main machine is the mould (die-box) and can be mounted on any frame and pressure can be applied as required. The variability of pressures and moisture content permissible in the machine suggest that different blocks can be produced for different engineering purposes.

In the process of block production, some problems were encountered which are currently under intensified study. One major problem is the verticality of the applied bottom pressure. If the hydraulic jacks transmitting pressure to the bottom bearing plate tilts a little, high friction is generated in the die-box leading to difficulty in removing the blocks. Even after removal, this results in a weak and cracked block. This problem is likely to be resolved when other alternative parts of our new equipment are installed and we can use the heavy universal hydraulic machine to apply vertical and higher pressures using the cylinder pistons. One also observes that high moisture content blocks even though easily removed often experience high shrinkage and are usually cracked on drying. If low moisture content is used, the block will crack on removing. The optimal moisture content is that which is sufficient to bind the materials together. This is about 12% moisture content. More research work is going on to establish the reliability of this optimum moisture content.

## 7. CONCLUSION

From the construction and tests of the sampling machine, the following conclusions can be made:

1. The sampling machine can conveniently be used for laboratory works. The present prototype require the replacement of the 200 kN compaction pistons by 500 kN ones. To find the optimal value of compaction pressure, higher values should be tested. For this reason, compaction pressure up to  $10 \text{ N/mm}^2$  or even  $15 \text{ N/mm}^2$  may be required.
2. Effort should be made to acquire a regular sampling machine produced by a specialised manufacturer after the preliminary tests of the prototype are completed. This will allow for detailed studies of the relation between the compaction pressure and the mechanical properties of soilcrete hollow blocks.
3. Verticality of the piston applying compaction pressures is of great importance. Small tilt from the vertical results into weak blocks and difficulty in removing the block after compaction.
4. Correct moisture content is also of importance since it affects the strength and durability of blocks.

## 8. ACKNOWLEDGEMENT

The initial research efforts of Professors S. Oleszkiewicz and A. Florek, both formerly of the Civil Engineering Department of Ahmadu Bello University in all aspects of soilcrete Research are acknowledged. The authors are also grateful to the research grant provided by the Nigerian Building and Road Research Institute (NBRRI), Lagos.

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## INTRODUCTION

One of the major factors so far identified as contributory to the housing problems in Nigeria's urban centres is the high cost of building materials. There is no gain-saying that the cost of building materials affect very significantly the cost, rate and methods of housing provision. The higher the cost of building materials, the higher the cost of housing construction, the fewer the number of people who can afford their desired houses, the slower the rate of housing supply, the fewer the supply, the more competitive the housing market becomes and the greater the problems of housing, especially to the lower income sector of the population. It is therefore very useful to attempt to have a thorough understanding of the historical, actual, and potential costs of building materials in the country. This paper examines the cost of building materials in Nigeria. It examines the price trends, the factors influencing the costs of building materials, and the ways by which building materials can be made more readily available to the would-be house owner at a price that can be affordable.

The paper, divided into a number of sections, presents the findings of a field survey conducted in four major cities in the country between 1982 and 1984. Apart from the introduction and the sources of data, the first major section attempts a classification of building materials while the next section presents the findings of the study of price trends of building materials between 1974 and 1984 (as shown in Tables, 1, 2, and 3). The third section attempts an explanation of the high trends illustrated in the tables while the last section offers some recommendations and conclusions.

## SOURCES OF DATA

The data on which this paper is based came from a questionnaire survey conducted in major cities in Nigeria. These cities included Lagos, Ibadan, Enugu and Kaduna. The cities represent the three geographical regions of Nigeria — the West, the East, the North and the Federal Capital. The choice of the cities was influenced by the fact that the cities represent the traditional regional capitals, the dominant administrative foci, and perhaps the most prominent distribution centers for each region. The questionnaire collected the selling prices of 120 different items of building materials from randomly selected sample of wholesalers/

retailers of building materials in each of the four cities. The sample is a good representative of all the major markets and sales depots of building materials in each of the cities.

It should be stressed that the prices in these cities can only serve as crude indicators of price trends in the country. Due to distance decay factors and decreasing economy of scale, the prices in areas outside of the major cities are likely to be higher than in the regional cities. The prices discussed in this paper, therefore, should be regarded as the lowest prices possible and prevailing in the country at the different points in time.

## CLASSIFICATION OF BUILDING MATERIALS

For the purposes of this exercise, building materials have been broadly classified into six categories, based on conventional construction methods. They are:

- (i) Flooring materials
  - (ii) Walling materials
  - (iii) Ventilation materials
  - (iv) Roofing and Ceiling Materials
  - (v) Painting materials, and
  - (vi) Sanitary wares
- (i) **Flooring Materials:**— These are granites and sand (of various grades per load), cement (plain and coloured), iron rods (of various sizes), tiles and terrazo.
  - (ii) **Walling Materials:** These include various sizes of concrete blocks and clay products.
  - (iii) **Ventilation Materials:** Comprise of windows and doors whose components include wood, louvres, plywood and metal frames.
  - (iv) **Roofing and Ceiling Materials:** These include iron sheets, asbestos sheets, long span aluminium sheets, ceiling boards, cardboards, ceiling tiles, nails and wooden planks (of various sizes)
  - (v) **Painting Materials:** These include gypsum lime, under-coat, wood liner, emulsion and gloss paints.

(vi) **Sanitary Wares:** These include water closets, wash-hand basins, showers, sinks, shower trays and bath, as well as galvanized pipes, p.v.c. pipes and asbestos pipes of various sizes. Though this list of building materials is in-exhaustible, depending on the taste of, and resources available to the builder, this study has limited itself to the above categorization for economic reasons.

This categorization is however not exhaustive as some of the materials for flooring, roofing and walling can be used inter-changeably and for interior decoration and detailed finishing. Electrical fittings and cables, and such traditional/local materials as bamboo, mud, raffia, thatch, coconut and palm tree trunks are not considered in this study.

### PRICE TRENDS OF BUILDING MATERIALS

Using Enugu, Kaduna, Ibadan and Lagos as indicators, price trends of building materials in Nigeria have shown varying degrees of escalation in the different parts of the country during the last decade. While the period 1974/1979 experienced gradual increases in the prices of building materials, phenomenal increases occurred between 1979 and 1984.

Out of about 120 items of building materials listed in table 1, only 24 items had more than 50 per cent price increase, between 1974 and 1979 in Nigeria. Out of this figure, 11 items had between 50 and 70 per cent price increase, leaving only 13 items of building materials which had sharp price increases ranging between 71.61 per cent (for plain Portland cement) and 200.00 per cent price increase (for the 1½" p.v.c. pipes). Other building materials in this group are ceramic double bowl sinks (150.00%), stainless double bowl sinks (140.59%) ceiling tiles (99.74%), ceramic single bowl sinks (87.50%), and telephone (double mixer) shower (80.77%). So also are 1½" and 2" p.v.c. pipes (183.33% and 94.64% respectively), 3" nails (76.25%) and ½" thick veneer plywood (73.82%). During the same period, a few items experienced little changes in price. These include: 1½" nails (0.34%); 4" nails (6.19%); 6" x 9" x 18" concrete blocks (7.99%); 9" x 9" x 18" concrete blocks (8.69%); and telephone (single mixer) showers (9.69%).

In the same period, Lagos experienced the least price increase on such flooring materials as soft sand (20%), unwashed gravel (42.86%), and iron rods, while Enugu enjoyed least price increase on cement and all grades of granite. This could be so since iron rods were generally imported and Lagos enjoyed (and still enjoys) port facilities, while Enugu is readily accessible to Onitsha and Calabar, also port towns, for imported cement, in addition to its proximity to cement factories at Nkalagu, Calabar and Asaba.

Ibadan had the highest price increase on almost all the listed flooring materials. The price of ventilation materials, especially plain louvres, were generally more stable in Kaduna than Lagos and Ibadan, while price of roofing and ceiling materials, especially planks, were more unstable in Kaduna than Ibadan. This could be so because while the latter situates within the southern rain forest belt, the former is in the savannah region where trees thrive less. It is however surprising that planks had high inflationary trends in Ibadan as reflected in the 1½" x 12" x 12" hard-wood (90.84%), 2" x 4" x 12" (101.20%) and 2" x 6" x 12" (70.87%) softwood planks, despite its geographical location. Iron nails experienced negative price changes in Enugu between 1974 and 1979, while the commodity's price was generally stable in the country during the period. The same observation goes for all types of painting materials. However, Kaduna and Ibadan had little price changes on sanitary wares, while Lagos experienced the highest inflationary trends.

It is noteworthy that between 1974 and 1979, there were a number of political developments in Nigeria which created an unsettled atmosphere needed for the rapid national economic development. These developments probably affected the inflation in the price of most market products, including building materials. Such political developments include the July 1975 change of government, the creation in 1976 of 19 states out of the 12 previously existing, the abortive coup-de-tat of March, 1976, and the preparation for the change from military to civilian administration between 1978 and 1979. It is however, pertinent to stress that despite the inflationary trends in the cost of building materials, the housing and construction sector was able to contribute between +3.1 percent and 13.8 percent average deviation from the national target. (National planning Office, 1981).

**TABLE 1**  
**PERCENTAGE CHANGE IN THE PRICES OF BUILDING MATERIALS IN NIGERIA,**  
**1974 - 1979**

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
1.	<u>Flooring</u>					
(i)	Granite (per lorry load)					
	10mm „ „	—	100	-7.14	—	46.43
	12mm „ „	—	100	-3.85	—	48.07
	16mm „ „	—	100	-3.85	—	48.07
	150mm Hadcore	—	50	—	—	50.00
(ii)	Sand (per lorry load) (SOFT)	20	83.33	—	—	51.66
(iii)	Gravel (per lorry load)					
	Washed „ „	57.14	50.00	—	—	53.57
	Unwashed „ „	42.86	77.25	—	—	60.05
(iv)	Cement					
	Plain	58.73	94.33	46.70	86.70	71.61
	Coloured Cement	—	—	—	—	—
(v)	Iron Rods					
	High Tensil					
	¼" x 30	—	45.84	40.00	—	42.92
	3/8" x 30 (33/112/500/-)	18.75	33.16	26.57	—	26.16
	½" x 30	25.00	26.66	25.00	—	25.60
	5/8" x 30	75.00	26.66	35.65	—	45.80
	¾" x 30	—	40.00	—	—	40.00
	7/8" x 30	25.00	40.00	34.62	—	33.21
	1" x 30	50.00	40.00	24.00	—	38.00
	Round Bars					
	¼" x 30	9.85	—	66.70	—	38.27
	3/8" x 30	10.60	66.67	62.50	—	46.59
	½" x 30	48.00	—	60.40	—	54.20
	5/8" x 30	37.83	—	27.50	—	32.66
	¾" x 30	—	50.00	—	—	50.00
	7/8" x 30	33.33	—	—	—	33.33
	1" x 30	66.67	—	—	—	66.67
(vi)	<u>Tiles</u>					
	Ceramic					
	P.V.C. 9" x 9" x 1/i	21.54	—	—	—	21.54
	15 x 15cm. (white per m <sup>2</sup> )	50.07	—	—	—	50.07
	20cm x 20cm „ „	29.41	—	—	—	29.41
	Floor tiles	—	—	—	—	—

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
(vii)	Terrazo White (per bag) Black „	— —	— —	11.11 33.30	— —	11.11 33.30
2.	<u>Walling</u>					
	Concrete Blocks					
	9 <sup>6</sup> / <sub>16</sub> x 9 <sup>10</sup> / <sub>16</sub> x 18 <sup>11</sup> / <sub>16</sub>	—	9.9	8.30	—	8.69
(i)	6 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub> x 18 <sup>11</sup> / <sub>16</sub>	16.28	0.28	0.00	7.70	8.69
(ii)	6 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub> x 18 <sup>11</sup> / <sub>16</sub>	—	28.27	—	—	28.57
(iii)	Clay products	—	—	—	—	—
(iv)	Fancy Blocks	—	—	—	—	—
3.	<u>Ventilation</u>					
(i)	Louvres					
	Plain type					
	36 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	36.84	44.95	—	25.00	35.59
	30 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	50.68	37.89	—	22.20	36.92
	24 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	29.41	26.03	—	23.80	26.41
	Obscure type					
	36 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	44.44	114.10	—	40.00	66.18
	30 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	17.65	15.52	—	42.90	25.36
	24 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub>	58.82	26.44	—	—	42.63
(iii)	Plywood					
	Ordinary type					
	¼ <sup>11</sup> / <sub>16</sub>	—	34.85	—	—	34.85
	½ <sup>11</sup> / <sub>16</sub>	—	54.76	—	—	54.76
	¾ <sup>11</sup> / <sub>16</sub>	—	145.20	—	—	145.20
	Veneer type					
	¼ <sup>11</sup> / <sub>16</sub>	—	29.20	—	—	29.20
	½ <sup>11</sup> / <sub>16</sub>	—	73.82	—	—	73.82
4.	<u>Roofing and Ceiling</u>					
	Planks: Hard Wood					
	1 <sup>6</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	82.90	—	183.33	133.115
	1½ <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	90.84	—	122.00	106.42
	2 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	53.85	—	71.43	62.64
	2 <sup>11</sup> / <sub>16</sub> x 6 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	59.58	—	100.00	79.79
	2 <sup>11</sup> / <sub>16</sub> x 4 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	43.65	—	110.53	77.08
	2 <sup>11</sup> / <sub>16</sub> x 3 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	30.83	—	86.70	58.76
	2 <sup>11</sup> / <sub>16</sub> x 2 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	61.43	—	58.33	59.88
	3 <sup>11</sup> / <sub>16</sub> x 4 <sup>11</sup> / <sub>16</sub> x 12 <sup>11</sup> / <sub>16</sub>	—	52.92	—	57.14	55.04

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
	Soft Wood					
	1 <sup>''</sup> x 12 <sup>''</sup> x 12 <sup>''</sup>	—	58.57	—	83.33	70.95
	1½ <sup>''</sup> x 12 <sup>''</sup> x 12 <sup>''</sup>	—	44.88	—	40.00	42.44
	2 <sup>''</sup> x 12 <sup>''</sup> x 12 <sup>''</sup>	—	58.25	—	—	58.25
	2 <sup>''</sup> x 6 <sup>''</sup> x 12 <sup>''</sup>	—	70.87	—	25.00	47.94
	2 <sup>''</sup> x 4 <sup>''</sup> x 12 <sup>''</sup>	—	101.20	—	32.00	66.60
	2 <sup>''</sup> x 3 <sup>''</sup> x 12 <sup>''</sup>	—	43.20	—	—	43.20
	2 <sup>''</sup> x 2 <sup>''</sup> x 12 <sup>''</sup>	—	57.89	—	73.30	65.60
	3 <sup>''</sup> x 4 <sup>''</sup> x 12 <sup>''</sup>	—	70.87	—	88.90	79.88
(ii)	<u>G. C. I. Sheets</u>					
	Olowo Brand	18.70	116.07	—	—	17.39
	Ordinary Brand	35.42	26.08	—	17.94	26.48
	5 Stars „	—	—	33.85	—	33.85
	3 „ „	—	—	43.75	—	43.75
	Swan „	—	—	52.94	—	52.94
	Carmel Star Brand	—	—	33.85	—	33.85
(iii)	<u>Asbestos Sheets</u>					
	4 <sup>''</sup> x 4 <sup>''</sup>	—	32.82	—	86.70	59.76
	8 <sup>''</sup> x 3½ <sup>''</sup>	—	—	33.82	—	33.33
	6 <sup>''</sup> x 3½ <sup>''</sup>	—	—	25.00	—	25.00
(iv)	<u>Aluminium Sheets</u>	—	—	—	—	—
(v)	<u>Nails</u>					
	½ <sup>''</sup>	100.00	—	11.11	—	55.50
	1 <sup>''</sup>	8.33	17.19	5.71	—	10.41
	1½ <sup>''</sup>	12.50	2.78	8.70	—	0.34
	2 <sup>''</sup>	35.59	30.47	15.15	—	27.07
	2½ <sup>''</sup>	35.49	54.47	17.86	—	24.06
	3 <sup>''</sup>	190.90	16.42	21.43	—	76.25
	4 <sup>''</sup>	20.00	16.42	17.86	—	6.19
	5 <sup>''</sup>	—	45.45	—	—	45.45
	6 <sup>''</sup>	20.00	36.36	-17.86	—	12.83
(vi)	<u>Asbestos Ceiling Boards</u>					
	4 <sup>''</sup> x 4 <sup>''</sup>	30.00	22.38	9.52	—	20.63
	0 x 4 <sup>''</sup> — 0 x ¼ <sup>''</sup> flat	32.14	—	—	—	32.14
(vii)	<u>Cardboard</u>					
	4 <sup>''</sup> x 8 <sup>''</sup> x 16 <sup>''</sup>	78.97	93.30	—	27.80	66.69
	4 <sup>''</sup> x 4 <sup>''</sup> x 16 <sup>''</sup>	—	—	27.27	—	27.27
(viii)	<u>Ceiling Tile</u>					
	0 x 2 <sup>''</sup> — 0 x 3/8 <sup>''</sup>	260.00	33.33	—	5.88	99.74

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
5:	<b>Painting</b>					
(i)	Gypsum lime	—	—	—	—	—
(ii)	Undercoat	7.50	213.20	9.09	25.49	58.53
(iii)	Wood Primer	8.19	108.25	—	60.00	58.81
(iv)	Emulsion Paints (Assorted)	21.00	91.75	7.40	8.57	32.18
(v)	Gloss Paints (Assorted)	8.57	106.60	14.00	20.00	30.29
6.	<b>Sanitary Wares</b>					
(i)	<b>Water Closets</b>					
	White high level w.c.	31.25	60.00	—	16.70	35.98
	White low level w.c.	123.33	—	—	16.70	70.02
	Coloured high level w.c.	5.00	—	—	33.30	19.15
	22" x 16" (Lavatory Basin)	94.74	40.00	—	46.70	60.48
(ii)	<b>Wash Hand Basin</b>					
	White Small Size	87.50	25.00	—	12.50	41.66
	White Medium Size	150.00	20.25	—	—	—
	White Large Size	181.25	30.00	—	16.70	85.13
	Coloured, Small Size	—	18.42	—	—	18.42
(iii)	<b>Sink</b>					
	Stainless Single bowl	100.00	50.81	—	—	75.41
	Stainless Double bowl	250.00	31.17	—	—	140.59
	Ceramic Single bowl	87.50	—	—	—	87.50
	Ceramic Double bowl	150.00	—	—	—	150.00
(iv)	<b>Showers</b>					
	Roses (L. M.)	47.00	25.00	—	40.00	37.33
	Telephone (Single Mixer)	—	—	—	8.69	8.69
	Telephone (Double Mixer)	—	150.00	—	11.54	80.77
	Pillar tap (Single Mixer)	—	—	—	27.80	27.80
	Pillar tap (Double Mixer)	—	—	—	28.21	28.21
(v)	<b>Galvanized Pipes</b>					
	¼"	45.80	—	—	—	45.80
	½"	57.67	15.56	—	11.10	27.44
	¾"	50.00	39.00	—	10.00	33.00
	1"	42.49	37.45	—	4.62	28.19
	1½"	35.06	48.00	—	—	41.53
	2"	11.11	44.80	—	—	27.95
	<b>P.V.C. Pipes</b>					
	½"	—	—	—	33.30	33.30
	¾"	—	—	—	27.80	27.80
	1"	—	—	—	20.00	20.00
	1¼"	200.00	—	—	—	200.00
	1½"	100.00	266.67	—	—	183.33
	2"	114.29	75.00	—	—	94.64

Source: Field Survey, May, 1984.

