

PROCEEDINGS OF NATIONAL TECHNICAL WORKSHOP ON BUILDING COLLAPSE IN NIGERIA

Theme

**CURBING THE INCIDENCES OF
BUILDING COLLAPSE IN NIGERIA**



NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE
(FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY)



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EDITED BY

MATAWAL D. S. AND OMANGE G. N.

DIRECTOR-GENERAL: PROFESSOR DANLADI SLIM MATAWAL

NBRRI

NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE
(FEDERAL MINISTRY OF SCIENCE AND TECHNOLOGY)

(Building Capacity and Setting the Pace in indigenous Construction Technology Development)

Administrative Headquarters: NBRRI, Plot 449 Samuel Ogedengbe Crescent, Jabi
Nigeria. P.M.B 5065 Wuse GPO, Abuja

National Laboratory Complex: NBRRI, Km 10, Idiroko Road, P.M.B 1055, Ota,
Ogun State, Nigeria

website: www.nbrri.gov.ng

Phone: +2348039245620, +234802381788

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FOREWORD

The World over, Collapse of Buildings is a rare phenomenon and usually an unexpected event in the construction industry. Building Collapses are always thought to be due to a large extent on unforeseen events such as natural disasters like earthquakes, landslides, tsunamis, etc. The reasons for this are because the design of buildings to withstand collapse is a standard codified and analytical process well enshrined in specifications of countries and civil/structural curricula of Universities.

One of the major challenges of the Nigerian construction industry at the moment, therefore, is the frequency at which buildings collapse in different parts of the country. These events are always accompanied by loss of lives, property, loss of livelihood and permanent injury. This is in addition to the embarrassment to the built environment and the country at large for the apparently helpless situation. In 2011 alone, several buildings collapsed in different parts of the country including Abuja, Lagos, Enugu, Sokoto, Port Harcourt, Awka, etc. Though within its mandate, the Nigerian Building and Road Research Institute (NBRRI) was able to investigate only a few cases due to limited resources. The collapses investigated included those in Mararaba (near Abuja), Adenubi Street in Ikeja and in Enugu environs. The reports of the investigations on the Mararaba and Ikeja collapses have been published as NBRRI Reports.

The outcome of the investigations were revealing and far reaching recommendations made. Some relevant Government establishments were sensitized. So also were some professional bodies such as COREN, CORBON, ARCON and NEMA. The outcome of the interactions with the professional bodies was the need to conduct a National Workshop on Building Collapse, as a short term measure, so as to bring together all Stakeholders to proffer lasting solutions to the hydra-headed challenge of Building Collapse in Nigeria. This culminated in the setting of a Planning Committee with membership of CORBON, COREN, NSE, ARCON, SON, NEMA, TOPREC and NBRRI. A National Workshop on Building Collapse was successfully held in Lagos between the 15th and 16th of May 2012 in Abuja.

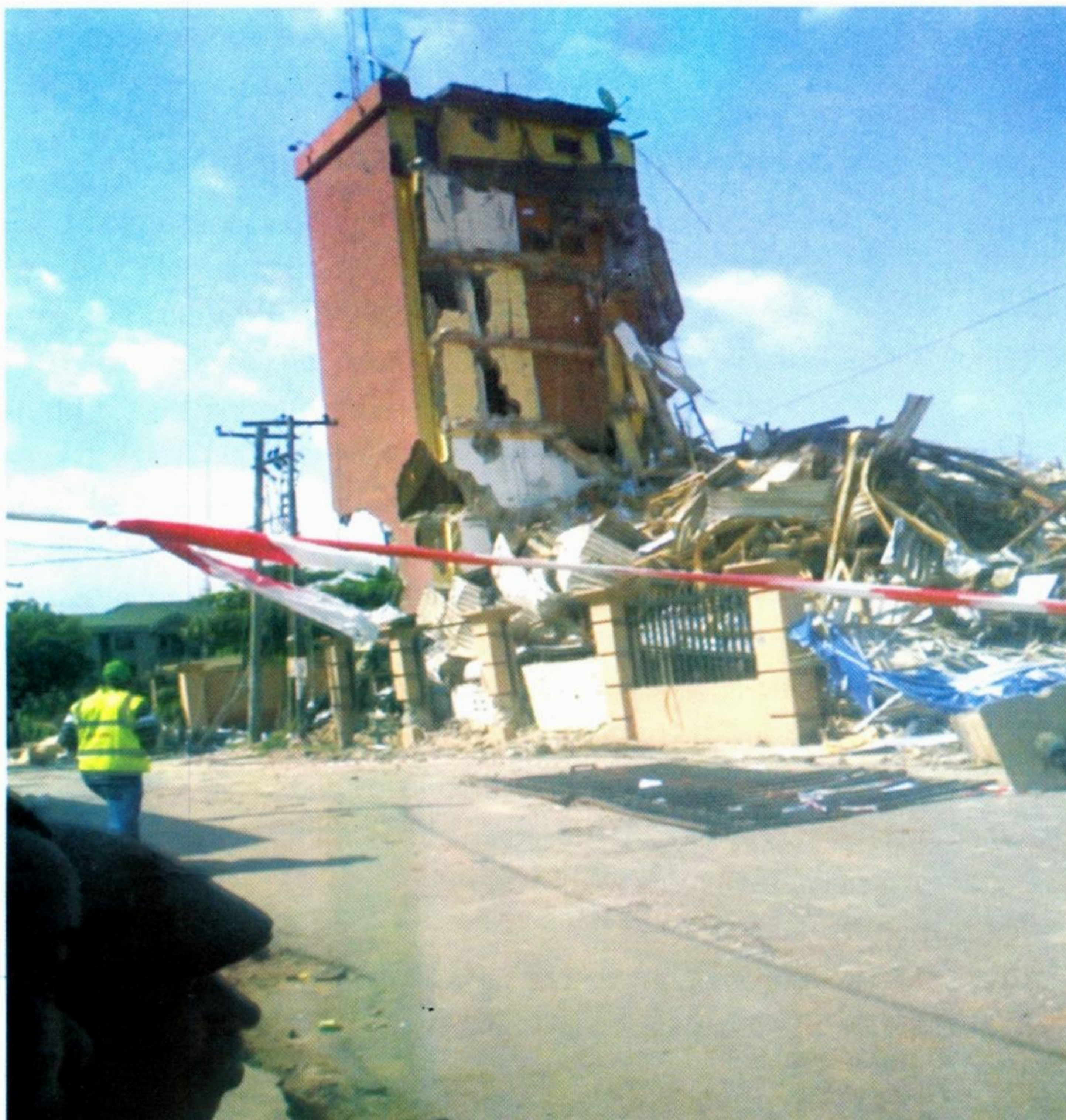
Ten (10) well researched and/or practical Papers were presented by eminent scholars and practitioners in the built environment in the well-attended, two-day Workshop. These cover issues like the Causative Factors/Remedies; Case Histories and Documentation of Trend of Building collapse; Sanctions and Legal Propriety; Building Collapse Site and Disaster Management; Synergy Promotion between Professional Bodies, Regulatory Authorities, etc. These Papers are presented in this Proceeding and will be found valuable by all Stakeholders in the built environment both in the public and private sector; and indeed by all Nigerians.

Prof Danladi Slim MATAWAL
Director-General/CEO, NBRRI

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The Challenges of Building Collapse In Nigeria



By

Danladi Slim MATAWAL

[BEng(ABU), MSc(London), DIC, PhD, CEng., FNSE, RE(coren)]

Professor of Civil Engineering

Director-General/Chief executive Officer

Nigerian Building and Road Research Institute, NBRRI

(Federal Ministry of Science and Technology, FMST)

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Nigerian Building and Road Research Institute, NBRRI

ABSTRACT

Although God has so much blessed us with good weather compared to other climate conditions in the world. One will still wonder why we are allowing man made conditions to Incessant incidences of Collapse of Buildings were recorded in 2011 in Nigeria and the situation has continued up to 2012. The revelations from Field Investigations, results of Tests and Technical Reports by NBRRI have revealed that the use of Poor Materials (especially Concrete) and the reduction in the sizes and specifications of Structural Elements (Foundations, Columns, Beams and Floor thicknesses) are primarily responsible for the unabated rate of failures of on-going and existing structures in the country. These reports have confirmed that if the quality of requisite "Skilled Manpower" on construction Sites can be improved upon and Proper Supervision machinery is installed on all Sites, the problem can be solved. The reports also deem minimal knowledge of Concrete behaviour as imperative and essential to curbing the associated phenomenon of catastrophic collapse. Since Cements (especially "OPCs") are the critical component adhesive/glues in Mortar and Concrete, some basic theorems, specifications and standards are espoused and numerous laboratory test results are presented. These results have confirmed that majority of Nigerian Cements meet with defined National and International standards although more work is recommended for sustainability. Currently therefore, proprietary standards of construction materials, especially those that are industrially controlled like Cements and Steel Rods, can be exonerated from contributing to the problem of collapse directly. The need for the training of "Skilled Manpower" and retraining professionals through the "Continuous Professional development, CPD" programs is recommended. The establishment of the NBRRI Academy is identified as one of the many measures to permanently check-mate the challenges posed by the incessant collapse of Buildings in Nigeria.