**TABLE II**  
**PERCENTAGE CHANGE IN THE PRICES OF BUILDING MATERIALS IN NIGERIA,**  
**1979 - 84**

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
1.	<b>Flooring</b>					
(i)	Granites (per lorry load)	—	—	—	—	—
	10 mm	—	—	—	—	—
	12 mm	—	—	—	—	—
	16 mm	—	—	-8.0	—	-8.0
	150 mm Hard Core	—	—	-9.6	—	-9.6
(ii)	Sand (per lorry load)					
	Soft	66.67	36.36	15.20	—	39.41
(iii)	Gravel (per lorry load)					
	Washed „	163.60	33.33	8.47	—	68.47
	Unwashed „	175.00	28.56	3.23	—	68.93
(iv)	<b>Cement</b>					
	Plain	117.50	25.73	110.36	30.71	71.08
	Coloured cement	—	—	—	—	—
(v)	<b>Iron rods: High Tensil</b>					
	¼ <sup>in</sup> x 30	68.75	20.70	78.57	—	56.00
	3/8 <sup>in</sup> x 30	100.00	74.69	180.69	—	118.46
	½ <sup>in</sup> x 30	103.20	46.63	227.17	—	125.66
	5/8 <sup>in</sup> x 30	85.71	46.63	142.83	—	91.72
	¾ <sup>in</sup> x 30	76.53	66.67	100.00	—	81.07
	7/8 <sup>in</sup> x 30	86.67	37.76	114.09	—	79.50
	1 <sup>in</sup> x 30	—	78.57	—	—	78.57
	Round Bars					
	¼ <sup>in</sup> x 30	154.50	—	146.67	—	150.58
	3/8 <sup>in</sup> x 30	143.00	75.00	125.00	—	114.33
	½ <sup>in</sup> x 30	102.70	—	76.47	—	89.59
	5/8 <sup>in</sup> x 30	110.30	—	42.16	—	76.23
	¾ <sup>in</sup> x 30	—	—	—	—	—
	7/8 <sup>in</sup> x 30	120.80	—	—	—	120.80
	1 <sup>in</sup> x 30	78.67	—	—	—	78.67
(vi)	10 <sup>in</sup> x 10 <sup>in</sup> (128 pieces)	—	—	20.00	—	20.00
	p.v.c. 9 <sup>in</sup> x 9 <sup>in</sup> x 1/8 <sup>in</sup>	34.60	—	11.11	—	22.86
	0 x 2 <sup>in</sup> — 0 x 3/8 <sup>in</sup>	—	—	7.14	—	7.14
	Ceramic					
	15 x 15mm (White per m <sup>2</sup> )	90.90	—	—	—	90.90
	20 x 20 cm „	15.18	—	—	—	15.18
	8 <sup>in</sup> x 8 <sup>in</sup> per carton	—	—	1.36	—	1.36

No.	Material	Lagos	Ibadan	Enugu	Kaduna	Nigeria
(vii)	Terrazo White (per bag)	—	—	-16.40	26.70	5.15
	Black „	—	—	25.00	100.00	62.50
	Marble tiles	—	—	40.00	—	40.00
2.	<u>Walling</u> <u>VConcrete Blocks</u>					
	9 <sup>1/2</sup> x 9 <sup>1/2</sup> x 18 <sup>1/2</sup>	41.67	33.33	30.77	—	35.26
	6 <sup>1/2</sup> x 9 <sup>1/2</sup> x 18 <sup>1/2</sup>	26.00	55.55	25.00	—	35.52
	6 <sup>1/2</sup> x 6 <sup>1/2</sup> x 18 <sup>1/2</sup>	—	33.33	11.10	—	22.22
(ii)	Fancy Blocks 6 <sup>1/2</sup> x 4 <sup>1/2</sup> x 18 <sup>1/2</sup>	—	—	—	—	—
3.	<u>Ventilation:</u>					
(i)	<u>Louvres</u>					
	Plain type					
	36 <sup>1/2</sup> x 6 <sup>1/2</sup>	323.07	277.20	112.78	233.30	236.59
	30 <sup>1/2</sup> x 6 <sup>1/2</sup>	309.09	293.90	200.00	327.30	282.57
	24 <sup>1/2</sup> x 6 <sup>1/2</sup>	279.50	313.04	61.11	169.20	205.71
	Obscure type					
	36 <sup>1/2</sup> x 6 <sup>1/2</sup>	323.08	274.90	80.00	364.30	260.57
	30 <sup>1/2</sup> x 6 <sup>1/2</sup>	350.00	307.50	40.63	250.00	237.03
	24 <sup>1/2</sup> x 6 <sup>1/2</sup>	209.25	263.60	57.22	—	176.69
(ii)	<u>Plywood</u>					
	Ordinary type					
	1/4 <sup>1/2</sup>	214.29	114.80	148.93	—	159.34
	1/2 <sup>1/2</sup>	105.88	72.92	44.44	—	74.41
	3/4 <sup>1/2</sup>	73.91	73.04	33.32	—	60.09
	Veneer type					
	1/4 <sup>1/2</sup>	86.67	94.08	34.98	—	71.91
	1/2 <sup>1/2</sup>	—	665.08	18.20	—	41.64
4.	<u>Roofing and Ceiling</u>					
(i)	<u>Planks</u>					
	Hardwood					
	1 <sup>1/2</sup> x 12 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	14.64	25.00	-16.67	7.66
	1 <sup>1/2</sup> x 12 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	33.33	11.36	-15.00	9.89
	2 <sup>1/2</sup> x 12 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	13.30	10.00	-20.83	0.82
	2 <sup>1/2</sup> x 6 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	39.16	10.00	-16.67	10.83
	2 <sup>1/2</sup> x 4 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	35.34	15.38	-12.50	12.74
	2 <sup>1/2</sup> x 3 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	38.85	18.42	-7.14	16.71
	2 <sup>1/2</sup> x 2 <sup>1/2</sup> x 12 <sup>1/2</sup>	—	8.85	16.70	-5.26	6.76

No.	Material	Lagos	Ibadan	Enugu	Kaduna	Nigeria
	3" x 4" x 12'	—	6.81	18.75	-3.64	7.31
	½" x 2" x 12'	—	—	50.00	—	50.00
	Softwood					
	1" x 12" x 12"	—	12.01	6.70	-5.50	4.40
	1½" x 12" x 12'	—	21.95	10.53	-16.67	5.27
	2" x 12" x 12'	—	10.58	7.70	—	9.14
	2" x 6" x 12'	—	7.37	14.30	6.67	9.45
	2" x 4" x 12'	—	10.18	14.60	15.20	13.33
	2" x 3" x 12'	—	53.01	16.70	13.64	27.78
	2" x 2" x 12'	—	38.33	4.80	53.85	32.33
	3" x 4" x 12'	—	7.37	15.40	41.18	21.32
	½" x 2" x 12'	—	—	66.70	—	66.70
(ii)	<u>G. C. I. Sheets</u>					
	Olowo Brand	263.00	290.00	—	—	276.50
	Ordinary Brand	278.90	338.20	—	421.74	345.61
	5 Stars Brand	—	—	141.38	—	141.38
	3 Stars Brand	—	—	313.04	—	313.04
	Swan Brand	—	—	323.08	—	323.08
	Carmel Star Branch	—	—	141.38	—	141.38
(iii)	<u>Asbestos Sheets</u>					
	4' x 4'	—	—	—	—	—
	8' x 3½'	—	68.60	20.63	—	44.62
	6' x 3½'	—	—	22.50	—	22.50
(iv)	<u>Aluminium Sheets</u>	—	—	—	—	—
(v)	<u>Nails</u>					
	½"	150.00	200.00	460.00	18.52	457.13
	1"	515.38	780.00	386.49	25.00	426.72
	1½"	677.70	734.30	239.05	26.67	419.43
	2"	150.00	152.90	123.68	25.00	112.89
	2½"	150.00	117.50	413.04	27.27	176.95
	3"	89.20	149.50	88.24	7.14	83.52
	4'	150.00	142.70	173.91	7.69	118.50
	5"	—	103.10	—	—	103.10
	6"	150.00	86.67	182.61	7.69	106.74
(vi)	<u>Asbestos Ceiling Boards</u>					
	4' x 4' x 4'	13.23	35.89	36.09	42.86	32.02
	0 x 4' - 0 x ¼ Flat	4.05	—	—	—	4.05

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
(vii)	<u>Card Board</u>					
	4' x 8' x 16'	40.29	58.40	—	160.87	86.52
	4' x 4' x 16'	—	—	89.14	—	89.14
(viii)	<u>Ceiling Tile</u>					
	0 x 2'' - 0 x 3/8''	-7.78	—	—	111.10	57.66
5.	<u>Painting</u>					
(i)	Gypsum Lime	—	—	—	—	—
(ii)	Undercoat	44.00	106.50	45.00	66.67	65.54
(iii)	Woodprimer	19.43	79.23	60.00	25.00	45.92
(iv)	Emulsion Paints (Asstd.)	15.37	86.96	57.00	59.21	54.64
(v)	Gloss Paints „	10.33	71.06	54.98	100.00	59.09
6.	<u>Sanitary Wares</u>					
(i)	<u>Water Closets</u>					
	White high level w.c.	176.20	75.00	—	107.25	119.45
	White low level w.c.	152.20	—	—	71.43	111.82
	Coloured high level w.c.	—	—	—	41.67	41.67
	22'' x 16'' Lavatory Basin	379.70	42.86	—	70.45	164.34
(ii)	<u>Wash Hand Basin</u>					
	White Small size	308.30	60.00	—	85.49	151.16
	White Medium size	200.00	68.42	—	—	134.21
	White Large size	161.10	125.90	—	114.29	133.76
	Coloured Small size	—	23.56	—	—	23.56
(iii)	<u>Sink</u>					
	Stainless single bowl	319.60	141.04	—	228.13	229.59
	Stainless double bowl	312.40	104.40	—	300.00	238.93
	Ceramic single bowl	200.00	70.00	—	—	135.00
	Ceramic double bowl	233.30	94.40	—	—	163.85
(iv)	<u>Showers</u>					
	Roses (L. M.)	60.00	700.00	—	257.14	139.05
	Telephone (Single Mixer)	—	28.57	—	240.00	134.29
	Telephone (Double Mixer)	33.33	28.57	—	151.70	71.20
	Pillartap (Single Mixer)	—	11.11	—	95.65	53.38
	Pillartap (Double Mixer)	—	80.00	—	200.00	150.00
(v)	<u>Galvanized Pipes</u>					
	1/4''	—	—	—	—	—
	1/2''	160.60	73.08	—	200.00	144.56

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
	3/4"	161.20	79.86	—	209.09	150.05
	1"	194.50	177.78	—	223.53	198.60
	1 1/2"	29.50	181.53	—	322.22	177.75
	2"	305.00	141.71	—	300.00	248.50
	P. V. C. Pipe					
	1/2"	—	175.00	—	25.00	100.00
	3/4"	—	83.33	—	95.65	89.49
	1"	—	166.67	—	66.67	116.67
	1 1/4"	66.70	—	—	83.30	75.00
	1 1/2"	66.70	63.64	—	100.00	76.78
	2"	83.30	67.14	—	100.00	83.48

As evident from Table 2, the 1979 – 1984 period represents an era of very high inflation in the prices of building materials. During the period, cement had between 25.73% and 117.50% price change; iron rods experienced 42.16% to 227.17% price increase, while concrete blocks had between 11.10% and 55.55% price increase within the study areas. As for ventilation materials, all of them experienced phenomenal price increases. For example, plain louvres had between 61.11% and 327.30% price increase; obscure type louvres had between 40.63% and 364.30% price increase; while ordinary and veneer plywoods experienced 33.32% to 214.29% and 18.20% to 94.08% price increases, respectively. Similarly, roofing and ceiling materials, especially G.C.I. sheets and iron nails had phenomenal price increases. The same is true of virtually all categories of sanitary wares, most of which were imported.

It is pertinent to note that despite the generally high price increases on most building materials in all parts of the country, during this period, Enugu had negative price changes on gravel, tiles and terrazo. Ibadan experienced least changes on

cement and iron rods, while the negative price changes recorded for almost all types of wooden planks in Kaduna is unbelievable. Concrete blocks increased in price by about four times during this period when compared with the 1974–1979 period.

Table 3 shows the percentage increases in price over the decade. The changes in the prices are very high indeed. While a few items of building materials such as granites, soft sand, flooring tiles, terrazo, concrete blocks, all categories of wooden planks and asbestos ceiling boards experienced under 100 per cent price increase during the period, all the other items increased by between two and six folds during the decade. Cement which is a very essential item of building had 185.52% price increase; iron rods had between 98.28% and 245.33% increase; louvres had between 348.34% and 587.89%; while plywood (of all types) had between 136.75% and 202.00% price increase. Cardboards, paints and iron nails are also in this group. The generally high inflation which characterized most of the building materials is an indicator of the hinderances to housing supply in Nigeria.

TABLE 3

PERCENTAGE CHANGE IN THE PRICES OF BUILDING MATERIALS IN NIGERIA,  
1974 - 84.

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
1.	<b>Flooring</b>					
	Granites (per lorry load)					
	10mm            ,,	—	100.00	-7.14	—	46.43
	12mm            ,,	—	100.00	-3.85	—	48.08
	16mm            ,,	—	100.00	-11.54	—	44.23
	150mm Hard Core ,,	—	50.00	-9.62	—	20.19
(ii)	<b>Sand</b> (per lorry load)					
	Soft             ,,	100.00	150.00	15.20	—	88.40
(iii)	<b>Gravel</b> (per lorry load)					
	Washed         ,,	314.29	100.00	8.47	—	140.92
	Unwashed      ,,	292.86	127.88	3.23	—	141.32
(iv)	<b>Cement</b>					
	Plain	—	—	—	—	—
	Coloured Cement	—	—	—	—	—
(v)	<b>Iron Rods</b>					
	High Tensil					
	¼" x 30'	68.75	76.03	150.00	—	98.26
	3/8" x 30'	137.50	132.62	225.30	—	175.14
	½" x 30'	154.17	85.71	308.96	—	182.77
	5/8" x 30'	225.00	85.71	229.41	—	180.04
	¾" x 30'	120.83	133.33	169.23	—	141.13
	7/8" x 30'	—	133.33	—	—	133.33
	1" x 30'	180.00	92.86	165.48	—	146.11
	Round Bars					
	¼" x 30'	179.54	—	311.11	—	245.35
	3/8" x 30'	168.87	191.67	265.63	—	208.72
	½" x 30'	200.00	—	183.02	—	191.51
	5/8" x 30'	189.78	—	81.25	—	132.52
	7/8" x 30'	194.44	—	—	—	194.44
	1" x 30'	197.78	—	—	—	197.78
(vi)	<b>Tiles</b>					
	10" x 10" (128 pieces)	—	—	20.00	—	20.00
	P. V. C. 9" x 9" x 1/8"	63.60	—	11.11	—	37.36
	0 x 2" — 0 x 3/8"	232.00	50.00	—	123.50	135.17
	Ceramic					
	15 x 15 cm (white per m <sup>2</sup> )	186.49	—	—	—	186.49
	20 x 20 cm            ,,	49.06	—	—	—	49.06
	8" x 8" per carton	—	—	1.36	—	-1.36

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
(vii)	<u>Terrazo</u> White (per bag) Black „ Marble tiles	— — —	— — —	-7.11 66.70 40.00	100.00 26.70 —	46.45 46.70 40.00
2.	<u>Walling</u>					
(i)	<u>Concrete Blocks</u> 9'' x 9'' x 18'' 6'' x 9'' x 18''	41.67 46.50 —	45.45 55.55 71.43	41.70 34.60 —	— — —	42.94 45.55 71.43
(ii)	<u>Fancy Blocks</u> 6'' x 4'' x 18''	—	—	11.10	—	11.10
3.	<u>Ventilation</u>					
(i)	<u>Lourves: Plain type</u> 36'' x 6'' 30'' x 6'' 24'' x 6''	478.95 516.44 391.18	446.79 443.16 420.55	— — —	316.70 422.20 233.30	414.15 460.60 348.34
(ii)	<u>Plywood</u> Ordinary type ¼'' ½'' ¾'' Veneer type ¼'' ½''	214.29 105.88 73.91 — —	189.71 107.62 324.31 150.75 186.95	— — — — —	— — — — —	202.00 136.75 199.11 150.75 186.95
4.	<u>Roofing and Ceiling</u>					
(i)	<u>Planks</u> Hardwood 1'' x 12'' x 12' 1½'' x 12'' x 12' 2'' x 12'' x 12' 2'' x 6'' x 12' 2'' x 4'' x 12' 2'' x 3'' x 12' 2'' x 2'' x 12' 3'' x 4'' x 12' ½'' x 2'' x 12'  Softwood 1'' x 12'' x 12' 1½'' x 12'' x 12' 2'' x 12'' x 12' 2'' x 6'' x 12' ½'' x 2'' x 12'	— — — — — — — — — —  — — — — —	109.68 154.45 74.31 122.08 94.42 81.67 75.77 63.33 —  77.60 76.68 75.00 83.46 —	25.00 11.36 10.00 10.00 15.38 18.42 16.70 18.75 50.00  6.70 10.53 7.70 15.40 66.70	100.00 88.90 35.71 66.70 84.21 73.30 50.00 54.43 —  50.00 20.00 — 166.70 —	58.67 63.68 40.00 49.69 48.50 43.35 35.60 33.38 50.00  33.58 35.74 41.35 66.39 66.70