1.0 INTRODUCTION

In the year 2011, the number of Building collapses that took place in Nigeria was not only disturbing but rather alarming. Following the pattern of previous years, our mega-city, Lagos, recorded the highest number of incidences involving Buildings under construction as well as a handful that had been in use for years. For example, Buildings collapsed at Maryland, in Ikeja, at Ketu, and in other parts of Lagos. Following on the heels of Lagos, was the fast growing federal capital city of Abuja and its suburban areas where Buildings collapsed at Jabi, in Garki, at Pape, in Mararaba and early this year (2012) at Gwarinpa estate (in process of a demolition exercise). In the same year of 2011, major Building collapses were also recorded in Enugu where three(3) buildings came down with a period of one month, while Ibadan, Sokoto and Yenagoa also witnessed collapses. In each of these collapses, lives were lost while injuries were sustained and huge economic losses were recorded from the impact of the absence of these structures, the property therein, the contribution

to the economy of the nation from the services provided in and from the structures. The lives lost and maimed represent colossal losses to the national economy in terms of human resources and potentials.



Figure 1: Collapse of 5-storey Hotel under construction at Adenubi Close, Ikeja - Lagos, March 2011

It is important to note that with the exception of one of the structures in Enugu, which belonged to a Teaching Hospital, the majority of the failed structures were private investments; like the Hotel building in Ikeja, Private Hospital Building at Pape-Abuja, Zenith Bank extension building in Mararaba, on the outskirts of Abuja, Private Residential building in Maryland, Lagos, private Offices, Shopping Malls, etc. It did not just end in 2011 because barely four months into 2012, there have been recorded collapse of Buildings in Abuja, Awka, and Ilorin. Each of these negative events has always been accompanied by the well-known sequence of loss of lives, injuries, and loss of property. So the occurrences events have led to many questions as to whether the frequency of these collapses is a normal sequence of events; whether national authorities and cognate organs in Nigeria care about the problem; whether the professional regulatory bodies in the building and construction sector do care and make attempts at solutions; whether the stake holders in the industry (Construction companies, Consultants, SON, NEMA, etc.) have appreciated the growing threats being posed by the problem. It has also become pertinent to explore and know whether the traditional Town Planning and Municipal authorities still exist when these collapses are still being continuously recorded since they

always possessed the roles of approval of building plans, vetting structural designs, certifying that there were comprehensive subsoil investigation and tests, monitoring to ensure that appropriate supervision mechanisms were always mounted on Sites, etc.

It is pertinent at this early stage to point out that most regulatory authorities as well as the Nigerian Building and Road Research Institute did not sit back to watch events unfold without intervening. As a matter of fact, the Institute has visited most of the Sites of the failed structures in 2011, even if just for the purposes of visual inspection and physical in-situ assessments in some cases.



Figure 2: Collapse of 6-Storey Building at MaryLand, Lagos, 26th October 2011

Within the limits of its resources, the Institute has raised technical teams of experienced and knowledgeable professionals to undertake comprehensive study, conduct tests on some of the sites, and on materials, for the purposes of forming an opinion as to measures necessary to mitigate, or even eliminate, this negative event from the national history of this nation. Some of the works (one from Lagos and the other from Abuja) have been published as NBRRI Technical reports available on the Institute's website or as hard copies from the Institute's Library in Abuja OR Ota. The Lagos work was achieved at great strain and risk to the Institute's Resource personnel and Staff because they were intimidated and turned back from Site several times. It is therefore courteous to take the opportunity to record appreciation to the Lagos Governor and the Director of Physical development of the state for supporting NBRRI until the report was made on the Adenubi Close, Ikeja, collapse. A high calibre technical team was raised with experts from Univeristy of Nigeria, Nsukka, Nnamdi Azikiwe University, Awka, Enugu State university, professionals in Enugu and Awka to study the three Enugu collapses, but the team has failed to submit a report since they were commissioned in June 2011.



Figure 3: Two Storey Zenith Bank Collapse at Mararaba, Abuja outskirts, 5th July 2011

The Nigerian Building and Road Research Institute, on its part, has presented some of its findings to a Committee comprising of Professional bodies and Stakeholders upon which it was decided to hold this National conference/workshop. Therefore the workshop is supposed to fashion out solutions that can be applied to effectively curb the incessant collapse of Buildings in Nigeria. Suffice it to state that the results of NBRRI works have revealed that there are needs for short-term and long-term solutions that include conferences such as this, training workshops for capacity building, training academies, sensitization and enlightenment campaigns, media chats, etc., to solve the problems. Some have been embarked upon already but this is just one of the recommended identified activities on this matter.

2.0 REASONS FOR COLLAPSE OF BUILDINGS IN NIGERIA

It has not been easy deciding which reasons supersede the others as the primary causative reasons for the collapse of Buildings in Nigeria. This is because many reasons can be adduced as suggested from the interventions undertaken by the Nigerian Building and Road Research Institute, NBRRI, on this matter. Amongst the many reasons, are some of those espoused in discussions in the paragraphs following below.

2.1 The Use of Poor Materials on Sites of Building Construction

The poor applications and use of inferior materials, especially Concrete, has been identified as a major causative factor for the collapse of Buildings in Nigeria, NBRRI Technical Reports Nos. 22 and 23. Almost the entire buildings, in 2011, that collapsed did so catastrophically; implying that the Structure and Loads came down without prior warning and the deformation movements were so fast that there was no time to evacuate. Whatever were the primary reasons that precipitated failure

(example, deficiencies of foundations, columns, beams or other structural elements), the failure of structures by explosion denote that there was poor concreting on site. Indeed, results measured on sites by NBRRI in the last one year have confirmed this assertion, as presented in Table 1 below, extracted from Technical Report No.23. The ultrasonic Pulse velocity tests were used for the determinations, which is a non-destructive test acceptable for lump specimens from the site of the collapsed structure. In fact, NBRRI Technical report No.22 had categorically asserted that the failure of one of the structures investigated was by rapid disintegration of concrete elements and almost transformation of sandcrete blocks into sand.



Figure 4: Disintegrated Building, Mararaba, Abuja outskirts, 5th July 2011

Consequently, the single most important cause of catastrophe in building collapses is poor concreting and this should be expatiated upon at a later stage. Concrete is generally designed in grades which, in Nigeria, correspond to classes of strength and therefore categories of concrete below those shown in Table 2 should never be used.

The concrete should be 'designed' OR 'designated' and in a 'designated concrete', the producer who is generally the constructor (not necessarily the same as a contractor) is required to produce a material to satisfy the designated strength and consistency (workability) using a particular aggregate size. Designated concretes are designated as Grade 30, for example, based on the cube strength up to Grade 50, according to the application involved. A designed concrete, on the other hand, is the one whose strength class, cement type, and limits to composition including water/cement ratio, cement content (mix ratio) are specified.

Table 1: Comprehensive Strengths of Concrete Elements (Adenubi Close, Ikeja)

Structural Element		Compressive Strength (N/mm ²)	REMARK
Type	No		
COLUMNS	1	12.3	Poor
	2	8.9	Poor
	3	8.7	Poor
	4	7.1	Poor
BEAMS	1	8.3	Poor
	2	7.3	Poor
	3	15.7	Poor
	4	8.1	Poor
SLABS	1	7.6	Poor
	2	8.5	Poor
	3	13.0	Poor
	4	19.7	Poor
	5	7.1	Poor

Source: NBRRI Technical Report No. 23

The symbol f_{ck} generally denotes characteristic strength based on cylinder strength of the concrete, which is a nomenclature in use in USA but not used in Nigeria. The concrete class therefore corresponds to the cylinder strength. The term f_{cu} denotes cube strength and corresponds to the Grade of the concrete in general use in Nigeria. If Tables 1 and 2 are compared, it will be observed that though Grades of concrete below 20 are generally unacceptable, but generally, most of the concretes in use on majority of Sites have strengths significantly far below the minimum. Of course lean concrete mixes are acceptable for blinding mixes and categories of mortar, but these applications are non-structural.