No.	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
(ii)	<u>G. C. I. Sheet</u>					
	Olowo Brand	330.89	352.68	—	—	341.79
	Ordinary Brand	410.42	452.47	—	513.40	459.43
	5 Stars Brand	—	—	223.08	—	223.08
	3 Stars Brand	—	—	493.75	—	493.75
	Swan Brand	—	—	547.10	—	547.10
	Carmel Star Brand	—	—	223.10	—	223.10
(iii)	<u>Asbestos Sheets</u>					
	4' x 4'	—	123.94	—	—	123.94
	8' x 3½'	—	—	60.83	—	60.83
	6' x 3½'	—	—	53.13	—	53.13
(iv)	<u>Aluminium Sheets</u>	—	—	—	—	—
(v)	<u>Nails</u>					
	½"	400.00	—	522.20	77.80	333.30
	1"	566.67	931.25	114.30	84.21	499.11
	1½"	775.00	711.11	209.60	100.00	448.93
	2"	238.98	229.93	157.58	100.00	181.62
	2½"	238.98	236.00	321.45	90.30	221.83
	3"	154.55	190.45	128.57	50.00	130.89
	4"	200.00	182.56	125.00	55.60	140.79
	5"	—	195.45	—	—	195.45
	6"	200.00	154.55	132.14	55.60	135.57
(vi)	<u>Asbestos Ceiling Board</u>					
	4 x 4	47.20	66.19	49.05	166.70	82.29
	0 x 4' - 0 x ¼" Flat	37.50	—	—	—	37.50
(vii)	<u>Cardboard</u>					
	4' x 8' x 16'	151.07	206.19	—	233.30	196.85
	4 x 4 x 16	—	—	141.09	—	141.09
(viii)	<u>Ceiling Tile</u>					
	0 x 2" - 0 x 3/8"	232.00	50.00	—	123.50	135.17
5.	<u>Painting</u>					
(i)	Gypsum lime	—	—	—	—	—
(ii)	Undercoat	54.80	546.80	31.82	104.00	184.38
(iii)	Wood primer	29.21	273.25	60.00	100.00	115.62
(iv)	Emulsion paints (Assrtd.)	39.60	225.00	68.62	71.43	101.16
(v)	Gloss Paints	19.79	253.40	33.28	140.00	111.62
6.	<u>Sanitary ware</u>					
(i)	<u>Water Closets</u>					
	White High Level W. C.	265.50	180.00	—	141.70	195.73
	White low Level W. C.	463.33	—	—	100.00	281.67

No	Materials	Lagos	Ibadan	Enugu	Kaduna	Nigeria
	Coloured High Level W.C. 22" x 16" Lavatory Basin	— 834.21	— 100.00	— —	88.90 150.00	88.90 361.40
(ii)	<u>Wash Hand Basins</u>					
	White small size	665.63	100.00	—	108.30	873.93
	White medium size	650.00	102.53	—	150.00	300.84
	White large size	634.38	193.75	—	—	414.07
	Coloured small size	485.00	46.32	—	—	265.66
(iii)	<u>Sink</u>					
	Stainless single bowl	739.13	257.14	—	—	498.14
	Stainless double bowl	1,343.30	168.17	—	—	755.74
	Ceramic single bowl	462.50	70.00	—	—	266.25
	Ceramic double bowl	733.33	94.40	—	—	413.87
(iv)	<u>Showers</u>					
	Roses (L. M.)	135.29	150.00	—	400.00	228.43
	Tele. (single mixer)	—	—	—	269.60	269.60
	Tele. (double mixer)	—	233.33	—	180.80	207.07
	Pillar tap (single mixer)	—	—	—	310.30	310.30
(v)	<u>Galvanized Pipes</u>					
	¼"	254.55	—	—	—	254.55
	½"	305.67	100.00	—	233.30	212.99
	¾"	291.75	150.00	—	240.00	227.25
	1"	319.63	281.82	—	238.50	279.98
	1½"	74.90	48.00	—	322.20	148.37
	2"	350.00	44.80	—	300.00	231.60
(vi)	<u>P. V. C. Pipes</u>					
	½"	—	—	—	66.70	66.70
	¾"	—	—	—	150.00	150.00
	1"	—	—	—	100.00	100.00
	1¼"	400.00	—	—	83.30	241.65
	1½"	233.30	500.00	—	100.00	277.77
	2"	292.86	175.00	—	100.00	189.29

## EXPLANATORY FACTORS

The unabated inflationary pressures on most building materials during the past ten years can be attributed to various reasons, some of which are listed below:

- (i) The large scale housing programmes of the federal and state governments put sudden and high pressure on demand.
- (ii) The reckless pace and style of development of the new federal capital, Abuja led to increased demand and artificial inflation which affected all parts of the country. During the 1979–83 period in particular "spending-maniac" psychology pervaded the country and gave everybody the impression that Abuja is the mine that creates emergency contractors and overnight millionaires. The sellers, producers and importers of building materials also cashed in on the psychology to inflate their prices.
- (iii) The turbulent political atmosphere in the 1979–83 era did not provide a suitable atmosphere for rapid national economic development. During this period, a number of factories jointly owned by many states and the federal governments were shaken or even closed down due to disagreement on operational modalities preferred by the individual joint owners. For example, the Igbeti Marble Industry was closed down (and it remained closed till 1984) because of disagreement between the federal government, the Oyo State Government and one of the original owners of the factory. So also was the Nkalagu Cement Factory closed down over political disagreements between the Imo and Anambra State Governments who are the joint owners of the company. O'dua Investment Company, jointly owned by Oyo, Ondo and Ogun State Governments, was seriously shaken and nearly split, over misunderstandings on issues.
- (iv) There was also large scale mismanagement of many public corporations such as the plywood factories, sawmills and steel rolling mills. This led to high cost of finished products and the closure of some of such factories. In Oyo State for example, the Government Sawmill at Gambari was closed down due to financial mis-management. So also was the Ondo State Clay Bricks Factory.
- (v) Absence or unreliability of essential public utilities such as water and electricity and inadequate services forced many industrial concerns to generate their own utilities at high costs which are later added on to the cost of finished goods.
- (vi) A greater emphasis was placed on public welfare schemes in many states of the federation at the expense of investments in the building materials industry. This puts a lot of pressure on the existing production levels thereby encouraging the importation of such materials at high prices.
- (vii) This period also witness the worst period of inflation in all sectors throughout Nigeria and this affected the building industry too. Foreigners cashed in on the oil boom and introduced a number of strategies to siphon the money away to their countries with the complicity of our leaders and businessmen.
- (viii) It was also a period of serious political instability and economic mis-management of the country which led many organisations, both in the private and public sectors to cut down on production shifts.
- (ix) There has been a heavy dependence on imported building materials, as a result, foreign inflation was nationally imported; the unfair logistics of allocation of imported licences and the gross mismanagement of the distribution processes escalated the cost of the imported goods.
- (x) The middlemen compounded the difficulties through hoarding, imposition of very excessive profit margins and creation of an unwarranted chain of hierarchical distributors. Each hierarchy of distributors doubles the selling prices of goods and by the time the goods reach the ultimate consumers the costs are prohibitive.
- (xi) Local Technology in the area of building remains virtually underdeveloped hence, the increasing dependence on foreign technology, imported building materials and very high component of imported materials in most of our buildings. A cursory analysis of a "modern" house will reveal that apart from the wood used for window frames and roof nugging, the sand and gravel for infilling for foundation, most of the other materials are wholly or partly imported. This is not a pleasant trend for a country that requires some 10 million dwelling units to meet the backlog in housing needs.

It is significant to note that the costs of the materials made in Nigeria are not cheap either — the rates of inflation were as high on them as those imported. This calls for further research on the processes and factors that were responsible.

## RECOMMENDATIONS AND CONCLUSIONS

The facts presented in this paper confirm the general notion that the rate of inflation in Nigeria is alarming. The rates in the area of building materials have reached a very disturbing level. The recommendations of the Anti-Inflation Task Force seem to have failed in stemming the galloping trend. The gross mismanagement of the economy and the indiscrete and corrupt nature of contract awards during the last civilian regime worsened the situation. To rectify the situation, steps must be taken along the following lines:—

1. The country should set for herself a goal to make Nigeria self-sufficient in the area of building materials within the next five years and the machineries of government should be mobilized to achieve this target.
2. All the available raw materials for the building industry in the country must be identified and conscious efforts should be made to exploit them.
3. All publicly owned building materials factories like those manufacturing cement, clay bricks, marble and the publicly owned saw-mills and plywood factories, previously closed down for political reasons or due to mismanagement or non-availability of essential raw materials should be re-opened as a matter of priority.
4. The public utilities companies like NEPA, the Water Corporation and the NITEL should be supported to improve their services substantially to bring down the cost of industrial production, and hence the cost of finished goods.
5. The Military Government should pursue with vigour its efforts to promote a favourable political climate conducive to rapid economic recovery of the nation.
6. Since wooden planks had relatively lower price increases within the last decade when compared with most other essential building materials, efforts should be made to promote increased afforestation throughout the country. In addition, wooden structures should be considered as substitutes for the conventional block and mortar type of structures, where suitable.
7. In order to bring down housing construction cost, all levels of government should encourage the establishment of cooperative societies for direct construction and distribution of building materials on behalf of its members. Such cooperative societies should have access to the funds of the Federal Mortgage Bank through the different Building Societies that should be set up.
8. For as long as the import content of our building materials is high, the cost of owning a home will be high. As a means of bringing down housing cost, government should encourage the establishment of industries for the production of building materials.
9. With reference to local materials, many writers have recommended the use of local materials as a way of cutting down the cost of housing in Nigeria.
  - (a) The question is what type of local materials, for what type of housing and at what cost in terms of money and level of comfort. What is the nature of the demand for "modern" housing? Research on modern and traditional building materials and methods in Nigeria has not received the desired attention from either the universities or government agencies.
  - (b) Much research is needed on low-cost masonry materials and components. For example, there is need for research on how to improve on the commonly used materials such as adobe, concrete block, burnt-clay brick and precast concrete.
  - (c) Research is needed on the use of stabilised earth using asphalt, rubber, petroleum residues and cementitious materials.
  - (d) There is need to investigate the use in Nigeria of fibrous materials such as lignocellulose, particle boards, sugar-cane residue, bamboo and bagasse.
  - (e) The possibility of bamboo reinforcement for concrete is another area for future research.
  - (f) The area of wood construction is another field for research. In parts of the country, woods are still plentiful and they could be excellent materials for low cost housing. Research is needed on the use of mixed hardwood species and on the seasoning, preservation and maintenance of woods.
  - (g) Polymeric materials including plastics are becoming increasingly important in the housing construction industry. For example, there is increasing demand for water-proof plywood and particle board and these depend on plastics based adhesives. Moreover, plastic piping for water supply and in-household plumbing has been shown to have an advantages over the asbestos pipes more commonly used in Nigeria. With the increase in the number of refineries in the country, research should look into the possible production and promotion of polymeric materials for the housing industry.

10. The existing research efforts on building materials should be regionalised and government should come out to invest heavily on research on building materials. It is necessary to properly fund the Nigerian Building and Road Research Institute.
11. Government should spearhead the promotion of the establishment of building materials industries in Nigeria. The private sector should however be allowed to have controlling shares as a way of ensuring efficient management.
12. With reference to the construction industry, the home-building industry in this country needs a thorough research which will assist in determining the problems and constraints. Most of the foreign construction firms are succeeding and performing efficiently; whereas most of the indigenous construction companies have been known to be incompetently and inefficiently run organizations with consequent poor performance. The simplistic approach is to abandon the indigenous constructors and patronise the foreign ones. However, this approach is not in the best interest of Nigeria as it makes the country technologically backward and continuously dependent on foreign countries. Besides it is an approach that constitutes a drain on our foreign reserve. More importantly, dependency on foreign construction companies is a risk to the security of the nation.

Research should examine the problems hindering the performance of the indigenous construction companies in Nigeria with a view to evolving solutions. Field research has shown that there is a soaring cost in the

house building industry. It is pertinent to examine the trend in housing vis-a-vis the trend in construction cost.

13. With reference to the area of building technology the emphasis of research should be on the application of existing knowledge in the natural and physical sciences. This includes the following:—
  - (i) An analysis of the different soils in Nigeria in terms of their characteristics and behaviour in relation to structure, sanitary disposal and landscaping.
  - (ii) the effect of Nigerian weather on the building industry;
  - (iii) examination of acoustics, illumination and fire prevention problems in Nigerian homes and offices and industrial projects with a view to discovering appropriate materials and structures.
14. The soaring cost of the different building materials has been extensively criticised. However, there are very few studies, if any, that have actually examined the economics of the building materials. Why are the prices of certain building materials unstable? What factors contribute to the price trends of different materials? What are the existing channels of distribution and what are the bottle-necks on the channels? Does monopolization of distribution exist and what effect has this got on cost? Research, based on case studies, on the above issues will be invaluable to policy and planning. These are areas for future research.

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## THE IMPORTANCE OF RED BRICKS AS FIRE SAFETY DESIGN MEASURES FOR BUILDINGS IN NIGERIA

By

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### ABSTRACT:

*The objectives of this paper is to discuss the state of the art in architectural and structural fire resistant design concepts. Hence, the paper is intended to discuss in depth the thermal properties of construction materials such as steel, concrete and much more importantly, red bricks. In addition to the above, this paper also covers the relative flammability considerations which builders, architects and engineers should consider seriously in specifying building finishes.*

*Finally, the paper will propose appropriate recommendations on utilization of red bricks for structural and architectural protection of buildings, particularly low cost housing estates and high-rise buildings. It is relevant to mention that this paper is primarily a state of the art paper based on literature survey and engineering research and practice experience. Further to the above comment, the paper is intended to stimulate discussions on this very important area of fire resistant design using abundant Nigeria clay. This measure will be in line with self-reliance through the new import substitution strategy of the Federal Military Government.*

### 1. INTRODUCTION:

#### 1.1. Background Information:

Building fire disasters have become a common tragedy in major Nigerian towns, particularly in Lagos where the high-rise trend in property development added a new complexity to an already bad situation. To be specific, the three separate inferno which engulfed the Federal Ministry of Education Building, the Republic Building and Nigerian External Telecommunications Buildings are still traumatic experiences for most Nigerians.

It is relevant to remark that building fires are not limited to Lagos metropolis alone. The Cocoa House disaster still remains a day dream for most citizens of Ibadan and even the entire states of Oyo, Ogun and Ondo. It will be cumbersome to mention specific incidences of fire in many Nigerian towns, but one point that is clear, is that there is an urgent need to discuss the limitations of Nigeria's fire fighting facilities as well as the requirements for fire resistant design and construction practices. Hence, the later is the objective of this paper involving engineers, builders, research fellows and teachers.

#### 1.2. Limitations of Existing Fire Fighting System in Nigeria:

It is important to note that the existing fire fighting equipments in Nigeria are ground based vehicles consisting only of red hydrant trucks, turn table ladder on trailers etc. Hence, the Nigerian fire fighting capability is entirely Ground Based. In the ideal situation an integrated fire command station should combine air, ground and water based equipments. The limitation of an entirely ground based fire fighting force are listed below:—

- (a) As evidenced by the Republic Building and Nigerian External Telecommunications fire incidences, fire victims in high-rise buildings, beyond the reach of turn table ladders, can only jump to their death.
- (b) The hydrant pressure head generated from the red fire truck is unable to effectively deal with conflagration beyond the 5th floor.
- (c) In situation where two high-rise buildings have a close spatial separation, ground based fire equipments are ineffective in protecting the adjacent building from fire spread due to wind or radiation.
- (d) Ground based units are only effective in dealing with floor by floor fire, but in situation where the entire building is engulfed, air and ground units are required.
- (e) In a congested city like Lagos, the time between reporting of and response time to fire emergency situations can be so great that the fire trucks may arrive when situation is hopeless due to high degree of conflagration. Helicopter borne fire operations require minimum response time. It provides a quick movement of firemen to the location. This can be very vital in checking spread and human rescue efforts.
- (f) Ground based fire equipments are not effective in dealing with all types of harbour and ship fires. An integrated fire command centre should have a fire control boat. This facility is not available to Nigerian fire fighters.

### 2.3. Smoke Diffusion as it Affects Circulation, Staircase and Elevator-shaft Design:

It is widely accepted in safety engineering that smoke is a weighted fire fighting problem. To a very large extent, the ability to fight fire in high-rise building and associated rescue activities depends on smoke control within the building envelope. In specific terms, poorly designed stair-shafts enhance early fouling of the air and reduced visibility for firemen. This makes rescue activities extremely difficult because elevator shafts are never recommended for rescue activities during fire situation.

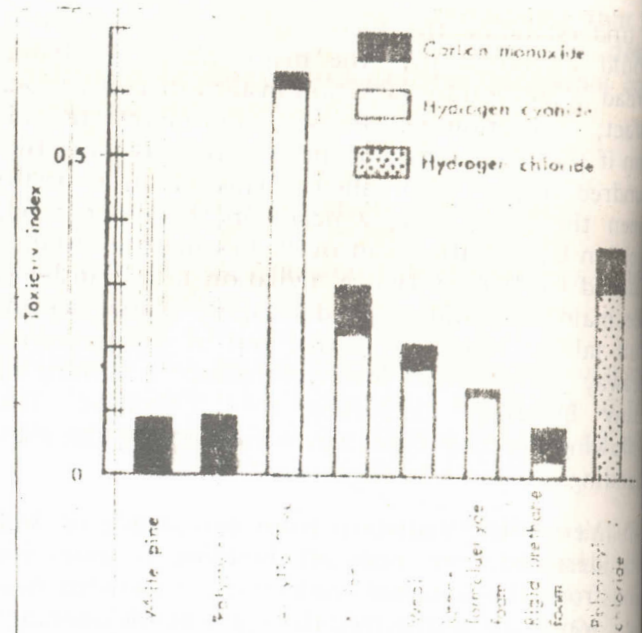
As discussed above it is clear that any design concept that does not fully emphasize the importance of smoke diffusion and stair shaft protection against contamination is grossly inadequate. In design proper, vertical stair shaft is a major channel for smoke diffusion during fire situations. In high occupancy buildings such as hotels, office blocks and public buildings, care should be taken to provide vertical shafts which are nearly divorced from the building.