Table 2: Strength Classes of Concrete

Class	Grade	Concrete Details		Normal lowest for application as specified
		f_{ck} , N/mm ²	f_{cu} , N/mm ²	
16	20	16	20	Plain concrete
20	25	20	25	Reinforced concrete
25	30	25	30	
28	35	28	35	Prestressed & Reinforced concrete subject to chlorides
30	37	30	37	Reinforced concrete in foundations
32	40	32	40	Special concretes and constructions
35	45	35	45	Special concretes and constructions
40	50	40	50	Special concretes and constructions
45	55	45	55	Special concretes and constructions
50	60	50	60	Special concretes and constructions
55	67	55	67	Special concretes and constructions
60	75	60	75	Special concretes and constructions
70	85	70	85	Special concretes and constructions
80	95	80	95	Special concretes and constructions
90	105	90	105	Special concretes and constructions

In some Sites of collapsed structures, the situation is even more lamentable because the concrete does not even have sufficient strength to be subjected to measurement, like the Pape 5-storey hospital site. In Gwarinpa Navy estate which collapsed while a demolition exercise was taking place, the NBRRI report, which is unpublished, read: "There is clear evidence that the reinforcement for all structural elements (floors, beams and columns) had dissociated from the concrete during demolition. Expert opinion is that this is evidence of poor concreting i.e. lack of bond between steel and concrete. The inspection also revealed that coarse aggregate size as large as 40mm may have been used in the batching process. However, specimen concrete samples brought to NBRRI Laboratory and measured using non-destructive testing process gave the following rebound hammer readings: 22, 15, 11, 20, 11, 14, 16, 12, 21, 12 and 14, 10, 10, 9, 8, 7, 6, 9, 9, 10, 9 with an average of 17.5 rebound value and 9 rebound value respectively. Consequently, the compressive strengths of the 2 large-size concrete samples, converted from the rebound values were 8.75N/mm^2 and 4.5N/mm^2 respectively. The second sample was retrieved from a column concrete". These results are disastrous and it is noteworthy, however, to mention that some of these results were questioned by colleagues who claimed that in a destroyed structure, the use of any elements for tests was unacceptable to them because of the weakening effect of the failure. However, this is viewed as an unimportant argument because internationally, back-analysis on failure sites in order to build case histories rely heavily on visual inspections and the use of intact samples retrieved in the best way possible. These arguments are also quite understandable coming, as they were, at the heels of legal action by the families of three (3) workers who died in the Gwarinpa collapse.

NBRRI Technical Report No.22 clearly identified poor concreting, low design mix ratio, lack of adequate OR improper curing, large impurities and organic matter in fine aggregates (sand) used for concrete batching, etc., in the inspected specimens of the collapsed building at Mararaba on the outskirts of Abuja.

Generally, the emphasis on concrete quality and strength is to underscore its significance in the event of a failure caused from whatever factors. Table 3, as example, is an elementary illustration of the widely differing properties of steel and concrete when they act in composite state in reinforced concrete.

Philosophy of design dictates that in design of reinforced concrete sections, a proper analysis must be undertaken in which resulting stresses from varied practical loading conditions are considered and provisions made for the worst, not optimal, conditions.

Table 3: Properties of Concrete and Steel

Property	Assessment of Composite or Individual Material Response	
	Concrete	Steel
Strength in Tension	Poor	Good
Strength in Compression	Good	Good but slender members will buckle
Strength in Shear	Fair	Good
Durability	Good	Corrodes if unprotected
Fire Resistance	Good	Poor as it suffers rapid loss of strength at high temperatures

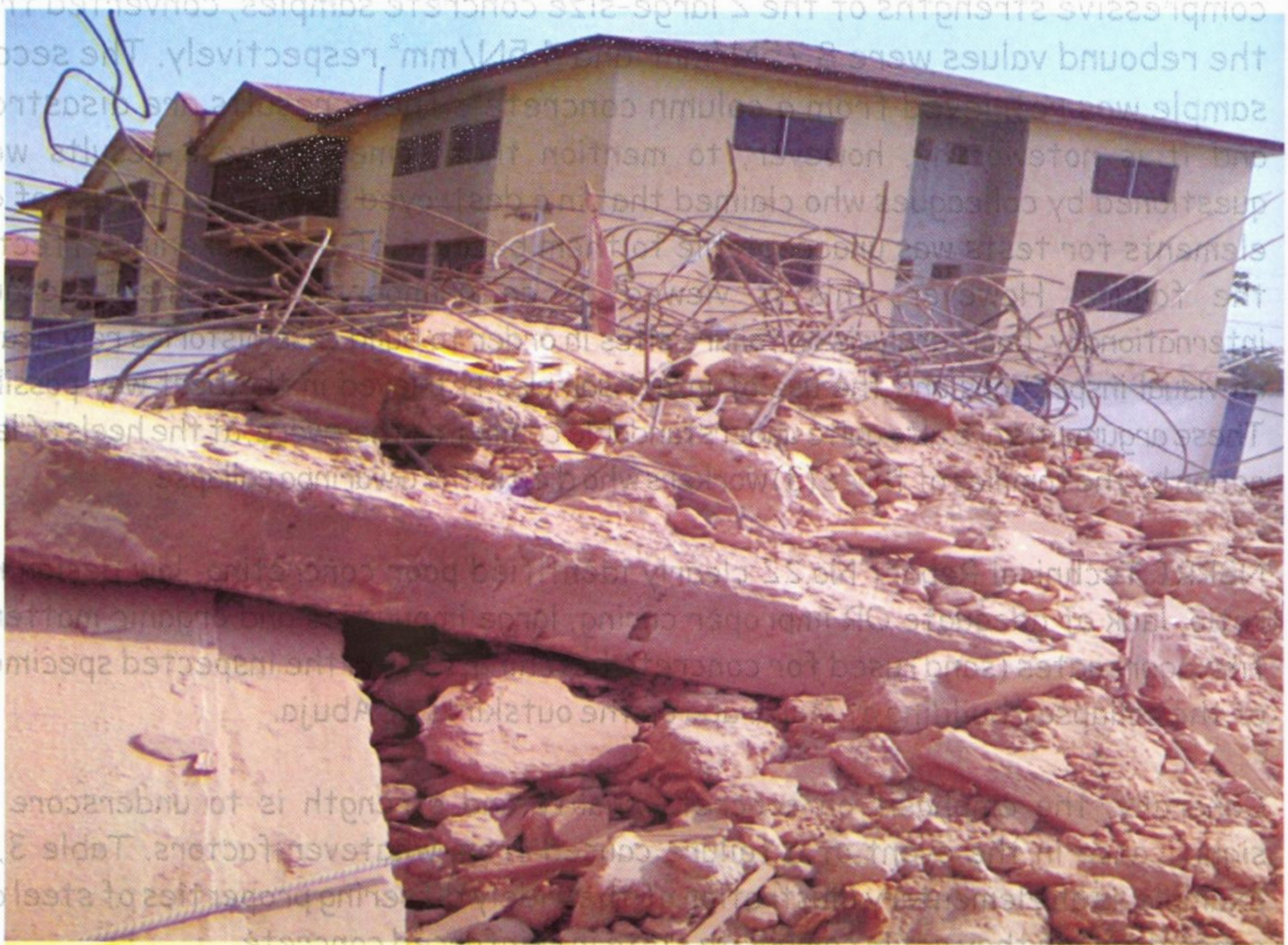


Figure 5: Building Collapse at Gwarinpa-Abuja, January 2012

The mathematical assessment is made so that in the composite action of the Reinforced Concrete elements, steel is made to take the stresses in sections where tensile stresses result from either bending, shear OR torsion (twisting) forces. However for this composite action to be effective, there are many conditions that must be satisfied. These include the need for the steel reinforcement to be as close to the surface of the element as possible so that an undue cracked section does not have to be permitted in the large concrete area, the cross-sectional area of the steel must be adequate in relation to the imposed forces, etc. However from the view-point of collapsed structures, a very important property is that there should be proper bonding between the concrete and the steel and these entails a proper concrete grade/strength as well as adequate surround of the steel with concrete so that there is good grip. Thus a structure may fail but will not collapse catastrophically if there is proper bonding. This discussion has much significance to the Nigerian situation of poor concreting and can be expatiated to throw a lot of additional light on the preponderance of collapsed structures in the country.

2.2 Improper Foundations and Lack of Sub-Soil Investigations

The terminology used (though primarily for strip footings beneath the building walls) for foundations in Nigeria is blinding which is grossly misleading because it could be responsible for many of the collapses. This is because 'Blinding' is the process of ground preparation in order to provide an even surface upon which the actual foundation of the structure can be built. It is made of lean concrete and will never exceed 50mm thick whereas the minimum thickness of a structural



Figure 6: Mararaba Collapsed Site Showing Footing Reinforcement clearly under-sized (450mmx450mm)

foundation (even for nominal situations below a wall) is 150mm prepared using concrete grade 25.

Sometimes in the last quarter of 2011, there was a catastrophic collapse of a 5-storey hospital building under construction in Pape, Abuja that led to loss of lives and injuries. The Press crew invited NBRRI to the Site and some of the physical revelations were astounding because apart from the structure standing on a waste dump site that had not been reclaimed prior to construction, there was hardly any foundation while the super-structural materials were poor. Similarly, when comprehensive measurements were made on the Site of a collapsed structure in NBRRI Technical report No.22, it was found that the design had recommended foundation sizes of 2.6m by 2.6m, 2.9m by 2.9m, and 3.2m by 3.2m; which were in all fairness, the sizes of bedrooms in some Servant's quarters; too bogus for a single storey building.. When the foundations were constructed, the size of all the footings was changed to 450mm by 450mm, which is the minimally allowed size of a strip footing. Because of the distortion of the structure at failure, it is sometimes not easy to measure the thickness of these footings but, very significantly, the depths of footings is usually too shallow for the desired pinning effect for stability. Thus a very important factor to be considered in relation to the catastrophes in our building industry is the impropriety of designing and constructing structures with no Geotechnical investigations, tests and reports; which are requested to provide for proper design of the foundations. A Structural foundation is aimed to transfer the structural loads from the superstructure safely to the ground below. If a foundation is not properly designed, any form of two failures can take place, namely:

- Ø Catastrophic collapse of the Soil beneath the foundation when the shear strength is inadequate to support the applied load. Failure of this type is not supposed to be very common but the preponderance of opinion is that it is possibly responsible for many of the Nigerian failures because nobody is checking the practice. Whenever it occurs, it tends to lead to large distortions of the superimposed loads and the structure, and will likely usually take place very rapidly.
- Ø Excessive settlement of the structure will take place due, in part, to the distortion of the soil mass as a result of the applied shear stress and in part due to the consolidation of the soil as a result of increased normal stresses.

Settlement and the resistance to shear failure depend on the size and shape of the foundation, its depth below the ground surface and the properties of the soil. In designing and constructing foundations, it is generally necessary to consider and examine the possibilities of both forms of failure. My Students will generally recall the equations of bearing capacity that governs the behaviour of structural footings to be:

$$q_{ult} = \left(1 + \frac{0.3B}{L}\right) c N_c + \gamma z N_q + \left(1 - 0.2 \frac{B}{L}\right) \frac{1}{2} B N_\gamma \dots \dots \dots \text{eq. 1}$$

Where q_{ult} is the ultimate bearing capacity, B and L are the lateral and longitudinal dimensions of the footing, respectively; \tilde{a} , c are parametric measured properties of the soil; z is the depth of foundation; while N_c , N_q and N_γ are bearing capacity factors dependent upon the soil intrinsic property, ϕ . The equation is primarily for rectangular foundations but can be modified for foundation of any shape.

2.3 Overall Design of the Structure

Except Churches and Mosques where the older Clergy and Imams usually insist on orthodox designs, architectural design has not constituted visible problems that precipitate collapse of buildings in Nigeria. The reason is that most developers will seek a measure of minimum guidance as to the size, shape and circulation (form and function) of the structure, and so will consult an architect; though most would stop at the draughtsman. The problem with most private developers appears to be with the structural designs which are the critical items that dictate the stability of a building. The foundation design, which is critical, has already been elucidated upon above while the role of materials, especially concrete, was earlier discussed. Structural design generally specifies the sizes of structural elements, their reinforcements, the limiting (yield or grade) specifications of the materials to be used and many other details (like concrete cover, w/c ratio, aggregate sizes, bar bending schedule, etc.) that will ensure smooth practical implementation. The structural framing elements that are important include, from the bottom which is the order of sequence of construction, Foundations, Columns, Beams, Slabs, Roof Members, Staircases in reinforced concrete, but there are many other items in Steel structures.

In NBRRI investigations, there has been no convincing evidence to suggest that structural designs were lacking though in most of the situations, especially in Lagos and Enugu, it was a risk to the lives of our Resource personnel to insist on obtaining these documents. Nonetheless, it is important to emphasize that care should be taken not only to ensure that there should be structural designs for each project,

but also to request that all Ultimate and serviceability Limit states are properly check and complied with. Theory of Analysis and design of Structures is well covered in literature (example Matawal, 1987, Mosley et al, 1999, and Reynolds & Steedman, 2005) and is comprehensively taught in the curriculum of Construction related courses in our Tertiary institutions.

2.4 Site Supervision

Site supervision on construction sites is both a professionally mandatory function as well as a regulatory role. For reasons that will be seen subsequently in this paper, it is very important that Site Supervision should be taken seriously on all Sites. Thus the Town Planning and/or Development Control authorities should insist that all mandatory documents necessary for the successful execution of a project are made available before the commencement of construction and that proper supervision machinery is set up on every site. In the projects that NBRRI has visited as a result of failures, there were no Project Sign Boards to state Name of Project, The Client, The Architects, The Structural Engineers, and The Quantity Surveyors. It is therefore very safe to say that there was no supervision which would have corrected anomalous designs and ensure that all design specifications are implemented on Site. Through routine inspections and tests (of materials, especially cube tests), the use of superior materials will be enforced and failures can be eliminated. Ejeh (2011) informed Stakeholders of NBRRI that 70.0, 23.3 and 6.7 per cent of building collapses in Nigeria belonged to Private, Public and Corporate organizations, respectively. This statistics sums up the scenario dictated by the lack of supervision because most private developers in this country including, unfortunately, some huge private individuals that can constitute corporate organization, do not set up any supervision for their buildings. Thus the very important matter of proper supervision machinery is a very critical factor that can alleviate our predicament on collapsed structures because if every structure can be properly supervised by proper professionals, not quacks, then there will be an immediate and drastic reduction in the number of collapsed structures in this country. Furthermore, the professional regulatory authorities in this country would have been empowered to punish erring members in situations where shortcomings are identified. To further buttress this point, Professionals on sites will identify design flaws, they will redesign elements according to the dictates of actual exposed environmental and site conditions, they will inspect and correct anomalous material imperfections.

2.5 Role of Artisans, Craftsmen and Construction Workers

Good Designs and even Poor designs are translated into real Life Structures by constructions workers such as Masons, Brick and Block Layers, Iron Benders,

Electricians, Plumbers, Welders, Carpenters assisted by labourers on Sites. These are supposed to be skilled workers and frequently, together with the Detailers and Draughtsmen, constitute the so-called 'quack engineers' of the construction sites that the society so much complains about. Unfortunately, the Nigerian construction industry is totally devoid of the truly skilled workers in the construction industry because many of these personnel in the contemporary practice lack any basic training to undertake the roles they are engaged in the Sites. They lack any basic knowledge of the trades they are engaged in; as example because all Nigerian Masons would insist that a very wet mix with much sand and very few stone aggregates is the best concrete because it is easy to mix and handle (pour/place, and vibrate) whereas the truth is that a high water content spells weak concrete because stone aggregates in dense batch represent the strength of concrete. NBRRI has identified the lack of skills of Artisans, Craftsmen and Construction workers as a basic problem of the construction industry responsible for building collapse. NBRRI believes that if these categories of personnel are trained, they will not only deliver good construction as a contribution of their trade but will also, additionally be empowered with skills to detect poor design, lack of detailing, poor construction materials, etc. NBRRI is therefore recommending a long-term solution in the form of a NBRRI Academy that will train these personnel at different levels.

2.6 Other Reasons for Collapse of Buildings

Even though the emphasis has been on Reinforced Concrete construction in this paper, it is important to know that a large number of elevated and even Ground Water storage tanks fail in Nigeria every year while classical Steel structures do fail. The point is that Steel construction is not a very common form of construction in the country but it is very attractive for large span structures and must be taken into consideration. For example, buckling failures are very common in Steel structures while special attention must be paid to joints and points of stress concentration in these structures. Thus wherever there is a joint, checks must be made and special stiffeners (in form of plate) provided to resist bearing, shear, punching shear and associated stress complications and concentrations due to peculiarities of construction.

In nature generally, failures could happen due to faulty construction sequence, scaffolding and formwork faults and early striking of formwork, extra-ordinary loads and unexpected failures detailed by Matawal (2008). Failures can also be due to a combination of reasons of known causes like design faults, foundation incapacities, etc. The issue of faulty construction is noteworthy because so many structures in Nigeria are standing not because they are technically safe but

because the block-work, rather than the structural framing, is helping them to stand. For example in NBRRI Technical report No.22, it was observed that if the collapsed structure catalogued therein had the block-work on the ground floor built before they started partitioning the upper floors, the structure may have survived. Similarly, in the Steel structure cited by Matawal (2008), if the roof bracing and the Purlins had been installed before the extra-ordinary load posed by the windstorm took place, the structure would not have collapsed because resistance against lateral loading conditions would be provided by these members.