The design objective above is to ensure a well aerated escape staircase. This does not imply that another functional staircase should not be provided as dictated by the architects conception. In fact, the number of staircases depends on factors like occupancy ratio, activity pattern and layout considerations. However, as far as fire safety design is concerned the writer is of the opinion that stair shaft design must provide adequate exposure for natural ventilation in addition to ease of access to occupants and fire fighters.

In the developed countries like the USA, specific elevator and stair shafts are designated for fire fighting and escape. If the experience of the Republic Building and NET building fire is anything to go by, Nigerian architects and engineers will agree that the above measure is in no way an over-design but a conscious architectural effort to ensure safety.

### 2.4 Building Finishes and Associated Toxic Gases:

It is relevant to discuss the problem of toxic gases created by ignition of cellulosic materials in building components and furnishings. In fire situations in high-rise buildings, toxic gases can be harmful to both occupants and firemen. The Canadian Building Research Institute analysed several building, lining and furnishing materials in order to determine the hydrogen chloride, hydrogen cyanide and carbon monoxide content as a criteria for deriving a toxicity index. Figure 1 illustrates the toxicity rating of a number of these commonly used materials. It is important to note that hydrogen chloride (HCl) is more toxic than carbon monoxide (CO). As evidenced below architects and designers should be extremely careful in the specification of untested synthetic fibres for partitions, ceilings, linings and even prefabricated partitions.



The toxicity index of the combustion products of various materials indicates the relative danger presented when these materials are involved in fire.

FIG. 1: TOXICITY INDEX  
SOURCE (1)

### 3. STRUCTURAL DESIGN PARAMETERS FOR FIRE PROTECTION:

#### 3.1. The Techniques of Structural Fire Protection:

The concept of structural fire protection involves a new design approach to ensure that building elements such as walls, columns, beams, floors, doors are designed with specific materials which meet minimum fire endurance rating. Fire endurance rating of building materials is an indicator of the ability of specific materials to withstand deformation after at least 2 hours of fire exposure.

The basis of fire endurance test is that there is a relationship between heat transmission through a material and the strain-stress response of such material in fire situation. This relationship can be determined through a regression analysis which will integrate such variables as thickness of material, refractive index, strength etc. In developed countries like USA, UK and Japan, manufacturers of building materials are required to specify the endurance rating of each component. This regulation, in effect, simplifies the work of the designer.

It is relevant to discuss the properties of building materials in order to clarify the concept of structural fire protection. One major material which is used as a structural element is steel. The rheological behaviour of steel will be discussed later. Concrete serves a dual purpose in building because of its use as a structural element and for thermal insulation. The properties of red bricks, steel and concrete will be discussed below:

### 3.2 Behaviour of Red Bricks at Elevated Temperature Conditions:

It is generally accepted that fired red brick is resistant to disintegration under high temperature conditions (i.e. temperature above 1,500°C)<sup>8</sup>. This thermal property of red brick, is expected because the production process involves firing in a kiln for at least twenty-four/thirty-six hours, during which the temperature is increased from time to time. Okyere (1978)<sup>8</sup> carried out extensive research on "Brick production in a continuous oil fired kiln" at the Building and Road Research Institute, Kumasi, Ghana. It is relevant to highlight some of the results of the above research in order to illustrate the thermal properties of red bricks.

As shown in Table 2, the plasticity of the entire 45 clay brick samples range from fair to good. The minimum water for plasticity is 12% while maximum is 34% with an average of 22%. Another important phenomenon is the firing shrinkage of the bricks when subjected to high temperature in the range of 1000°C/1100°C. The average firing shrinkage for the 45 brick samples is 1.1%. Hence, this value implies that the firing shrinkage, is in most cases, less than 10% of the drying shrinkage. This phenomenon is indicative of the degree of resistance to crystalline deformation offered by clay bricks under elevated temperatures. As a matter of emphasis the ratio of firing shrinkage to drying shrinkage is an effective parameter for measuring creep, rate of crack and ultimate disintegration of building materials under elevated temperature.

Water absorption and compressive strength are also two other important criteria for evaluating the applicability of red bricks in building construction. The values in Table 3, illustrate the compressive strength of bricks packed at the top, middle and bottom of the kiln respectively. The salient point is that red bricks packed at the bottom and top of the kiln have higher compressive strength due to greater exposure to the heat source and effect of radiation. The rate of water absorption also decreases from top to bottom.

In summary, the discussions above indicate that under elevated temperature conditions (i.e. 1000°C/1500°C) red bricks tend to resist shrinkage and associated cracks. This behaviour implies that the disintegration temperature of red bricks is extremely high. It is known that cement:crushed burnt brick:sand mortar mixed in proportion of 1:1:3 can effectively resist temperatures above 1,500°C, without exhibiting cracks. Hence, it is apparent that burnt bricks tend to shrink gradually under elevated temperature conditions.

By implication, the rate of creep is minimized. In macroscopic terms, crack formation and time of ultimate disintegration are elongated, during fire incidence in buildings. These delay characteristics have some positive multiplier effects on fire fighting and rescue efforts, particularly in multi-storey, petrol station, and industrial buildings. The above contention also applies, to a great extent, on residential buildings particularly low cost housing estates where spatial separation of housing units is not always adequately considered.

TABLE 2: PROPERTIES OF HWERESO CLAY, KUMASI, GHANA

Sample No.	Colour	Plasticity	Water for Plasticity %	Drying Shrinkage %	Firing Temperature °C	Fired Colour	Firing Shrinkage %	Total Shrinkage %	Absorption %	Remarks
1.	Red Brown	Fair	34	5.0	1000	Red	0.4	5.4	23.7	
2.	Buff	Fair	12	2.4	1100	Very Light Red	0.0	2.4	12.3	
3.	Brown	Good	22	5.6	1100	Red	0.5	6.0	17.6	
4.	Brown	Good	22	5.5	1100	Light Red	0.5	6.0	17.9	
7.	Brown	Fair	25	5.6	1100	Light Red	2.5	8.0	18.1	
6.	Brown	Good	22	5.2	1100	Light Red	0.8	6.0	17.2	
5.	Brown	Fair	22	5.6	1100	Very Light Red	1.2	6.8	17.3	
8.	Brown	Fair	28	6.0	1000	Red	1.1	7.1	23.7	
11	Buff	Fair	20	5.4	1000	Very Light Red	0.3	5.7	17.4	
9.	Brown	Fair	24	5.9	1100	Light Red	0.5	6.4	10.4	
10	Brown	Poor	30	3.0	1000	Red	5.5	8.5	21.9	
34	Red Brown	Fair	29	7.0	1000	Red	1.2	8.2	22.2	
14	Brown	Fair	19	5.3	1000	Light Red	0.3	5.6	17.3	
12	Brown	Good	22	5.8	1000	Red	0.5	6.3	19.3	
13	Brown	Fair	25	6.5	1000	Red	1.1	7.6	19.2	
15	Brown	Fair	27	7.0	1000	Red	3.2	10.2	18.9	
17	Buff	Good	16	4.0	1000	Light Red	0.0	4.0	14.9	
16	Brown	Fair	24	5.9	1000	Light Red	0.8	0.7	18.9	
17	Brown	Good	25	6.1	1000	Light Red	1.5	7.6	21.5	
18	Brown	Good	26	5.9	1000	Red	1.6	7.5	21.1	
21	Buff	Good	20	5.4	1000	Very Light Red	0.4	5.8	17.3	
20	Buff	Good	22	5.7	1000	Light Red	1.3	7.0	18.8	
22	Buff	Good	23	6.3	1000	Light Red	1.2	7.5	19.1	
23	Brown	Poor	30	7.3	1100	Light Red	2.7	10.0	19.3	
31	Brown	Poor	—	—	—	—	—	—	—	Unable to make bars
25	Brown	Fair	23	6.3	1000	Red	0.8	7.1	18.3	
24	Brown	Good	22	5.3	1100	Red	2.3	7.6	16.4	
26	Brown	Fair	26	6.6	1000	Red	1.2	7.8	20.2	
27	Brown	Fair	26	6.0	1100	Red	4.7	10.7	16.0	
32	Brown	Fair	29	8.1	1000	Red	1.3	9.4	21.6	
42	Red Brown	Fair	30	7.4	1000	Red	1.3	8.7	23.3	
29	Buff	Good	23	5.1	1000	Light Red	0.5	5.6	18.0	
28	Brown	Good	24	6.0	1100	Red	3.1	9.1	17.0	
30	Brown	Good	23	5.5	1000	Red	0.5	6.0	19.5	
33	Brown	Good	21	5.4	1000	Red	0.5	5.9	18.6	
35	Brown	Fair	29	6.3	1000	Red	1.5	7.8	22.4	
36	Buff	Good	22	5.6	1000	Light Red	0.3	5.9	18.9	
37	Brown	Fair	25	6.4	1000	Red	0.8	7.2	20.1	
38	Brown	Fair	30	7.1	1000	Red	0.8	7.9	21.9	
39	Brown	Poor	—	—	—	—	—	—	—	Unsatisfactory
40	Red Brown	Good	24	5.5	1000	Red	0.4	5.9	20.6	

TABLE 2: PROPERTIES OF HWERESO CLAY, KUMASI, GHANA

Sample No.	Colour	Plasticity	Water for Plasticity %	Drying Shrinkage %	Firing Temperature °C	Fired Colour	Firing Shrinkage %	Total Shrinkage %	Absorption %	Remarks
41	Buff	Fair	20	5.3	1000	Very Light Red	0.1	5.4	17.6	
43	Brown	Fair	16	3.3	1000	Red	0.1	3.4	15.4	
44	Brown	Fair	16	4.0	1000	Red	0.0	4.0	16.0	
45	Red Brown	Good	32	6.4	1000	Red	2.0	8.4	24.9	

SOURCE (8)

TABLE 2: PROPERTIES OF HWERESO CLAY, KUMASI, GHANA

Sample No.	Colour	Plasticity	Water for Plasticity %	Drying Shrinkage %	Firing Temperature °C	Fired Colour	Firing Shrinkage %	Total Shrinkage %	Absorption %	Remarks
41	Buff	Fair	20	5.3	1000	Very Light Red	0.1	5.4	17.6	
43	Brown	Fair	16	3.3	1000	Red	0.1	3.4	15.4	
44	Brown	Fair	16	4.0	1000	Red	0.0	4.0	16.0	
45	Red Brown	Good	32	6.4	1000	Red	2.0	8.4	24.9	

SOURCE (8)

TABLE 3: WATER ABSORPTION AND COMPRESSIVE STRENGTH OF FUMESUA  
RED BRICKS

	End Columns			Middle Columns		
	Top	Middle	Bottom	Top	Middle	Bottom
Kg/cm <sup>2</sup>	70.5	59.1	78.8	66.5	72.0	86.8
Water Absorption %	21.3	20.3	16.6	21.0	21.2	16.0

SOURCE (8)

### 3.3 Rheological Behaviour of Steel:

Rheological or strain-stress characteristics of steel under elevated temperature conditions, include the analysis of the following variables; modulus of elasticity, yield strength, ultimate strength, elongation and shrinkage. At temperatures between 1000°C and 1300°C, changes in the above variables create deformation in steel. This microscopic deformation commonly referred to as creep, ultimately leads to failure of steel construction. It should be noted that under elevated temperature conditions creep occurs on both structural steel and cold-rolled pre-stressed steel. However, cold-rolled pre-stressed steel can withstand higher temperature before failure.

In view of the above theoretical background, it is clear that in a steel frame design, especially in high-rise buildings, unprotected steel beams and columns are vulnerable to failure at temperature range of 1100°C to 1200°C. Hence, it is a standard design practice to protect steel with suitable materials, red brick or concrete. This measure provides a 'composite structural effect' which increases the buckling temperature. As a matter of emphasis, structural engineers in developing countries should discourage unprotected steel - columns in high-rise building such as hotels and office blocks. Lightly protected steel columns are also not appropriate to developing countries where local fire fighting departments are not well equipped. In general, our structural engineers should always adhere to the traditional concept of composite design which emphasises maximum protection.

### 3.4 Properties of Concrete at Elevated Temperature:

Concrete can be simply defined as a mixture of sand aggregates, water and cement in a specified volume or weight to yield a solid mass with desired strength. Hence, the behaviour of concrete under elevated temperature conditions involves the deformation and disintegration of the components of the mix under fire situations. The variation of the stress-deformation of concrete materials under varying temperature condition is a major index for determining the fire resistance of concrete. Of all the materials mentioned earlier, cement paste is the most

unstable in elevated temperatures. At temperatures above 200°C the process of dehydration creates cracks and deformation. Disintegration of concrete ultimately occurs at temperatures<sup>10</sup> above 1400°C.

Concrete aggregates like gravel and stone chips also exhibit changing specific heat with increase in temperature. However, research has shown that light-weight aggregates has 1/3 to 1/2 thermal conductivity of normal weight aggregates at room temperature but at elevated temperature the difference diminishes.<sup>1</sup>. A good design approach for material engineers is to recognise the fact that aggregates with high conductivity are not suitable for thermal insulation. Concrete mix specification for fire resistant design must consider such factors as the water-cement ratio which is indicative of the amount of moisture that a concrete can hold. Other related variables include specific heat of concrete and moisture sorption. Both variables can delay or enhance dehydration under elevated temperature conditions.

Quality control is imperative in any development. Washing of aggregates will ensure that there is no contamination of the concrete by any organic materials which are unsuitable. These organic materials, to a great extent, reduce the critical or failure temperature of concrete. The quality of cement paste and degree of curing provided are extremely essential in consideration of moisture sorption characteristics and associated thermal failure. Hence, the importance of good quality control cannot be over emphasized at design and construction phases of buildings. The overall objective of a design engineer is to provide an effective bonding which will not only develop the design strength but eliminate premature crystalline transformation at elevated temperature conditions.

### 3.5 Application of Red Bricks in Building Design and Construction:

#### 3.5.1 Low Cost Housing Estate:

In this austere times, there is a need to utilize abundant Nigeria clay in the construction of low cost houses. Red bricks and stabilized clay blocks offer suitable substitute to sandcrete blocks. It is still fresh

in our minds that the Federal low cost housing units (i.e. over 5,000 units) added greatly to the undesirable situation of our foreign reserve during the last civilian administration. Over 40% of the cement utilized and even the door pannels were imported from abroad.

Figure 2(a) illustrates a new approach in construction of low cost housing with red bricks. The emphasis on red bricks is justified because potential home owners have confidence on its strength and durability. To some extent, the same opinion applies to stabilized bricks. However, stabilization involves extensive use of cement which contradicts the 'self sufficiency' objective. This statement is justified because EEC study of 1980 confirmed that over 60%<sup>1</sup> of cement used in Nigeria is still imported. This same study found out that most of our cement factories operate below 50% of installed capacity. Please note that in figure 2(a) thermal comfort has been incorporated in the design by providing open spaces and adequate windows.

### 3.5.2. Red Bricks in the Construction of Petrol Stations:

Figure 2(b) illustrates the traditional approach in the construction of petrol stations. As mentioned earlier, multi-national oil companies like Mobil, Texaco and Elf adopt the "red brick wall" standards for their outlet stations. It is unfortunate that some Nigerian independent marketers now build anything, in the name of petrol station. The overall aim of employing red bricks is to provide fire resistant material which will retard ignition and fire propagation. In fact, the brick wall acts as a life saving buffer for the petrol attendants/clerks in case of petrol fire propagation; which is usually by diffusion.

### 3.5.3. Red Bricks in the Construction of Multi-purpose Buildings:

Figure 3 shows the use of red bricks for total construction of a multi-purpose residential building or cottage industry. This type of building is appropriate for high altitude locations like Jos or Obudu where temperature is semi-temperate for several months.<sup>12</sup>

### 3.5.4. Application of Red Bricks in the Construction of High-rise Buildings:

The areas where red bricks, blocks or tiles can be employed in the fire resistant design of high-rise buildings are shown in figure 4. In brief, the following applications should be seriously considered and accommodated in the new building codes:

- (a) Red bricks should be employed in the construction or facing of the inside and outside walls of fire escape staircases.
- (b) Red bricks need to be used in facing of regular staircase walls.

- (c) Red bricks should be employed in the construction or facing of the basement walls or the underground plant housing facilities.
- (d) Services ducts should be lined with red bricks or other suitable materials, particularly if these ducts are very large.
- (e) Red bricks can be employed in the construction of retaining walls, service roads, drainage systems etc.
- (f) The fact that red bricks emit less toxic gases, makes brick or well made clay tile a good material for corridor finishing.
- (g) Red bricks provide effective fire protective casing for steel columns and beams. In effect, the buckling and ultimate failure temperature of steel is increased by brick casing of steel columns.
- (h) Experience gathered in America, Canada and UK, confirm that besides aesthetic values, red bricks are highly durable even with minimum maintenance and under very harsh weather conditions.

## 4. RECOMMENDATIONS ON THE UTILIZATION OF BRICKS IN FIRE RESISTANT DESIGN AND BUILDING CONSTRUCTION:

4.1 There is a need for all building professionals to adopt a fire safety approach in building design and construction. This consideration should be extended to residential houses, industrial houses, public buildings like schools and more especially business towers located in central business districts. The incorporation of red bricks in the construction of building components will not only be cost effective but functional as a fire deterrent measure.

4.2. In residential family houses red bricks should be employed in facing or tiling of kitchen walls apart from any other aestetical considerations. The idea is to deter possible fire spread due to cooking activities. It is also important to mention, that when the external walls of buildings are made of red bricks the propagation of fire from adjacent buildings either by radiation or convection are minimized. To a less extent, the same effect is achieved when building external walls are tiled with bricks. It is known, as discussed in section 3.2, that bricks are resistant to fire propagation either by convection or by radiation.

4.3. In most countries like USA, UK and other countries of western Europe, the walls of petrol stations are finished with red bricks. The principal consideration is based on the fire resistant characteristics of red bricks, which tend to have a delay effect on both the ignition potential and the rate of spread.