At this juncture, it is imperative to simply mention that the case of unexpected loads is a peculiar situation that stakeholders like NEMA, should always be prepared for. The threats from the continuous bombings in Nigeria is an unexpected load while Floods, earthquakes, Tsunamis, Hurricanes, Tornadoes, etc., are other unexpected situations that only nature can control, attenuate or tame, because their occurrences are beyond the scope of ordinary human minds.

3.0 ROLE OF ORDINARY PORTLAND CEMENTS

The term CEMENT is applied accurately to any adhesive and cohesive material and the category of these materials applied for the production of concrete specifically referred to as HYDRAULIC cement. It is hydraulic because the setting and hardening is achieved by the addition of water, in mixing OR in curing. On the general sense, Cements are broadly classified as Portland or Non-Portland cements and NBRRI is deeply and intensely interested in all types of cements to make housing affordable to the citizenry of this country and, in particular, those types whose manufacturing procedures are based on local raw materials and are environmentally eco-friendly involving green processes. The Institute has, in its plans this year, the initiative to produce Pozzolana cements by the code name 'NBRRI CEMENT'. However in Nigeria, the most widely used are the Portland Cements which account for 90 percent of all cements produced globally. The setting of cement is a chemical reaction between cement and water, a process known as HYDRATION, Matawal (2001). The reaction is exothermic (evolves heat) and is irreversible. The setting of cement is a gradual stiffening process defined by empirical limits in relevant standards all over the world, dictated by practical experience in association with certain experimental guidelines. Strength continues to increase after hardening and usually takes several years to reach an ultimate value. Among the Portland cements, the ordinary Portland cement, OPC, is most widely used in the construction industry.

3.1 Chemistry of Ordinary Portland Cement

The raw materials used in the manufacture of Portland cement consist mainly of Lime (from limestone), Silica, Alumina and Iron Oxide (all from Clay). They

constitute the main raw material compounds of Portland cement. These compounds react in the kiln at high temperature resulting in the four main Portland cement components shown in Table 5. The shortened notations, used in Cement chemistry by Engineers, describe each oxide by one letter, (Matawal, 2000): $\text{CaO}=\text{C}$; $\text{SiO}_2=\text{S}$; $\text{Al}_2\text{O}_3=\text{A}$; and $\text{Fe}_2\text{O}_3=\text{F}$. Likewise, H_2O in hydrated cement is denoted by H.

Table 4: Main Raw Material Compounds of Portland Cement (BS 12: 1999)

Raw material	Compound	Formula	Notation
Limestone OR Chalk	Lime	CaO	C
	Carbon Dioxide	CO_2	-
Clay	Silica	SiO_2	S
	Alumina	Al_2O_3	A
	Iron Oxide	Fe_2O_3	F

Table 5: The Four Main Components in Portland Cement (BS 12: 1999)

Names of Component	Oxide Composition	Notation of Components
Tricalcium Silicate	$3\text{CaO}.\text{SiO}_2$	C_3S
Dicalcium Silicate	$2\text{CaO}.\text{SiO}_2$	C_2S
Tricalcium Aluminate	$3\text{CaO}.\text{Al}_2\text{O}_3$	C_3A
Tetracalcium Aluminaferrite	$4\text{CaO}.\text{Al}_2\text{O}_3.\text{Fe}_2\text{O}_3$	C_4AF

A general idea of the composition of Portland cement can be obtained from table 6, which gives the oxide composition limits of Portland cements. The computation can be easily made from first principles by using the 'Bogue's equation' to calculate the approximate proportions (% by weight) of each component of Portland cement (as shown in Table 7).

Table 6: Approximate Composition Limits of Portland Cement (BS 12: 1999).

Oxide	CaO (C)	SiO_2 (S)	Al_2O_3 (A)	Fe_2O_3 (F)	MgO	Alkalis ($\text{K}_2\text{O}, \text{Na}_2\text{O}$)	SO_3
Content, %	60-67	17-25	3-8	0.5-0.6	0.1-4.0	0.2-1.3	1-3

Bogue's Equations:

$$C_3S = 4.07 (CaO) - 7.60 (SiO_2) - 6.72 (Al_2O_3) - 1.43 (Fe_2O_3) - 2.85 (SO_3) \dots \text{eq.2}$$

$$C_2S = 2.87 (SiO_2) - 0.754 (3CaO \cdot SiO_2) \dots \text{eq.3}$$

$$C_3A = 2.65 (Al_2O_3) - 1.69 (Fe_2O_3) \dots \text{eq.4}$$

$$C_4AF = 3.04 (Fe_2O_3) \dots \text{eq.5}$$

Table 7: Approximate proportions of Component in Ordinary Portland Cement (BS12: 1999)

Component	C ₃ S	C ₂ S	C ₃ A	C ₄ AF	Others
Approximate Proportion (% by wt.)	45	25	12	9	9

The silicates C₃S and C₂S are the most important components which are responsible for the strength of hydrated cement paste. Together they constitute 70 to 80 percent of Ordinary Portland Cement. The average C₃S content in modern cement is about 45% and that of C₂S is about 25%. C₃S has rapid hydration with water, evolves considerable heat and is responsible for early strength. C₂S has slow hydration with water and little heat evolved and is responsible for ultimate strength. Logically therefore, C₃A is responsible for initial setting time. It has rapid hydration with water, considerable evolution of heat, low sulphate resistance, little cementing behaviour, but it is a useful flux in manufacture. The presence of C₃A in cement is undesirable: it contributes little or nothing to the strength of cement except at early ages, and when hardened, the Cement paste is attacked by sulphates, the formation of calcium sulphoaluminate (ettringite) may cause disruption. However, C₃A is beneficial in the manufacture of cement in that it facilitates the combination of lime and silica. C₄AF amount depends upon iron in clay, gives the grey colour to cement. It is flux during manufacture of cement and is difficult to remove. Its quantity is small in cement and compared with the other three components, it does not affect the behaviour significantly; however, it reacts with gypsum (CaSO₄) to form calcium sulphoferrite and its presence may accelerate the hydration of the silicates.

During the grinding of clinker, gypsum is added to adjust setting time. It also improves the soundness of cement. ASTM C150 -92 and BS12: 1999 specify the amount of gypsum as the mass of sulphur trioxide (SO₃) present, i.e. between 1 and 3 percent of cement clinker.

In addition to the four main components in Portland cement listed in table 3, there exist minor components. They usually amount to not more than few percent of the mass of cement. Two of the minor components are of interest: the oxides of sodium and potassium, Na_2O and K_2O , known as the alkalis (although other alkalis also exist in cement). They have been found to react with some aggregates, the products of the alkali aggregate reaction causing disintegration of the concrete and have also been observed to affect the rate of the gain of strength of cement. It should, therefore, be pointed out that the term 'minor components' refers primarily to their quantity and not necessarily to their importance (Neville & Brooks, 2003).

The advancement made in the various spheres of science and technology has helped us to recognize and understand the micro structure of the cement compounds before hydration and after hydration. The X-ray powder diffraction method, X-ray fluorescence method and use of powerful electron microscope capable of magnifying 50,000 times or even more has helped to reveal the crystalline or amorphous structure of the unhydrated or hydrated cement. Both Le Chatelier and Tomebohm observed four different kinds of crystals in thin sections of cement clinkers. Tomebohm called these four kinds of crystals as Alite, Belite, Celite and Felite. Tomebohm's description of the minerals in cement was found to be similar to Bogue's description of the compounds. Therefore, Bogue's compounds C_3S , C_2S , C_3A and C_4AF are sometimes called in literature as Alite, Belite, Celite and Felite respectively. The chemical reactions that take place between cement and water is referred as hydration of cement. Figure 2 shows a schematic representation of the formation and hydration of Portland Cement (Shetty, 2010). The chemistry of concrete is essentially the chemistry of the reaction between cement and water. It has been observed that the hydrates of both C_3S and C_2S (silicates) will turn out to be the same.

It can actually be shown that the reaction of C_3S with water produces more quantity of calcium hydroxide $\{\text{Ca}(\text{OH})_2\}$ than that of C_2S . C_3S reaction with water also produces lesser quantity of calcium silicates gel (C - S - H gel) than that of C_2S . Calcium hydroxide, $\text{Ca}(\text{OH})_2$ is not a desirable product in the concrete mass, it is soluble in water and gets leached out making the concrete porous, particularly in hydraulic structures. Under such conditions it is useful to apply cement with higher percentage of C_3S content (Shetty 2010).