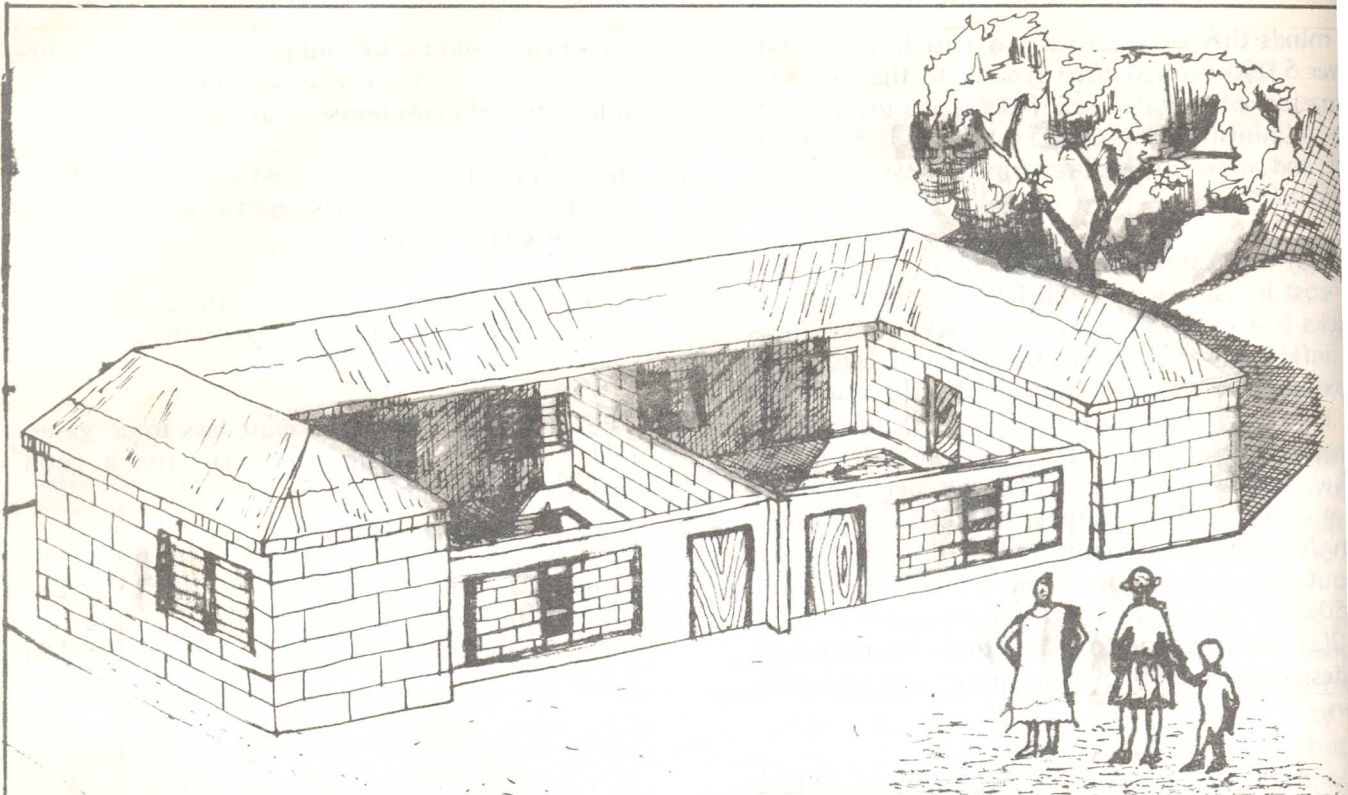


FIG. 2 a

APPLICATIONS OF RED-BRICKS IN  
LOW COST HOUSING ESTATE

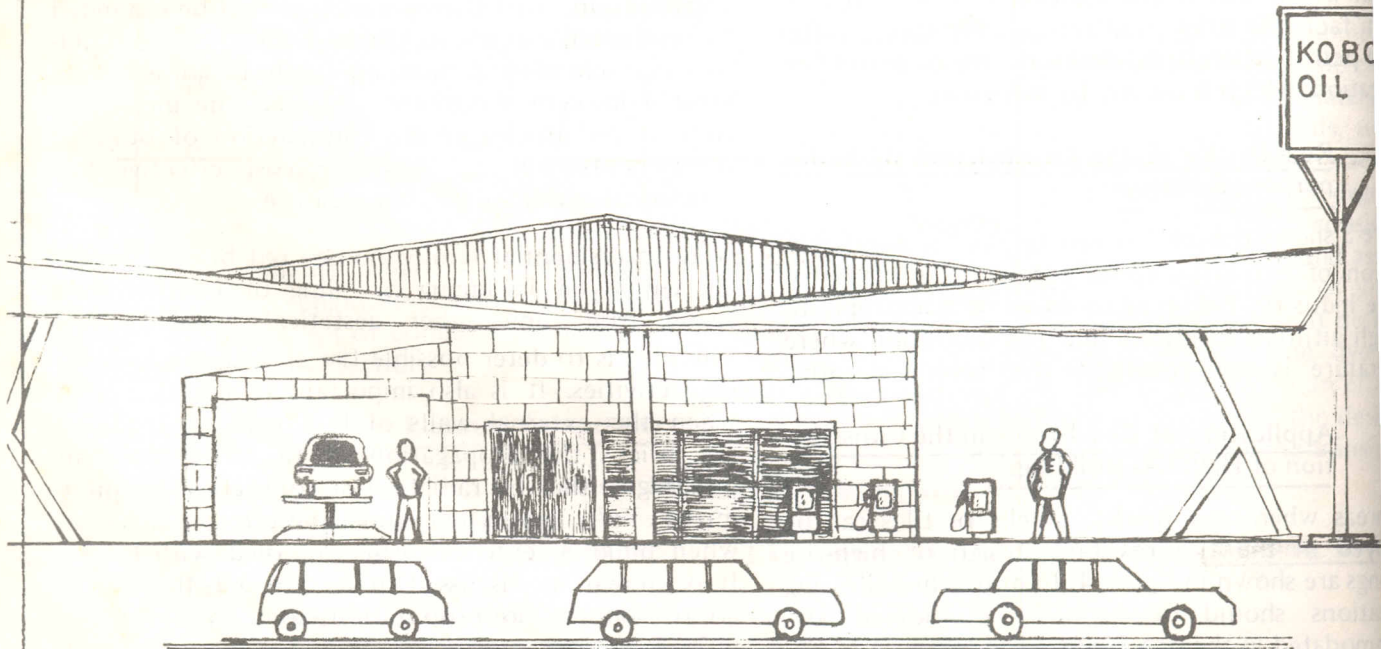


FIG 2 b

APPLICATIONS OF RED BRICK IN  
PETROL STATION CONSTRUCTION

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On the other hand, in Nigeria only major oil companies like Mobil, National, Texaco insist on red brick walls or facing for their petrol outlets. In recent times the new comers to the business, usually referred to as *independent marketers*, do not appear to recognize the importance of fire resistant design in petrol station construction. There is an urgent need, for the appropriate authorities to set a uniform standard and enforce such regulations.

4.4. Industrial developers in Nigeria should recognize the importance of red brick walls around their furnaces and other heat generating sources. In some cases brick buffer walls need to be constructed around industrial boilers as safety protection. In multi-level factories the need to line fire escape staircases with bricks cannot be over emphasized. In most cases, lift shafts and stair walls need to be lined with red bricks in order to minimize both the rate of ignition and rate of fire propagation.

4.5. In the design of high-rise buildings, red brick should be integrated as a composite component of the structure. To be specific, steel columns should be encased with red bricks, where this is not structurally possible, a brick facing or tiling need to be considered. Another area where red brick walls should be adopted is in the design of stair walls and fire escape stairs. The idea is to delay fire spread and facilitate evacuation efforts. In addition to the above, red bricks do not produce toxic gases.

4.6. In the design of high-rise buildings, ducts and other appurtenances need to be lined with red bricks, to serve as a fire deterrent. In countries like the USA and UK, basement walls are made with bricks and other refractory materials including slag furnace bricks.

4.7 It is important to note that when property walls are constructed of red bricks an effective buffer zone is created when the adjacent property is on fire. The above statement applies mainly to bungalows and low cost housing estates.

4.8 In the opinion of the writer, building professionals have an important role to play in the development and mass production of fired clay bricks and brick tiles. The high fire endurance rating of red bricks justify the utilization of bricks for encasing structural members like columns and load bearing walls.

4.9 There is a need for extensive research in the development and mass production of all forms of construction bricks and blocks, particularly fired clay bricks and tiles. This research should be directed on improvement of their fire endurance rating. The production techniques necessary for large scale production need to be evolved quickly. The overall

objective will be to produce considerable quantity at an acceptable unit price. It is well known that brick construction is labour intensive; hence only a significant reduction in the price of bricks will induce developers to use brick and clay blocks.

4.10 Finally, it is timely to review Nigeria's National Building Code, in order to incorporate new standards, particularly in the area of fire resistant design and new construction techniques. It is also on record, that Nigeria has vast clay resources which can be easily employed in the development of all forms of building bricks, particularly fire resistant bricks.

## 5. CONCLUSIONS:

In conclusion, there is a need to educate Nigerians on aesthetic and structural acceptability of brick buildings. It is common knowledge, that most residential developers regard brick walls as vestiges of the colonial era. However, in recent times a few elites are turning to brick construction as a class symbol. It is unfortunate that these elites are still in the minority. The generality of the people need to be induced by attractive reductions in the price of bricks. This measure will counter-balance the high cost of labour. The production of brick/blocks will also reduce the cost of bricklaying.

In the segment of industrial construction and the construction of high-rise buildings, the building codes should be updated to cover all aspect of fire resistant design. The need to enforce the new regulations to the letter cannot be over emphasized.

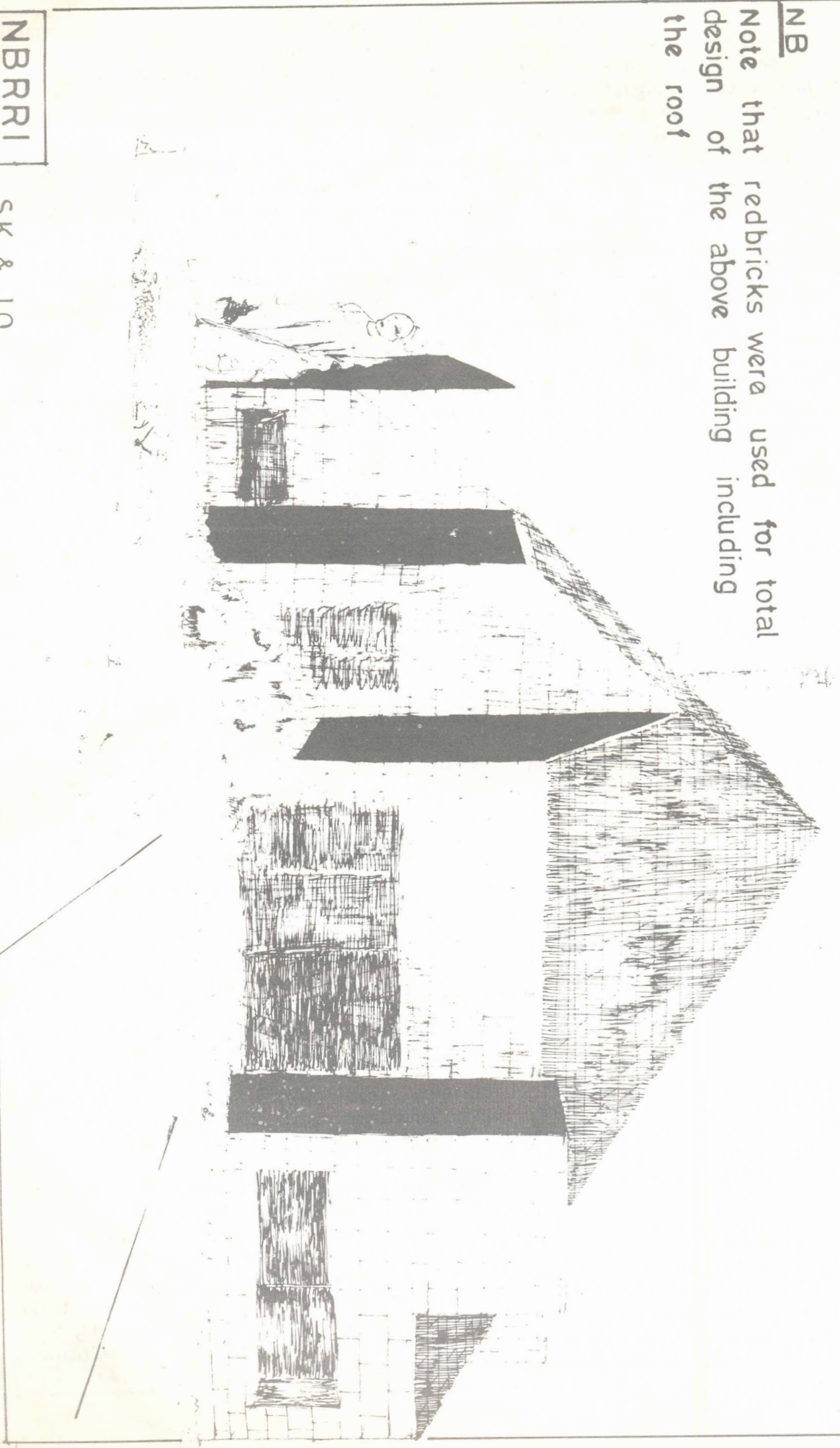
## AUTHOR'S BACKGROUND

Dr. Samuel K. Nnama graduated B.Sc. in Civil Engineering from the University of Nigeria, Nsukka with thesis emphasis on "Design and Materials Specification for Multi-storey School Buildings". Before proceeding to the USA for further studies, Dr. Nnama was employed for three years as a Civil/Structural Design Engineer. In the USA, Dr. Nnama was appointed an Adjunct Assistant Professor for three years in Lansing Community College. In this position, he presented several courses in soil erosion, building design and particularly solar systems applicable to buildings.

Dr. Nnama was later appointed an Assistant Professor in both the Department of Civil Engineering and the Engineering Research Division at Michigan State University. He is currently the head of Roads Research Division at Nigerian Building and Road Research Institute and also the Chairman of the National Technical Committee for Concrete, Steel and Building Construction of the Standards Organization of Nigeria (SON).

**FIG. 3**  
**APPLICATIONS OF RED BRICKS IN FIRE RESISTANT**  
**DESIGN OF RESIDENTIAL OR PUBLIC BUILDINGS**

**NB**  
Note that redbricks were used for total design of the above building including the roof



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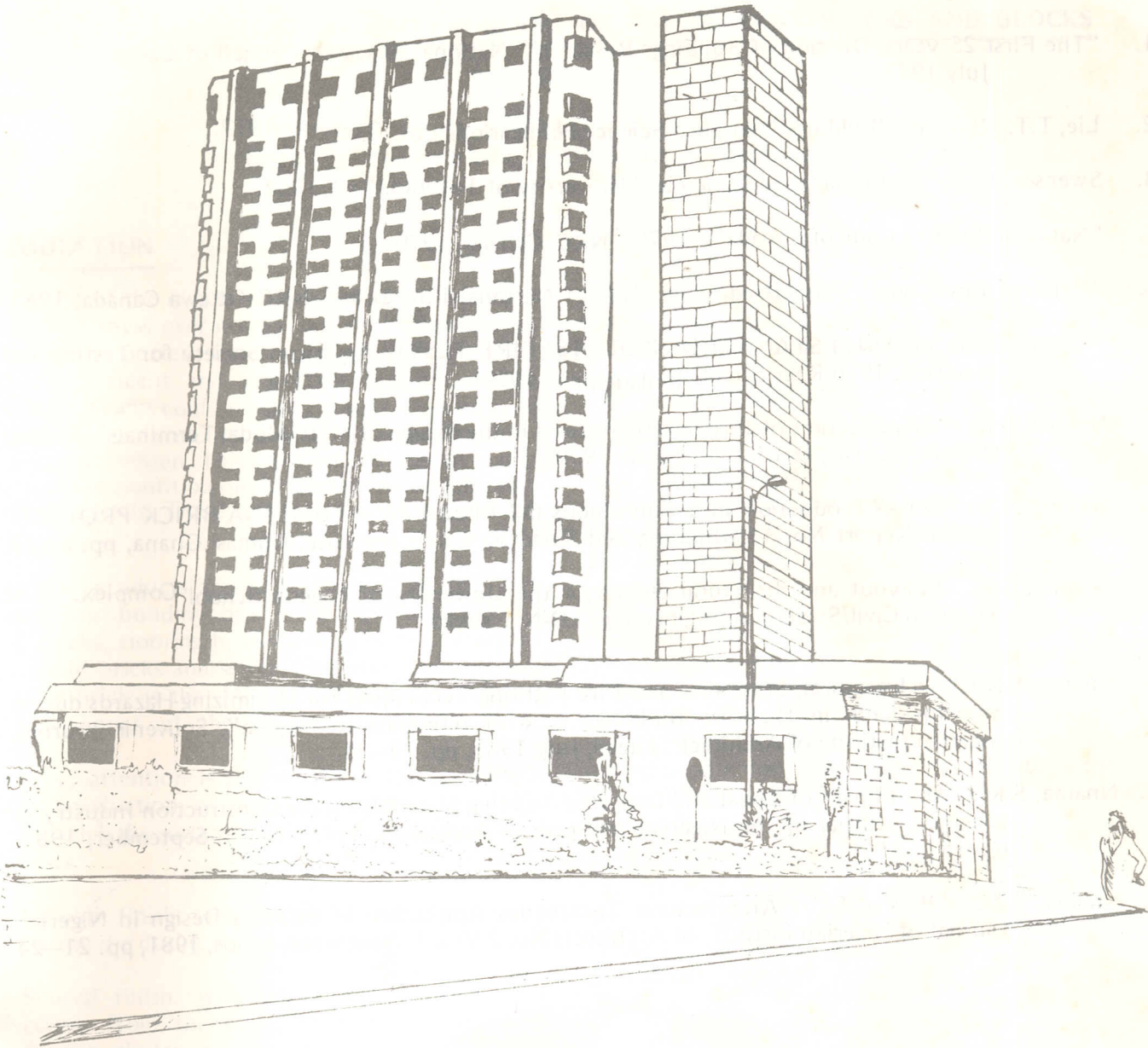


FIG. 4 APPLICATIONS OF RED-BRICKS IN FIRE RESISTANT DESIGN OF HIGH RISE BUILDINGS

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## STANDARD SPECIFICATION AND PROBLEMS OF USE OF CLAY BRICKS AND BLOCKS

By

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### INTRODUCTION

Clay is one of the oldest materials that had been put into various uses over generations by human beings. Apart from pottery-wares produced from clay, another significant and important product is clay brick. Clay bricks could be described as small units of building materials moulded from clay and fired or sun-dried to harden. There are other types of bricks made from cementitious materials that harden through chemical actions. These are the "sand-lime-and cement bricks".

Burnt clay products are made available in the form of common building bricks, facing bricks, glazed facing bricks, flooring bricks, paving bricks, refractory bricks, acid bricks and sewer. The dried-out and sun-hardened brick is the "Adobe". The Adobe brick is the fore-runner of the present day burnt brick.

Generally, attention is paid to the surface condition in the production of bricks. According to Caleb Hornbostel,<sup>1</sup> the surface finishes could be categorised as follows

1. Smooth finish: with the surface plane as formed by the die during manufacture.
2. Scored finish: with the surface grooved as it comes from the die. This increases bond for mortar, plaster or stucco.
3. Combed finished: with the surface altered by parallel scratches or scarfs to produce a desired texture or to increase bond for mortar, plaster or stucco.
4. Roughened finish: with the surface entirely broken by wire cutting etc to provide a desired texture or to increase bond for mortar, plaster or stucco.

Generally, the texture i.e. surface quality, apart from colour, includes the texture of the clay body of the brick, which can range from fine through to medium and to coarse.

### TYPES AND SPECIFICATION OF BRICKS

There are different types of clay bricks and they vary also in the standard of production. Whereas the clinker is a thoroughly hard-burned fired brick, building bricks are not as deeply fired. Thus the

Clinker is a special hard type of bricks that are for specific use. They absorb less water and are frost resistant than the standard ones.

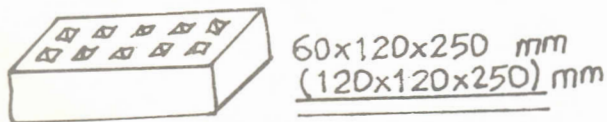
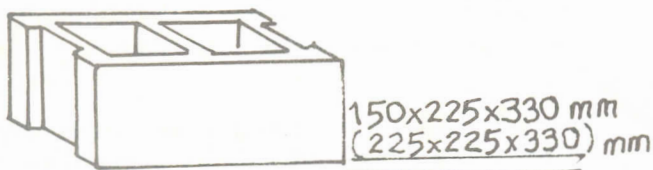
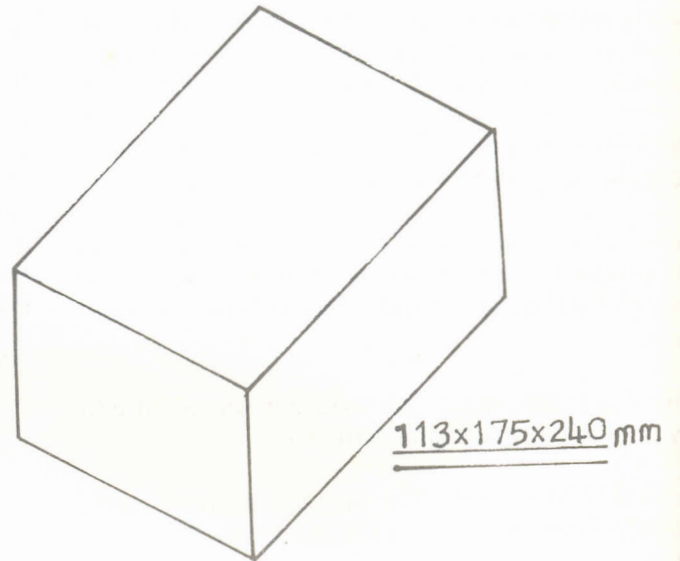
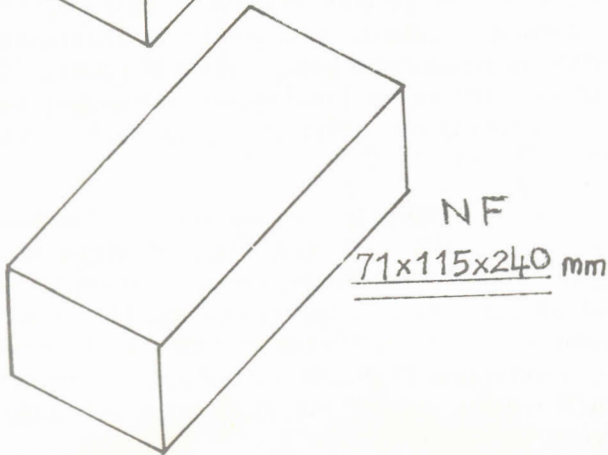
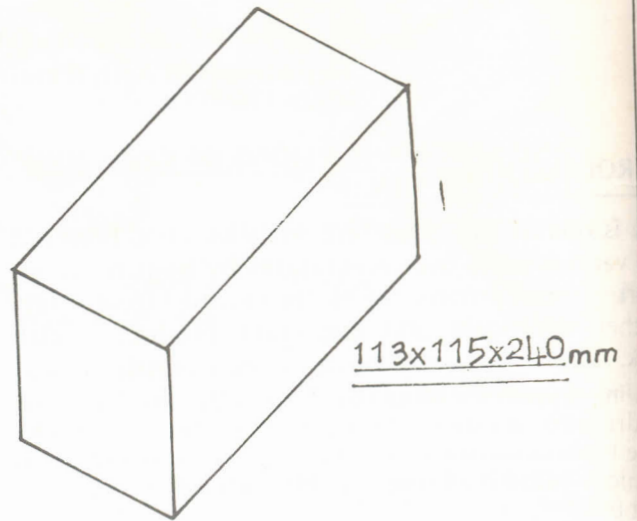
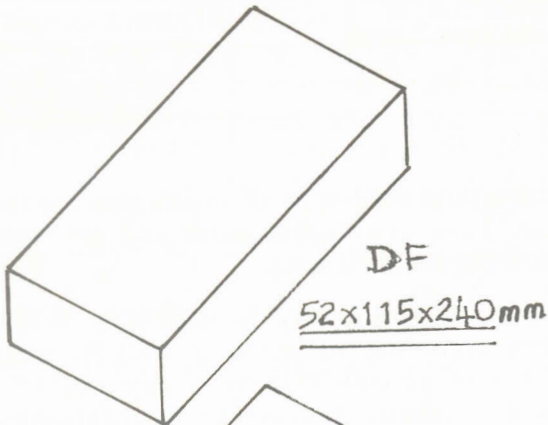
The common clay brick vary in sizes (Fig. 1) and specification according to manufacturers in some cases and use in general. However, some countries have general standards that are to be maintained, not only in production and handling but also in the use of clay bricks for building and other purposes. The Standards Organisation of Nigeria also has issued some guidelines.

In Europe for example, the German standards (as contained in DIN 105 for building clay-bricks) prescribe among other things, the sizes; strength and use of all types of building bricks and blocks with the tolerances in measurement allowed within a batch during production (Table 2). Unfortunately, there is no such regulations for the local manufacturers in the country.

As seen in Tables 1, 2 and 3, the standards as expressed in Tables 1 and 2 are, according to DIN 105, fixed while table 3 shows what is available in the country as produced by local manufacturers. Those available in the country and their uses are:-

- (1) Standard brick (varied dimensions)  
These are used for internal and external building walls and also for decorative purposes.
- (2) Solid bricks  
These are used for flooring purposes especially in areas where heavy traffic (Figs. 2 and 3) and/or heat resistance is expected e.g. bakeries and incinerators; Pedestrian ways. etc.
- (3) Partition blocks  
These type of blocks are used exclusively for partitioning and other non-load bearing walls e.g. fencing.
- (4) Standard blocks  
These are used for different types of walls in buildings.
- (5) Sun-breakers (single/double)  
The sun-breakers are used for ventilation and decoration purposes. They can also be used as sun-protector and shades for house corridors and passages.

Sizes of different clay bricks and blocks.



SOURCE:

1. The building bricks, (Hart and Oldenberger)  
Press - R. Oldenburg 1969
2. Bronchure - Clay Industry (Nig) Limited  
Oregon - Lagos

(6) Ceiling Stones; Ports and Beam Units.

These are structural parts used in decking construction along with concrete floor slabs, while the beam units are used as lintels for windows.

TABLE 1

TYPES AND SPECIFICATIONS OF CLAY BRICK ACCORDING TO DIN 105

a	b	c	d
	Measurement in mm		
	Length L	Width b	Height h
1. Flat Size (DF)	240	115	52
2. Standard Size (NF)	240	115	71
3. 1½NF = 2DF	240	115	113
4. 2¼NF = 3DF	240	175	113
5. Special Order Type A	240	240	115
6. Special Order Type B	240	240	175
7. Special Order Type C	240	240	238

Source: The building Brick (Der Mauer-Ziegel) Hart and Bogenberger, R. Oldenbury 1969.

TABLE 2

TOLERANCE IN DIMENSIONS OF BRICKS AND BLOCKS WITHIN A DELIVERY ACCORDING TO DIN 105 STANDARD.

MEASUREMENTS IN MILLIMETER

NORMAL	MINIMUM	MAXIMUM	TOLERANCE
240	230	250	12
238	228	248	12
175	168	182	9
155	149	161	8
115	110	120	6
113	108	118	6
71	68	74	4
52	50	54	3

Source: Building Bricks (Transl) Hart and Bogenberger – Oldenburg 1969

TABLE 3

LOCALLY PRODUCED CLAY BRICKS AND BLOCKS

CODE NO.	DESCRIPTION	MEASUREMENT IN MM		
		L	b	h
001	NF (Ordinary) Brick	240	115	71
002	NF (Solid) Brick	240	115	71
003	Big Block BB1.	300	175	225
004	Single Sunbreaker	250	200	71
005	Partition Block BB¾	300	115	225
006	ceiling Stone (Including Beam)	340 x 220 x 125	480 x 240 x 135	

Source: LACON (Nig.) Ltd., Ikorodu.

NOS	DESCRIPTION	MEASUREMENT IN MM		
		L	b	h
1.	Partitioning Clay-brick	330	50	225
		330	75	225
		330	100	225
		330	150	225
		330	200	225
2.	Hollow Clay (Load bearing)	330	150	225
		330	225	225
3.	Burnt Brick	250	120	60
		250	120	120
4.	"Velox" Beam Unit	250	140	115

Source: Clay Industry (Nig.) Ltd. Oregon, Lagos.

According to information from Clay Industries (Nig.) Ltd. the present standard specification (See Table 3) for their clay bricks, blocks and others are based on the observation that thickness of walls used mostly in Nigeria is about nine inches or 225mm, and as such the blocks are (225 x 225 x 330)mm. The dimensions of their burnt brick (60 x 120 x 250 and 120 x 120 x 250)mm however are out of tune with the produced block standard; perhaps they are doing that only to suit their production line. Another firm LACON (Nig.) Ltd. of Ikorodu however adopted a modified DIN. 105 standard of 240 x 115 x 71 for their bricks, thus showing that there is no common standard among local producers.

This non-uniformity in size of clay bricks creates delay in building processes whenever a particular firm's products are not available. It also leads to varied and unsightly structures if the different products were to be mixed for use in case of scarcity of any particular type.

Unlike the locally produced clay bricks and blocks in the country that have no common standards among various producers, those produced in some other countries (Europe and/or America) — that are standardised bring out clearly the many advantages inherent in the use of standardised bricks. There is flexibility of choice in construction works, and the competition by the manufacturers in terms of satisfying the public with varied sorts often ensure good quality products. Figures 4 and 5 below show clearly how these various standardised blocks and bricks could be used in wall construction to achieve the same objective. While Figure 4 — shows clearly the dimensional relationship according to standard DIN 105, Fig. 5 illustrates, however, side by side the use of various bricks and blocks. One notices, for example, that the fourth wall-layer (course) of a construction can be achieved using the least dimensioned burnt clay brick (240 x 115 x 52)mm. This same level could be achieved by the third course of normal (240 x 115 x 71)mm standard and second course of 1½ normal standard or 2-Flat size blocks (240 x 115 x 113)mm.

#### POSSIBLE USE OF CLAY BRICKS AND BLOCKS AND THEIR LIMITATIONS.

With due attention paid to good quality, texture and standards, one could conclude that the clay bricks and blocks have a lot of advantages in use that have not yet been properly explored in this country. As seen in Figs. 4 and 5, one notices that mere use of these bricks and blocks for wall construction alone only limits the technical and potential advantages they could have over many other materials. The clay-brick or block walls in housing construction should normally not go beyond four floors if stability and safety of life are to be maintained without having to be supported by concrete, steel or other structurally stronger materials as columns and beams thereby incurring additional cost.

Other uses, as seen in Figs. 2 and 3, are for pedestrian ways and light vehicle parks. These bricks can also be used to stabilise marshy areas and have been effectively employed in the construction of small bridge and arch-ways in Europe and America. All these uses depend solely on technical ability and experiences of both the designers and the artisans alike. In this country, the technical knowledge of most construction workers is limited to cement blocks. More supervisory personnel are needed to see to the careful handling of these bricks during transportation so as to avoid damages (chipping and breakages) that are often seen on building sites.

Another militating factor, apart from the technical know-how, is the cost of these bricks and blocks. A simple load bearing block of normal size (225 x 225 x 330)mm costs about 80 kobo from the factory whereas the cement/sandcrete block of normal size (225 x 225 x 450)mm costs about 85k to purchase. Thus, a clay brick of (120 x 120 x 250)mm, from Clay Industries (Nig.) Ltd., Oregon, costing forty-two kobo (42k) becomes less competitive in terms of cost. It is therefore necessary that the cost of finished clay bricks be made competitive by finding ways of reducing production cost.

#### OBSERVATIONS AND RECOMMENDATIONS

Having noted the above limitations of massive use of clay bricks through non-standardisation and quality control of any kind, one is inclined to ask how one could improve on the present situation. To this end, the following suggestions are hereby made to take cognisance of the inherent problems of technically trained personnel to handle the bricks in construction.

It is clear that no government or private organisations had made attempt up till now to control and check regularly the qualities of the various clay bricks and blocks produced in the country. The custom, whereby any initial test would be carried out by individual firms just to have references for their sales brochure should stop, and a regular random quality test by government Standards Organisation should be introduced. The composition of such organisation should reflect its aim by embracing seasoned technical personnel and other relevant members. The Organisation should bring up adequate regulations and standards on production of clay bricks and blocks that are relevant to our socio-cultural background. This aspect should put into consideration the varied and diversified building habits in the country and also take the varied climatic conditions into consideration.

Efforts should be intensified by the government and other organisations to encourage massive use of clay-bricks at the local level. To achieve this, the government should discourage its own agencies from using other materials for structures where clay-bricks could be easily and perfectly used. Such considerations should also be extended to private organisations and the public at large.

The other crucial problem is the training of artisans and other technical personnel involved in the production, handling and laying of these materials. On the local level, a practical demonstration with organised discussions on the handling on site of these materials would be very necessary. This is due to the present experience whereby artisans do not lay the clay bricks and blocks on site with the correct type of mortar mix and without adequate care. Thus one sees very rough and badly laid clay brick and block walls which give unsightly view of the building.

As for mortar mix in use, pure cement/sand mortar should not be employed as this leads to decoloration

Fig. 2 Bricks as bicycle & pedestrian way.

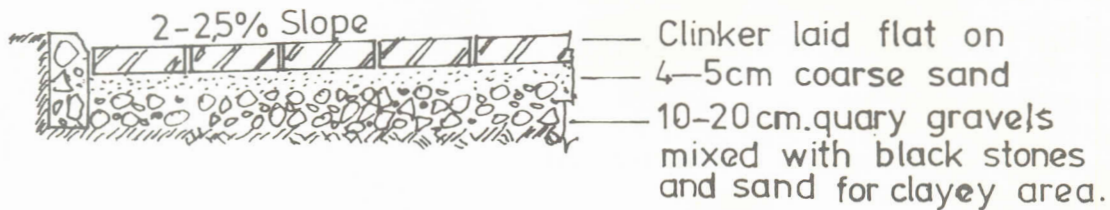
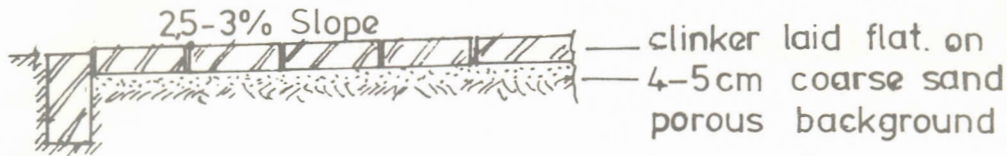
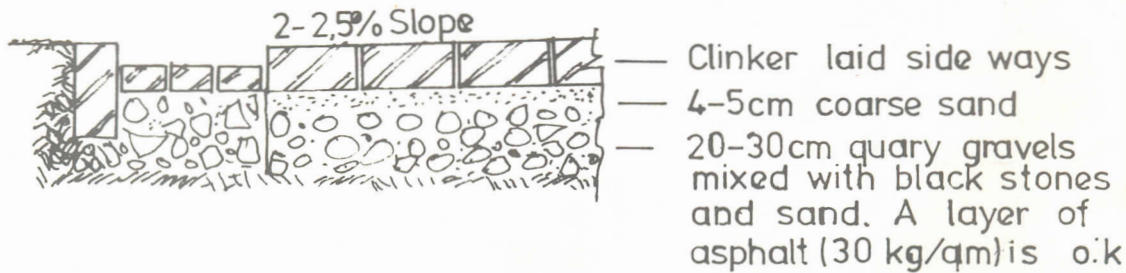


Fig 3 Light traffic and Parking-spaces.