Since C_3S readily reacts with water and produces more heat of hydration, it is responsible for early strength of concrete. A cement with more C_3S content is better for cold weather concreting. The quality and density of calcium silicate

hydrate formed out of C_3S is slightly inferior to that formed by C_2S . Because C_2S hydrates rather slowly, it is responsible for the later strength of concrete and, maybe also logically, produces less heat of hydration. The calcium silicate formed is rather dense and its specific surface (calcium silicate) is higher. In general, the quality of the product of hydration of C_2S with water is better than that produced in the hydration of C_3S . The other products of hydration of C_3S and C_2S with water are calcium hydroxide. In contrast to the calcium silicate hydrate (C - S - H), the calcium hydroxide is a compound with distinctive hexagonal prism morphology and constitutes 20 to 25 percent of the volume of solids in the hydrated paste. The lack of durability of concrete is on account of the presence of calcium hydroxide. The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C_3A and cause deterioration of concrete. This is known as sulphate attack. To reduce the quantity of $Ca(OH)_2$ in concrete and to overcome its bad effects by converting it into cementing product is an advancement in concrete technology. The use of blending materials such as fly ash, rice husk ash, silica fume, and such other Pozzolanic materials, are the steps to overcome bad effect of $Ca(OH)_2$ in concrete. The only advantage is that $Ca(OH)_2$, being alkaline in nature, maintain pH value around 13 in the concrete which inhibits the corrosion of reinforcement. Therefore, to understand the behaviour of concrete, it is necessary to acquaint oneself with the structure of hydrated hardened cement paste. If the concrete is considered as two phase material namely, the paste phase and the aggregate phase, the understanding of the paste phase becomes more important as it influences the behaviour of concrete to a much greater extent. Note that the strength, the permeability, the durability, the drying shrinkage, the elastic properties, the creep and volume change properties of concrete are greatly influenced by the paste structure. The aggregate phase though important, has lesser influence on the properties of concrete than the paste phase. Therefore, in our study to understand concrete, it is important that we have a deep understanding of the structure of the hydrated hardened cement paste at a phenomenological level.

3.2 Structure of Hydrated Hardened Cement Paste in Concrete

Even though it is difficult to explain the behaviour of concrete fully and exactly, it is possible to explain the behaviour of concrete for better understanding of the structure of the hardened cement paste. It is necessary for concrete technologists to fully understand the structure of hardened cement paste in great detail to be able to appreciate and rectify the ills and defects of the concrete.

For simplicity's sake, it is convenient to consider only the structure of the paste phase. Fresh cement paste is a plastic mass consisting of water and cement. With

Figure 9 represents the microscopic schematic model of structure of hardened cement paste. C_3S requires 24 percent of water by weight of cement and C_2S requires 21 percent. It has also been estimated that on an average 23 percent of water by weight of cement is required for chemical reaction with Portland cement compounds. This 23 percent of water chemically combines with cement and, therefore, it is called bound water. A certain quantity of water is imbibed within the gel-pores, this water is known as gel-water. It can be said that bound water and gel-water are complimentary to each other. If the quantity of water is inadequate to fill up the gel-pores, the formations of gel itself will stop and if the formation of gel stops there is no question of gel pores being present. It has been further estimated that about 15 percent by weight of cement is required to fill up the gel-pores. Therefore, a total 38 percent of water by weight of cement is required for the complete chemical reactions and to occupy the space within gel-pores.

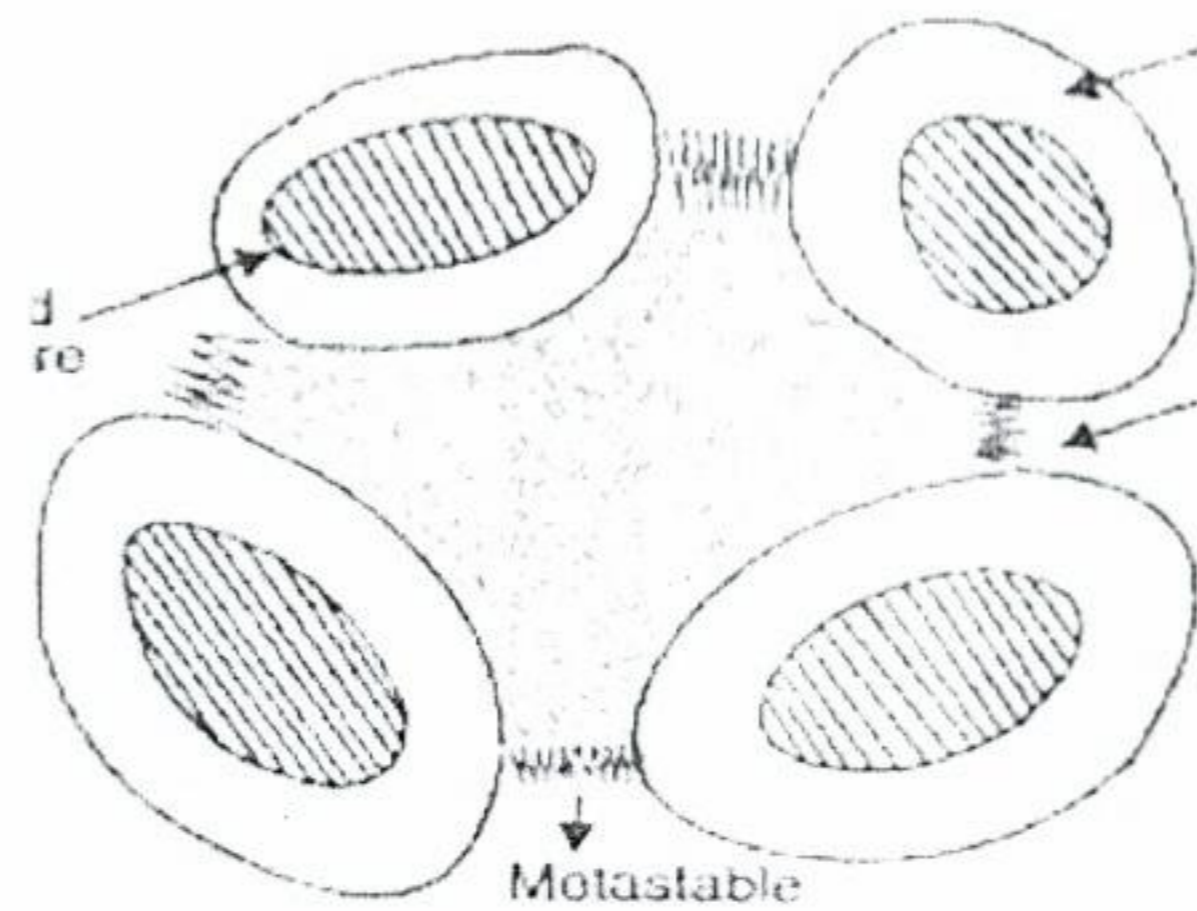
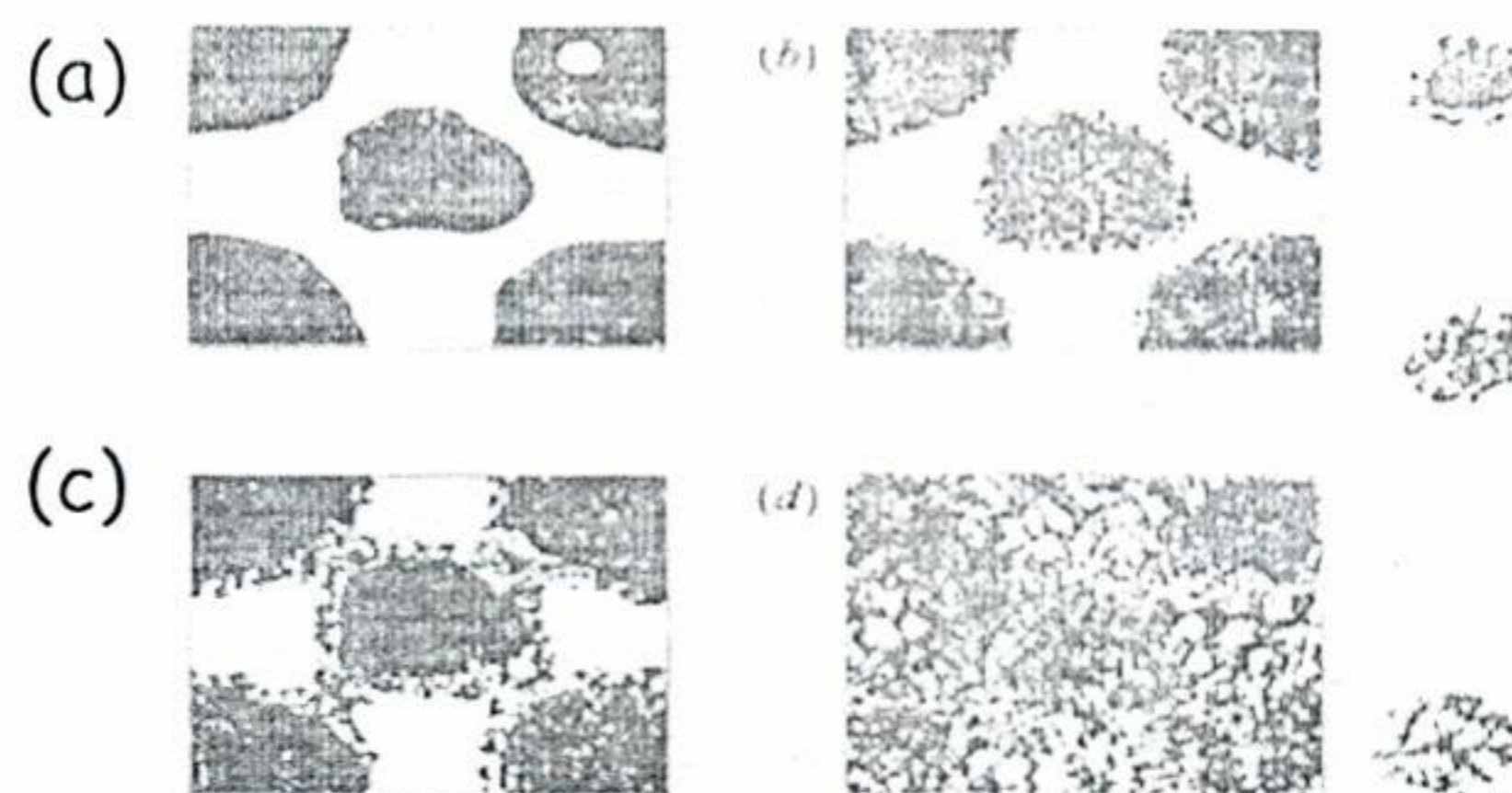


Figure 9: Microscopic schematic model representing the structure of hardened cement paste.

If water equal to 38 percent by weight of cement is only used, it can be noticed that the resultant paste will undergo full hydration and no extra water will be available for the formation of undesirable capillary cavities. On the other hand, if more than 38 percent of water is used, then the excess water will cause undesirable capillary cavities.



Unhydrated cement particles
Cement gel Capillary pores and cavities

Fig. 10: Diagrammatic representation of the hydration process and formation of cement gel

Therefore, the greater the water above the minimum 38 percent required used, the more will be the undesirable capillary cavities. In all these, it is assumed that hydration is taking place in a sealed container, where movement of moisture to and from the paste does not take place. It can be seen that the capillary cavities become larger with increased water/cement ratio. With lower w/c ratio the cement particles are closer together. With the progress of hydration, when the volume of anhydrous cement increases, the product of hydration also increases. The increase in the volume of gel due to complete hydration could fill up the space earlier occupied by water up to a w/c ratio of 0.6 or so. If the w/c ratio is more than 0.7, the increase in volume of the hydrated product would never be sufficient to fill up the voids created by water and such concrete would ever remain as porous mass. This is to say that gel occupies more and more space that was once occupied by mixing water. It has been estimated that the volume of gel would be about twice the volume of unhydrated cement.

3.3 Physical and Chemical Properties of Ordinary Portland Cement

The cement to be used in construction must have certain given qualities in order to play its part effectively in a structure. When these properties lie within a certain range, the engineer is confident that in most of the cases the cement performance will be satisfactory. Also, based on these properties, it is possible to compare the quality of cement from different sources. Routine tests are carried out on the cement either on dry powder or hardened cement paste, or sometimes on the concrete made from the cement, to maintain quality within specified limits. Some of the physical properties of Ordinary Portland Cement are elaborated upon in the following sections.

3.3.1 Fineness: The Fineness of a cement is a measure of the size of particles of cement and is expressed in terms of 'specific surface of cement'. It can be calculated from particle size distribution or one of the air permeability methods. It is an important factor in determining the rate of gain of strength and uniformity of quality. For a given weight of cement, the surface area is more for a finer cement than for a coarser cement. The finer the cement, the higher is the rate of hydration, as more surface area is available for chemical reaction. This results in the early development of strength. The amount of water required for constant slump concrete decreases with the increase in the fineness of cement. (Gambhir 2007). Fineness is a vital property of cement, and both British standard (BS) and American standard (ASTM) require the determination of the specific surface (in m^2/kg). The specific surface of cement can be determined by the air permeability (Lea and Nurse) method (BS 4550: part 3: section 3:3:1978) which measures the

pressure drop when dry air flows at a constant velocity through a bed of cement of known porosity and thickness. From this, the surface area per unit mass of the bed can be related to the permeability of the bed. A modification of this method is that of Blaine in which the air does not pass through the bed at a constant rate, but a known volume of air passes at a prescribed average pressure, the rate of flow diminishing steadily; the time taken for the flow to take place is measured, and for a given apparatus and standard porosity, the specific surface can be calculated and a lot of details can be obtained from Neville and Brooks (2003). The BS 12:1999 limits the specific surface area of cement per kilogram (fineness) to $225\text{m}^2/\text{kg}$. Also the same value is given by Indian Standard Specification (IS 8112-1989).

3.3.2 Setting Times: For finding out initial setting time, final setting time, soundness of cement, and strength, a standard consistency of the cement has to be used. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat apparatus plunger having 10mm diameter and 50mm length to penetrate the cement paste inside the mould to a depth of 5mm above the bottom of the mould. The apparatus used is called Vicat apparatus. The apparatus is used to find out the percentage of water with respect to the weight of cement to be used, required to produce a cement paste of standard consistency. This test is required to be conducted in a constant temperature ($27 \pm 2^\circ\text{C}$) and constant humidity (90%). Initial setting time, for convenience, is regarded as the time elapsed between the moment that the water is added to the cement to the time that the paste starts losing its plasticity. After completing the standard consistency test on a cement paste specimen, the plunger is to be removed from the Vicat apparatus and replaced with the initial setting time needle which is about 1mm thick. The period elapsing between the time when water was added to the cement and the time at which the needle penetrates the cement paste specimen to a depth of 5mm above the bottom of the mould (specimen) is taken as initial setting time. The British Standard BS 12:1991 specifies a minimum of **45 minutes for initial setting time** of Ordinary Portland Cement, American Standard ASTM C150- 92 prescribed **60 minutes as the minimum setting time** for Ordinary Portland Cement and Indian Standard IS 8112-1989 specifies minimum of **30 minutes**. Standards Organization of Nigeria (SON) specifies **minimum of 60 minutes** for all OPCs.

The final setting time is the time elapsed between the moment the water is added to the cement and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. The setting process is accompanied by temperature changes. The temperature rises rapidly from the initial setting to a peak value at the final setting. The setting time

decreases with rise in temperature up to 30°C and vice versa (Gambhir, 2007). The same Vicat apparatus is used for final setting test. The initial setting needle is to be replaced by the final setting needle with a metal attachment hollowed out so as to leave a circular cutting edge 5mm in diameter and set 0.5mm behind the tip of the needle. Final setting is said to have occurred when the needle makes an impression on the paste surface but the cutting edge fails to do so. British standards prescribe the final setting time as a **maximum of 10 hours** for Ordinary Portland Cement, which is the same as that of the American Standards and Indian Standards. Since temperature affects the setting time, BS 4550(1978) specifies that the mixing has to be undertaken at a temperature of 20±2°C and minimum relative humidity of 65 percent.

3.3.3 Soundness: The unsoundness of cement is caused by the undesirable expansion of some of its constituents, sometimes after setting. The large change of volume accompanying expansion results in disintegration and severe cracking. The unsoundness due to the presence of free lime and magnesia in the cement which prevents direct contact between lime and water. After the setting of cement, the moisture penetrates into the free lime resulting in its hydration. Since slaked lime occupies a larger volume, the expansion takes place resulting in severe cracking. The unsoundness due to the presence of magnesia is similar to that of lime. The unsoundness may be reduced by limiting the MgO content to less than 0.5%, fine grinding OR allowing the cement to aerate for several days and thorough mixing. The primary tests for soundness are the Le Chatelier test (free lime test only) and Auto Clave test (free lime & alumina test). The expansion carried out in the manner described in BS4550 : 1978, ASTM C 151-89 and IS: 8112-1989 should **not be more than 10mm** in Le Chatelier test and **0.8 percent** in Autoclave test. No test is available for the detection of unsoundness due to an excess of calcium sulphate, but its content can be easily determined by chemical analysis

3.3.4 Strength: The compressive strength of **hardened cement** is the most important of all the properties. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found by the mortar cube crushing tests and concrete compression tests. These are conducted on standardized aggregates under carefully controlled conditions and therefore give a good indication on strength qualities of cement. The strength of concrete appropriate for different reinforced concrete tests were already discussed in chapter One and standard cube sizes 100mm cube and 150mm cube are used. For **fresh concrete**, the workability tests can be used to project the ultimate strength of the concrete where the Slump Cone Apparatus is used. NBRRI has made original contributions in the last one year in this respect. Because the rate of development of strength of

concrete depends on the effective curing age, it is necessary to predict the strength as the curing age progresses for the purposes of monitoring the rate of development in the field. The Table 8 gives some of the code recommendations in this respect. Matawal and Abba-Gana (1998) measured these developments at various curing temperatures and made a comprehensive conclusion revealing that high temperatures are detrimental to the ultimate strength of concrete.