Background for grass area

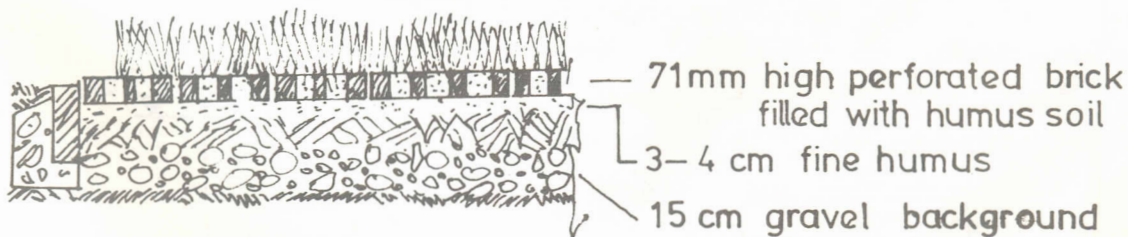
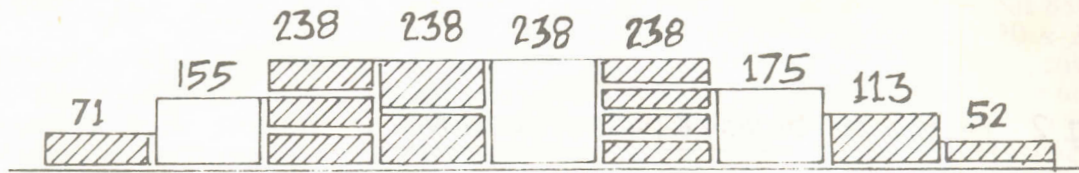


FIGURE 4

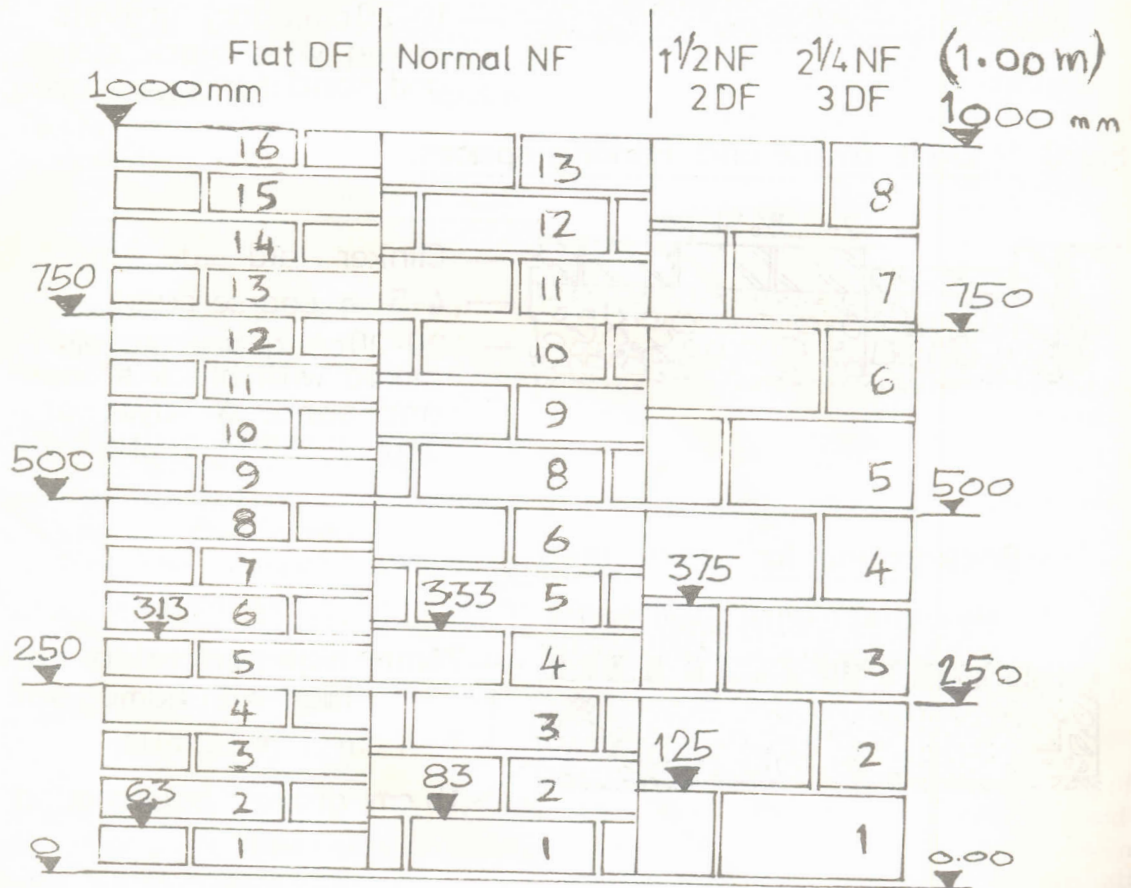
Relationship of various standard sizes of bricks



Standard sizes as in Table 1 in mm.

FIG. 5

Height of wall-layers (courses) using different brick-sizes



All dimensions in mm.

Source: Building bricks by Hart and Bogenberger in R.Oldenburger press

structural walls. To avoid this, artisans should be trained to use appropriate colour-cement and also to aggregate. A look at some buildings, (e.g. Nursery School) where clay bricks and blocks would demonstrate this.

So the training of the local artisans is the key to the production of middle-level manpower that act as the backbone of these artisans. These middle-level manpower also need both on-site and in-classroom training so as to make them effective. They should be kept up-to-date in the use of clay-bricks under prevailing climatic conditions in the country.

For cost consideration, a thorough research into the market use, manpower and handling of the bricks should be made. Then, it would enable the firms to improve on the handling of these products from their premises to the delivery site. Presently, a lot of the bricks and blocks are lost through breakages and scratches, hence it would be necessary to ensure proper handling to save cost wastage. A better transportation and packing system should be developed by technically trained personnel in the trade.

Moreover since the materials used are locally available, a thorough review of location policy for future industries should be carefully looked into. This review, if properly done, would reduce the transportation cost of raw materials from site to industry and market.

The firms should also try to organise exhibitions where their products should be introduced to the public and models of buildings where clay bricks and blocks have been put into good use be shown to the public.

Finally it is very necessary for these firms to have good research personnel. These personnel would be responsible for conducting thorough research into the effects of different weather conditions on clay bricks — be it dry or humid — and also their reaction to other building materials. The research department should also be made to look into the present varied standards and specifications and come out with more dynamic results that would afford the public the opportunity to have choice in the use of clay materials. Until these aspects are done, the public would continue to shy away from the use of clay products.

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## THE PROPERTIES OF FIRED BUILDING BRICKS VIEWED AGAINST THAT OF SANDCRETES

By

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### ABSTRACT

*Quite aware of the lukewarm attitude towards the use of red building bricks in Nigeria today, an attempt has been made to give the true and wonderful properties of this building unit. Descriptions of the basic differences and similarities in the physical and chemical structures of both the red building brick and the cement block have been made. This paper relied mainly on the description of the standard tests required for good bricks, as stipulated by the Nigerian Industrial Standard and standard text-books, with some references to that required for cement materials. Included in this paper are some test results from work actually done in PRODA as well as case histories of experiments as reported in literature on red building bricks, to show how comparable and sometimes, how better suited clay brick is than cement block in general, for virtually all construction purposes.*

### INTRODUCTION

The existence of good building materials, namely red bricks, floor and roofing tiles, perforated bricks etc to be used for walls, floors, roofs and facings of various designs, all of which can easily be manufactured from abundant Nigerian clay deposits, has so far in our development history become known, but not enough effort has been made to project this awareness to a greater part of the population of this country.

For centuries, clay has been the basic part of the average Nigerian's dwelling, and the object of this paper is to throw some light on some of the works done so far by man to improve on red clay building products. Red clay building brick is presently not popular amongst a greater number of builders in Nigeria. This may be due to ignorance of the overriding advantages of bricks over sandcrete blocks, or the conservative tendencies of the average Nigerian on the use of bricks or the belief that brick laying is a difficult task to achieve. Much as there may be some bit of truth in all the above, the fact remains, that a comparative study of the properties of red bricks and those of cement blocks will increase the awareness which will initiate the inevitable rivalry between these two building units.

### MATERIALS FOR AND STRUCTURES OF BRICKS AND SANDCRETE BLOCKS

Both clay bricks and sandcrete blocks come under ceramics. Bricks are made of simple clay plastic enough to form, and with enough iron compounds

and alkalis to vitrify into dense products at temperatures, ranging from 750°C – 1050°C or slightly over, as need and design may dictate. Sandcrete blocks on the other hand are made of cement, sand and water. The range of water/cement ratio often recommended is between 0.4 to 0.7 and the sand/cement ratio lies between 6.0 to 13.0.

Sandcrete blocks and clay bricks come under multiphase solids with two or more phases, which complicate their structures, but still give them their unique properties. The nature of the phases, their distributions, amounts and the sizes of their domains in the micro-structures differ. The distributions can be macroscopic, microscopic or even submicroscopic. The most common of solids as described above are rocks and ceramics with its red building bricks and sandcrete blocks; are rock-like solids, hard but brittle in character. Bricks and cement blocks however differ from rocks both in origin and in the structures of their phases. The phases of rocks nucleated and grown over the ages by the forces of nature are usually (though not always) crystalline. But the matrix of a brick is a GLASSY silicate, formed during firing in the furnace or kiln. The glass bonds the particles of sand and unfused clay materials into a solid mass.

On the other hand the matrix phase of a sandcrete block is a silicate GEL, a mixture of different sizes of sand or gravel, bonded together physically by the hydrated gel of Portland cement, a two-phase mixture.

Building brick and the sandcrete block are similar in the sense that they are made up of aggregates bonded together by a non-crystalline matrix, a glassy silicate for the former and a silicate gel for the latter. But they differ in the degree of bonding. The glassy phase of a building brick has a stronger binding force on all it is in contact with, than the silicate gel which holds the sandcrete block together. Hence, while both are brittle ceramics, the cement block is so many times more brittle than an average brick.

### SPECIFICATIONS FOR BRICKS BY STANDARDS ORGANISATION OF NIGERIA.

The Standards Organisation of Nigeria has some laid down requirements on both burnt clay bricks and sandcrete blocks.

The Nigerian Industrial Standards 74: 1976 UDC 624. 012.8 has laid down requirements for dimensions, quality and strength in particular for burnt clay units; solid, perforated or hollow to be used in constructions. A brick is defined as a walling unit not exceeding 337mm (13.29 inches) in length, 225mm (8.86 inches) in width and 112mm (4.43 inches) in height. A clay block is said to be a walling unit exceeding in length, width or height the dimensions specified for bricks. It also defined facing, engineering, solid, perforated and hollow bricks.

The Nigerian Standard of 1975 on the other hand defines sandcrete block as a masonry unit other than a unit used for bonding, e.g., half block, exceeding in length, width and height, the dimensions specified for a brick in A 15, 74. It said that the height of a block shall not exceed either its length or six times its thickness to avoid confusion with slabs and panels. The blocks are either solid or hollow and the main dimensions are:—

- 228 x 228 x 457 (mm) solid and hollow types approximating to 9" x 9" x 18".
- 228 x 152 x 457 (mm) solid and hollow types approximating to 9" x 6" x 18".
- 228 x 127 x 457 (mm) solid type approximating to 9" x 5" x 18".

The Standards Organisation of Nigeria has laid down required tests for certain properties for both bricks and cement products. These involve chemical analysis and other relevant physical tests. For bricks, physical tests like compressive and tensile strength tests, water

absorption, dimensional changes, efflorescence and warpage are performed.

The Standards Organisation has also specified tests for cement in N.I.S. 11 — 1974, UDC 666, 94 as from page 8, in sections 4.1., 4.2, 4.3 and 4.4., covering all the 1 day, 3 days, 7 days and 28 days strength tests, initial and final setting times, fineness and soundness.

Of all the tests, the chemical and strength tests are the most important. To the architect and the eventual user of a house, the other tests, though good for what they stand for in quality control aspects, are not as vital as the chemical analysis which predicts the brick or cement for what it is, or the strength and the colour which are physically manifested in the house or a construction.

### CHEMICAL ANALYSIS

Table I. shows the close relationship between the nature of the building brick and that of cement from which sandcrete blocks and concretes are made.

Chemically, both the fired red brick and the cement block contain basically the same type of mineral oxides. Cement is made from a combination of clay and limestone burnt into a "clinker" at a high temperature (1500°C — 1650°C.) This "clinker" in turn is ground to very fine powder as the cement which is mixed with sand and water to form sandcrete blocks.

TABLE I. COMPARISON TABLE OF OXIDE CONTENTS FOR BRICKS AND CEMENT

Percentage Oxides	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	K <sub>2</sub> O	Na <sub>2</sub> O	SO <sub>3</sub>	Li
Ordinary Cement	22	5.5	—	3	64.1	1.4	—	—	2.1	—
Brick	64.7	12.7	1.6	8.3	7.9	1.9	1.5	0.4	1.4	0.3

Cement can be subjected to further chemical tests to determine the percentages of C<sub>3</sub>A (tricalcium Aluminate), C<sub>4</sub>AF (Tetra-calcium Aluminoferrite) C<sub>3</sub>S (tricalcium silicate), and C<sub>2</sub>S (dicalcium silicate).

### PHYSICAL TESTS

For the physical tests this paper dwells more on the procedures for testing building bricks, with relevant references to cement blocks. The Standards Organisation of Nigeria has also laid down procedures for sampling bricks required for different physical tests.

Before these tests are carried out proper sampling is encouraged so as to have a good representative sample result registered. This sampling either requires

- (a) random sampling or

- (b) stratified sampling.

A random sampling gives every brick in the produced group a chance of being selected. But in stratified sampling, the group of bricks are divided into sections from which required numbers are then picked to complete the required samples to be tested. Again these samples may be withdrawn in motion, that is, as bricks are being moved from one place of handling to the other. Alternatively selection of samples could be done on sectioned stacks, although this method does not suit all types of tests, e.g., for efflorescence, contaminations may affect localised groups, thus giving room for false results. A guiding scale to ensure effective sampling is given by the Nigerian Standard.

**TABLE II, SCALE FOR SAMPLING, AND THE PERMISSIBLE NUMBER OF DEFECTIVES FOR VISUAL AND DIMENSIONAL CHARACTERISTICS**

No. of Bricks in the consignment	No. of Bricks to be selected	Permissible No. of defectives
2,001 – 10,000	20	1
10,001 – 35,000	32	2
35,001 – 50,000	50	3

Table II is taken from NIS.74 1976 UDC 624.012.8 showing the number of brick samples to be tested and the number of defective bricks that are allowed for

any given number of mass-produced bricks. This sampling is done mainly for visual and dimensional changes and the use for which the bricks will be employed; and it must be done either by random or by stratified sampling. Any number of defectives greater than the number specified in the table is deemed unsatisfactory and the products are thereby rejected.

Table III from the same standards provides a guideline for sampling of bricks to be tested for other physical properties like strength, water absorption, efflorescence and warpage.

**TABLE III: SCALE FOR SAMPLING FOR OTHER PHYSICAL CHARACTERISTICS**

Size of Consignment	Compressive strength, Water Absorption and Efflorescence		Warpage	
	No. of Samples for each Test	Permissible No. of Defectives for each Test	No. of Samples	Permissible No. of Defectives
2,001 – 10,000	5	0	10	0
10,001 – 35,000	10	0	20	1
35,001 – 50,000	15	1	30	2

Dimensional disorders can also be taken care of as shown in figure 1. Simple assessment of bricks for dimensional disorder can easily be made by arrangement of good bricks in the above forms. In between them, one can slot in samples of new bricks as they come out of production line after which they can be viewed or plumbed with a bar, or line or with a spirit level. This confirms with the British Standard Requirement B.S. 3921 1974.

### STRENGTH

Strength tests are common to both bricks and sandcrete blocks/concretes, using the same types of equipment, both for the transverse and axial compressive strengths. Of these two tests the axial compressive strength test is more common.

It is interesting to know that the strength of solid sandcrete block as opposed to hollow sandcrete block, is at its best about a third of the strength obtainable in a building brick. The variables that can easily affect the strength of a cement product are many, namely water/binder ratio, cement/sand/gravel ratio, locality and temperature of curing, quality of cement used, method of compaction, block geometry, type of additives e.g. lime etc. But once clay is properly kneaded or mixed and moulded, and once the requi-

red firing temperature is attained, the strength of its brick will approximate to more than that of sandcrete block. The compressive strengths of sandcrete blocks range between 400psi – 6,000psi (2.8MN/m<sup>2</sup> – 40MN/m<sup>2</sup>) while the compressive strength of building bricks can range from 5,000psi – 20,000psi (35MN/m<sup>2</sup> – 140 MN/m<sup>2</sup>). This obvious greater strength of the brick is a consequence of the glassy matrix of a brick which is as a result of metamorphosis and chemical reactions under intense heat as opposed to the gel structure of hydrated cement which binds aggregates together in sandcretes.

### COMPRESSIVE STRENGTH TEST

For the compressive strength test, a brick is to be sampled out as specified in TABLE III. It is first immersed in water at 27°C for 24 hours. It is removed and surplus water wiped off. The frog, if any, is filled flush with 1:3 cement/fine sand mix before curing for another 24 hours. After that the brick is again immersed in water for 3 days before another withdrawal and mopping of dripping water.

The compression is done on the flat faces with the mortar-filled side facing up. The brick is to lie between 2–3-ply plywood sheets, each 3 mm, all

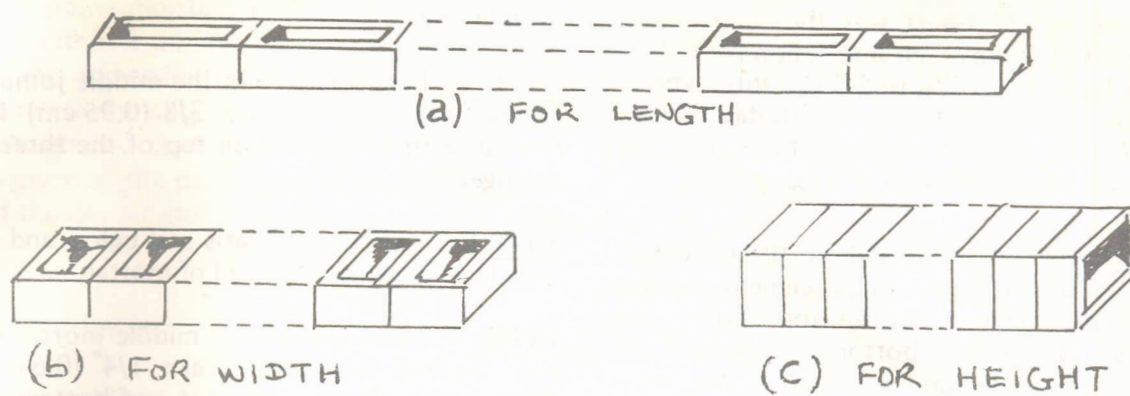


FIG. 1 Simple Brick Arrangements For Inspecting Dimensional Conformity In Bricks As In B. S. (British Standard) 392: 1914.

carefully centered between the pressing plates of the machine. Load is then applied axially at a uniform and shock-free rate of  $140 \text{ Kg/cm}^2$  per minute until there is failure. The compressive strength is given by:

$$\frac{\text{Maximum load at failure (Kgf)}}{\text{Cross Sectional Area of brick (cm}^2\text{)}}$$

An average of all the values obtained from the various bricks so crushed, gives the average compressive strength.

For perforated bricks the same procedure is followed, except that application of cement mortar is omitted and the consequent curing and second immersion in water precedes the crushing of the bricks.

It is important to note that while the strength of cement product is tested and rated according to its duration since fabrication, that of bricks is tested on one production (firing) temperature. Once a brick is out of the kiln, and is cooled to ambient temperatures, not much can happen to alter the strength it has already attained by vitrification unless it is refired to a higher temperature. Overfiring and underfiring should be avoided. When properly fired, the brick becomes a metamorphic rock which lasts for centuries unaltered. The same cannot be said of sandcrete blocks which can alter with age. The strength of a sandcrete block depends on variables that affect it during production viz the amount of cement, aggregates, water, the curing conditions, age of the cement block/concrete, location of fabrication, e.g. above or under water, and whether in the dry or rainy seasons. For the above reasons, sandcrete block tests are exacting, usually after 1, 3, 7 and 28 days because the strength is assumed to be almost fully

attained only after 28 days. Further still, building brick strength can decrease slightly if it contains some soluble salts, such as those of magnesium, sodium and calcium. Magnesium sulphate can cause disintegration in the bricks if it exists therein in significant quantities. The salts which had crystallized in the kiln within the surface pores of the bricks, may recrystallize due to hydration from rain and the consequent stresses gradually break off parts of the brick. Sodium sulphate attack is not very common, though it can cause problems too. But calcium sulphate which can at the worst cause unsightly scums or whitish discolorations of brick walls, can be quite disastrous if it attacks cement products.

When calcium sulphate in solution reacts with the calcium aluminate of portland cement products, it forms calcium-sulpho-aluminate, known as ettringite. This compound carries with it up to 20% expansion, which has caused many fatal collapses of buildings, because it seriously weakened the original strength attained by the cement product after its first month of fabrication.

The distinctive difference between the strengths of building bricks and sandcrete blocks may be made much clearer by looking at CUBE TEST experiments performed at the British Building Research Station. In this experiment the  $9'' \times 4\frac{1}{2}'' \times 3''$  normal brick size and such corresponding size of mortar "cubes" were put into different arrangements (designated types A to F) below and crushed to note the differences in strength. Two bricks of the above dimension were laid side by side to form the "cubes" and in each case, three layers or courses of a "cube" was built up, so that each course of two bricks were arranged at right angles to the preceding lower ones. All the arrangements had cement mortar joining them

on both sides of the middle course.

The curing time of 24 hours was the same under damp sacks and so too was their immersion for 6 days into water at between 15°C to 20°C. Only type E cubes were taken out of soak on the 7th day to have the plaster of pairs cast on the cube faces, top and bottom, eight hours before crush-testing.

TYPE A. arrangement consisted of three "cube" courses with 3/8 (0.95cm) thick cement mortar joining the middle course to the top and to the bottom course. Below the bottom course a third 3/8"(0.95 cm) thick mortar was added. All were crushed between three 1/8" (.32cm) thick plywood packing.

TYPE B. did not have the extra bottom 3/8"(0.95cm) mortar layer and was crushed between three 1/8" (0.32cm) thick plywood sheets.

TYPE C. was tested with no packing, just the two 3/8"(0.95 cm) joining the top and lower cubes to the middle one.

TYPE D. here apart from the middle joining mortar layers, had another two 3/8 (0.95 cm) layers' of mortar both below and on top of the three - course arrangement.

TYPE E. had Plaster of Paris cast below and on top of type D arrangement instead of mortar.

TYPE F. had the normal middle mortar joints but was crushed instead between 1/4" (0.64cm) thick straw board placed at the top and bottom. Table IV shows results got by arranging brick and cement mortar cubes in the fashion described above and crushing the different arrangements for bricks and cement mortars separately in order to demonstrate differences in strength.

TABLE IV: CEMENT MORTAR CUBE AND BRICK CUBES STRENGTHS (MN/m<sup>2</sup>)

TYPE A ARRANGEMENT		TYPE B		TYPE C		TYPE D		TYPE E		TYPE F	
Corresponding Mortar Cube Arrangement	Brick Cube Arrangement	Mortar Cube Arrangement	Brick Cube Arrangement	Corresponding Mortar Arrangement	Brick Cube Arrangement	Corresponding M/Cube Arrangement	Brick Cube Arrangement	Corresponding M/Cube Arrangement	Brick Cube Arrangement	Corresponding M/Cube Arrangement	Brick Cube Arrangement
2.10	48.23	2.10	61.32	1.88	57.75	2.25	44.59	2.55	45.08	1.77	58.66.
2.58	50.33	2.58	65.38	2.25	67.69	2.97	54.74	2.97	45.92	2.55	62.23
3.28	52.15	3.28	63.49	2.97	61.32	2.47	50.19	2.49	43.68	2.97	76.65
2.08	48.93	2.08	74.83	2.47	62.44	2.66	42.77	2.37	44.94	2.49	73.01
2.74	52.15	2.74	64.40	2.66	63.14	2.38	42.77	2.35	50.05	2.37	72.52

From the above table, it becomes evident that whatever the type of testing arrangement, bricks are stronger by far. What is emphasized here is the load-bearing capacity of brick constructions.

Engineering bricks, usually bluish-black or metallic black in colour, are even much stronger due to the reduction technique applied during firing. Such bricks should however have less than 20% porosity.

Crushing of 6" brick walls have also been tested by axial loading by specially large machines to determine strengths of brickworks. Values of up to 12,500 p.s.i. (87.5MN/m<sup>2</sup>) have been obtained. Strengths of brickworks are dependent also on the quality and the strength of the jointing cement mortar.

TEST FOR WATER ABSORPTION:

The test for water absorption is of two types, for both solid and perforated bricks. These are the 24-hour immersion in cold water test and the 5-hour boiling water test

The 24 hour immersion test

The sampling is done as specified in table III. The specimen is dried at a temperature of 110°C to 115°C to constant weight and cooled at ambient temperature before it is weighed.



The dry sample is immersed completely in clean water at 27°C + 2°C for 24 hours. After that, it is removed and dripping moisture is mopped up before it is reweighed within 3 minutes. But if the sample is relatively dry the immersion may be extended to 48 hours. If it is relatively wet, then a few hours can be allowed till it attains constant weight. The water absorption is given as the percentage of water absorbed to that of the dry weight.

$$\text{Water Absorption (\%)} = \frac{M_2 - M_1}{M_1} \times 100$$

Where  $M_1$  = dry weight  
 $M_2$  = Wet weight

yields higher figures than the 24 – hour immersion test. This is because in fired ceramics there are open pores and sealed pores. The former is easily accessible to air and liquids, but it requires the greater pressures of steam to push water into the sealed pores. So, while the brick gains some weight after soaking for 24 hours, only five hours of steam pressure increases the recorded weights of samples over and above that gained by the brick in 24 hours. In a production factory, the determination of water absorption is used for quality control, because it is much simpler and less time-consuming than the measurement of porosity. This is because absorption tests are good indications of the apparent porosity of the brick. For most ceramics the apparent porosity is approximately twice the figure obtained for water absorption. Their relationship depends on the bulk density of the material in question, because while apparent porosity is based on apparent volume, (absorption per unit volume) the water absorption is based on the weight of the materials, (absorption per unit weight). Table V. shows the relation between water absorption and apparent porosity while Table VI shows the different results of absorption tests conducted by this author from the same test samples, using 24 hours soaking method and the 5 hours boiling method.

5 – Hour boiling test:

This test is the same as above except that the specimen is boiled for five hours and the absorption percentage is given as

$$\text{Water Absorption (\%)} = \frac{\text{Wet weight} - \text{Dry Weight}}{\text{Dry weight}} \times 100$$

These experiments which the author conducted at PRODA (though mostly on refractory bricks), confirm the general experience that the boiling water test

TABLE V. SAMPLE RESULTS OF APPARENT POROSITY, WATER ABSORPTION AND BULK DENSITY FROM PRODA DENSE REFRACTORY TEST SAMPLES.

Sample No.	Apparent Porosity %	Water Absorption %	Bulk Density %
1	35.37	20.26	2.70
2.	36.36	21.09	2.71
3.	36.04	20.95	2.70
4	34.08	19.34	2.68
5	34.45	19.55	2.69

TABLE IV – 24 – HOUR SOAKING TEST AND 5 – HOUR BOILING TEST RESULTS FOR WATER ABSORPTION FROM THE SAME TEST SAMPLES

Sample Code Numbers	1	2	3	4	5	6	7	8	9	10
% Water Absorption – 24/hrs. Soaking Test	17.99	17.39	17.44	17.39	17.34	17.12	17.18	17.44	16.86	16.99
% Water Absorption – 5/hrs Boiling Test.	21.44	19.71	20.02	19.60	20.03	19.67	19.72	19.93	19.07	19.02

The absorption test immediately gives the idea of how porous, and more importantly, how permeable a brick is. This is a good pointer to the behaviour of a brick during its life-time stuck away in the wall. Too porous a brick will cause dampness. It also causes the migration and consequent deposition of soluble salts from the interior of the brick to the outside, forming some whitish discolouration. This is known as efflorescence.

### TEST FOR EFFLORESCENCE

The Nigerian Standards Organisation requires that sampling be done according to Table III. The brick is partially immersed 25 mm in water in a flat-bottomed dish or basin. The basin in turn is placed in a well ventilated room until all that water evaporates. A second doze of water is poured into the basin after the initial water has been completely evaporated. The brick is then examined after the second evaporation. The efflorescence, is then reported as "NIL", "SLIGHT", "MODERATE", "HEAVY" or "SERIOUS" following these definitions: NIL is used to describe the brick if there is no trace of efflorescence.

**SLIGHT:** is used when not more than 10% of the brick surface is covered with salt deposits.

**MODERATE:** is used when the area covered is greater than 10% but not more than 50%.

**HEAVY:** denotes a covering of over 50%

**SERIOUS:** indicates that there is not just some deposits but also some powdering and flaking of the brick especially as further wetting continues.

This defect is best avoided by doping the raw clay with adequate amounts of barium carbonate which reacts with the sulphates of magnesium, potassium, sodium and calcium, in the clay.

It may be possible to avoid dangers of efflorescence altogether by dropping some raw clay into a beaker filled half-way with a 50% dilute (HCl) hydrochloric acid. If there is vehement frothing, this particular source of raw material could be abandoned for a better choice.

The author has performed this test on 11 clays from different localities in Anambra State. The test for scums has also been performed on some clay at PRODA as well. Samples were fabricated and fired at 800°C, 900°C and 950°C. Samples from each at 800°C, 900°C and 950°C. Samples from each firing temperature were withdrawn to form 3 groups of fired test samples. Group (A) samples partially immersed in distilled water and stored at room temperature. Group (B) samples tied up and exposed

to the atmosphere during rainy season and Group (C) samples were partially immersed in ordinary tap water. These samples were inspected at weekly intervals for two months. The duration was long enough but the samples were free from efflorescence, as no discolourations were observed within the period.

The effect of efflorescence is that it spoils the red beauty of any brick structure, and this may require cleaning the brickwall with powerful water jet after some years.

### TEST FOR WARPAGE

The same sampling procedure stated in Table III is required by the Standards Organisation of Nigeria.

The Standards state that the apparatus should be a steel ruler graduated from one end in 0.5mm divisions, or a measuring steel wedge 50mm in length, 15mm in width and 15mm thick at one end to zero thickness at the other end. This wedge should be graduated in 0.5mm divisions and numbered to show the thickness of the wedge between the base and the slope. It may be said here that the inclusion of details like 0.5mm seems to make the standard impractical. Such measurements would require the use of other precision tools like the calipers. Another item required is a flat surface of steel or glass not less than 300 x 300 (mm).

The surface of the bricks is scraped of all dirt in preparation for measurements.

- (a) For concave warpage, the brick is placed on the straight edge lengthwise or diagonally along the surface to be measured. Then the location with the greatest departure from straightness is selected. The greatest distance of the brick from the straight edge is measured by a steel ruler or wedge.
- (b) For convex warpage the brick is placed on the plane surface with the convex side in contact with the plane surface, and positioning the four corners approximately equidistant from the plane. Then measurement is taken to the nearest 0.5mm of the distance from the plane surface to the four corners of the brick. The average of the four measurements is taken as the warpage.

Generally it was observed by the author that the Nigerian Standards are not far different from that of other countries, e.g. the British Standards, Indian Standards, Korean, Japanese, American etc.

Temperate countries test for a few more properties like frost resistance which is not relevant to tropical climates. Tests for soluble salts is quite relevant to us.

It is specified in the British Standard 3921: 1974 that contents by mass percent of the following soluble radicles shall not exceed:— sulphate 5% calcium 0.3%. magnesium 0.03%, potassium 0.03% and sodium 0.03%.

It may be mentioned here that there are other text-book requirements for bricks which have not been mentioned by the Standards Organisation of Nigeria. Tests or inspections of bricks for colour and texture are of relevance to users but there have been no standard tests agreed upon.

## CASE HISTORIES

Over the years there have been various uses and application tests employed for building bricks. Studies of the strength of bricks have been carried into the testing of actual wall strengths. Porosity and water absorption capacities as well as the effects of these on soluble salts inherent in the bricks have been observed experimentally. A few of such experiments are discussed briefly. M.S. Tite and Y. Maniatis (1975) made studies on clat bricks of calcareous nature. Their findings agreed with studies by Freeman and Rayment on the lower Oxford clays, used for producing the Fletton Bricks. Using the scanning electron microscope, the different internal morphologies developed when non-calcareous and calcareous clays are fired at temperatures ranging from  $750^{\circ}\text{C}$  –  $1200^{\circ}\text{C}$  were observed. The presence of  $\text{CaCO}_3$  (calcium carbonate) resulted in the lowering of the vitrification temperature in calcareous clays, and also produced porous structures which remained over a wide temperature range of  $100^{\circ}\text{C}$  –  $250^{\circ}\text{C}$ . The explanation for the open cellular structures was tied to the release of  $\text{CO}_2$  as the  $\text{CaCO}_3$  decomposed. The increased pressure that goes with the  $\text{CO}_2$  gas release displaces aggregates of micaceous flakes in the vicinity of these calcite inclusions, thereby leaving pore inclusions, which could not heal during the subsequent vitrification.

Hence for bricks production, it is advantageous to fire calcareous clays with lower energy consumption. Secondly, because of the wide range of temperatures over which the morphology remains unchanged, temperature control is a less critical factor. But it is to be noted that the porosity of such bricks may constitute a problem in the bricks' life time. Also, if the calcite inclusions are not well reacted during firing, the problem of efflorescence emerges. To avoid this, fine grinding of the raw materials and higher firing temperature are advised. In the alternative, such a deposit can be abandoned in favour of a better one if possible. If better ones are not available it becomes very costly to use additives like barium carbonate.

Another work was done on the moisture expansion of bricks and brick structures, using Fletton bricks in particular at the Building Research Establishment. By this moisture expansion is meant the ability of fired clay materials to be open to the absorption of atmospheric water vapour over a long time, into the surface of pores within the fired brick.

Bricks were drawn from the factory production line before they had time lying around and absorbing atmospheric moisture, and were used to build several test walls. Some were exposed to the weather and the others were built under sheltered conditions, using two different samples of the bricks in the different walls, which were then studied over a period of four years. It was found out that the ratio of the moisture expansion of the walls to that of individual bricks alone was about 0.6.

Under the wettest exposure conditions, further expansion of the walls occurred, caused by sulphate attack on the mortar joints. These happened to be the sulphates from bricks. But there was no observable difference between the expansions of strong and weak mortar.

From the findings, the storing of bricks before use is encouraged since a large proportion of the brick expansion from moisture absorption occur before being put into a structure. This will lessen the degree of expansion in any finished brickwork. There is need then for manufacturers to test the moisture expansion of their bricks and communicate same to buyers, to ensure the best use of their bricks. It was also noted that dipping of bricks in water, though it helps easy laying, does not offer prevention of any subsequent moisture movement. It all means that freshly manufactured bricks are so dry that they take in atmospheric water at an enormous rate thereby registering high expansions.

A similar study on water and air penetration through brick walls was done by A.J. Newman and D. Whiteside (1981). It was a theoretical and experimental study which investigated the penetration of water through 100mm (about 8") single-leaf brickwork.

These were wetted on their external faces at a rate similar to severe stormy weather conditions, imposing different pressure differences to imitate different wind speeds. Air leakages were also measured through these walls.

It was shown that water in time saturated these walls which looked very well built, even when there was no applied pressure differences across the wall. Excess water flowed freely on the other side of the walls while imposed pressures increased penetration. These leakages were found to be through the cracks estimated at about 0.1mm between bricks and mortar at their interface. Air leakage measurements were also made with some specially constructed apparatus and a correlation was established between air and water leakage for a wide range of brick types and standard constructions tested.

This last experiment may be of some relevance to certain parts of Nigeria, e.g. the riverine areas. People are therefore advised not to construct the outside walls of buildings with single-leaf-laid bricks,

except for internal partitioning. By single-leaf is meant the laying of bricks on the flat face, giving only a wall thickness of about  $4\frac{1}{2}$ ".

There is a need for our architects and civil engineers to make similar studies with regard to water exposed constructions, which involve the use of bricks in our weather conditions.

### CONCLUSION:

The last part of this paper dwelt on case histories of tests done on bricks and brick structures. Brick as a material has many advantages over sandcrete block. While cement is basically a physical gel bond affected by a few variables like the percentage of  $C_3A$  and the

mixing ratios of cement/water, cement/sand, etc, a brick is a result of pure chemical reaction, the intense heat of the furnace. Apart from oxides in the raw clay which can be manipulated to advantage, there are many other fabrication and production techniques to get the best results. Of these, the greatest importance to the builder. General strength of cement products can in no way compare with that of brick as was evidenced in the civil-war-affected zones, where the colonial columns stood against the 106mm mortar bomb the grenade, while sandcrete blocks were either shatteringly shattered or gapingly punctured by Mark 4 gun bullets.

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