Table 8: Recommended Developmental Strengths of Concrete with Curing Age

Test Type	Strength recommended by standards at given curing ages, N/mm ²		
	Curing Age, days	BS 12:1999	ASTM 150-92
Mortar Method	3	23 ± 5%	13
	7	-	20
	28	41 ± 5%	28
Concrete Method	3	13 ± 5%	-
	7	-	-
	28	29 5%	-

3.3.5 Chemical properties of Ordinary Portland Cement.

The ratio of percentage of lime to percentage of silica, alumina and iron oxide is used to measure the chemical properties of Ordinary Portland Cements using the formula given by equation 6.

$$\frac{\text{CaO} - 0.7\text{SiO}_2}{2.85\text{SiO}_2 + 1.2\text{Al}_2\text{O}_3 + 0.65\text{Fe}_2\text{O}_3} \dots\dots\dots \text{Eq. 6}$$

This ratio should not be greater than 1.02 neither should it be less than 0.66. The formula is called lime Saturation Factor (LSF) percent and both British standard BS12:1991 and Indian Standard IS 8112-1987 agree on the limiting values. The numerator relates to the lime component, while the denominator relates to the clay. Thus LSF is a measure of the correct balance between the two materials of adequate combination in the kiln and also it assumes that no excess of free clay is present. The 'insoluble residue', another chemical property, is determined by treating cement with hydrochloric acid, is a measure of adulteration of cement, largely arising from impurities in gypsum. BS12:1999 limits the insoluble residue to 1.5% (maximum) of the mass of cement. The corresponding limit of ASTM C150 -92 is 0.75% (maximum) while the Indian Standard IS 8112-1989 limits the insoluble residue to 2%. The loss of the ignition (LOS) is also another chemical property of Ordinary Portland Cement. It shows the extent of carbonation and hydration of free lime and free magnesia due to the exposure of cement to atmosphere. The specified limit both of ASTM C150-92 and BS 12:1999 is 3%. The Indian Standard IS 8112-1989 limit the loss on ignition to 5% (maximum).

4.0 TESTS RESULTS ON OPCs IN COMMON USE IN THE NIGERIAN CONSTRUCTION INDUSTRY

Sofar, the emphasis in this paper has been on the state of concrete practice as its design and handling (including concrete mix-design, influence of mixing water, batching process, and operational handling). But the problem still presents a possibility that Nigerian Cements may be constituting part of the reasons for incessant building collapse in the country. In this regard, there have been a number of research outputs that have considered the qualitative parameters of cement discussed in Chapter Three. One of these reports emanating out of a postgraduate work in process for publication by Matawal and Ze-Gyang (2011) investigated the quality of fourteen (14) Ordinary Portland Cement (OPC) brands in Nigeria and labeled them as Samples A, B, C, D, E, F, G, H, J, K, L, M, N and P being brands (but not corresponding to any order of identification) from Ashaka cement, Atlas, BUA, Burham, Dangote (2 samples from BCC and Obajana plants), Diamant, Eagle, Elephant, Ibeto, Magen-Roi, Pure-Chem, Sokoto and Unicem cements. The need to give sharp focus and attention to Cement quality by the Researchers was to assess its role, amongst other concrete elements, as a principal component in the production of mortar and concrete for structures as an explanation of the structural failures in Nigeria. To determine their conformity to Nigerian standards, the cements and concretes at 2, 7, 14, 21 and 28 days were subjected to compressive strengths and analyses of other chemical and physical parameters, enumerated in chapter Three of this paper. According to the grouping dictated by categorization of Nigerian cements adopted by the authors, in the CEM I group of cement strength class 42.5, Sample C had the highest cement strength of 60.01 N/mm^2 while in CEM II group of the same strength class; Sample E had the highest cement strength of 56.26 N/mm^2 . In CEM II group of strength class 32.5, Sample K had the highest cement strength of 46.70 N/mm^2 . Sample H was the only cement adjudged not to have met the Nigerian cement standard with respect to cement strength: attaining strengths of 8.35 N/mm^2 and 30.40 N/mm^2 at 2 and 28 days of curing, respectively. It also had the highest fineness residue of 32.4 percent while Sample C had the lowest fineness residue of 4.4 percent retained in the $45\mu\text{m}$ sieve. Apart from the chemical constituents of cements, its fineness was observed to be the most critical physical parameter relevant to its maturity strength. Some of the details of the research are further espoused in this chapter.

4.1 Test Procedures and Specifications

The report by Matawal and Ze-Gyang (2011) notes that the Standards Organization of Nigeria (SON) specifies the minimum criteria for manufacture and importation of Cements for sale and distribution in the Nigerian market. The concrete used in

the research was prepared from the Cement Samples, Fine Aggregate (Washed river sand), Standard sand, Coarse Aggregates (10 and 20mm), and Water (distilled and tap). The tests conducted were:

- Ø Cements (Chemical):- Chemical composition test
- Ø Cements (Physical Tests):- Standard Consistency Test, Initial Setting Time, Final Setting Time, Strength Test, Free Lime (F/L), Insoluble Residue (I.R.), Fineness Test, Specific Surface Area (S.S.A.), Loss On Ignition (L.O.I.).
- Ø Concrete (Fresh): Slump Test
- Ø Concrete (Hardened):- Compressive strength at 2, 7, 14, 21 and 28 days.

Samples A, B, C and D were classified as CEM I brands while Samples E, F, G, H, J, K, L, M, N, and P were classified as CEM II brands.

4.1 Chemical Tests on Cements

In the chemical analyses of the Cements, the relative proportions of Lime saturation factor (LSF), Dicalcium Silicate (C_2S), Tricalcium Silicate (C_3S), Tricalcium Aluminate (C_3A), and Tricalcium Alumino Ferrite (C_4AF) of CEM I brands were considered with a view to observing their practical Nigerian effects on the strength properties of the cement samples. The chemical compositions were determined more accurately for CEM I brands as the amount of additives to the clinker was less than 5% of the total cement. In CEM II, the addition of inert fillers (e.g. limestone) reduces the cement reactivity; thereby affecting the chemical analyses results which vary widely in interpretation from that of CEM I. However, the quality of CEM II depends solely of the quality of clinker used in their production and on their physical properties.

4.1.1 Lime Saturation Factor (LSF): The standard specifies that this value should be between 66 and 102 percent or ratios of between 0.66 and 1.02, respectively. The correlation coefficient between the LSF's of CEM I's and their cement strengths at 28 days was 0.28 which indicated that the higher the LSF, the higher the strength of the cement. The results showed that its effect on cement strength was not very significant.

4.1.2 Dicalcium Silicate (C_2S): The results obtained for CEM Is proved that an increase in the proportion of C_2S led to a corresponding increase in the 2 day strength of cement. Negative values were observed for all CEM II's with the exception of Sample M and N. A correlation test (correlation coefficient = 0.82) of percentage C_2S and 2 day strength of the CEM Is revealed a high significance between an increase in strength and percentage of C_2S .

4.1.3 Tricalcium Silicate (C_3S): In the CEM I's samples, Sample C had the highest cement strength of $60.01N/mm^2$ with percentage C_3S of 61.96 percent. Though Sample D had a higher C_3S value of 63.78 percent, it was observed that Sample C had higher Specific Surface Area and a lower fineness residue.

Tricalcium Aluminate (C_3A) which affects the setting time and heat of hydration and Calcium Alumino Ferrite (C_4AF) which is responsible for the coloration of cement were not given priority as they had less significance on the strength of cement.

Table 9: Chemical Analysis results.

Compound	Percentage Present in Cement Sample													
	A	B	C	D	E	F	G	H	J	K	L	M	N	P
$SiO_{2(tot)}$	19.43	19.78	19.5	19.12	20.04	19.38	18.04	18.69	18.25	16.69	16.79	22.67	19.86	17.76
$SiO_{2(c)}$	18.78	19.40	18.23	18.79	17.31	16.82	15.15	17.15	16.33	15.15	16.15	21.35	18.32	17.02
IR	0.65	0.38	1.27	0.33	2.73	2.56	2.89	1.54	1.92	1.54	0.64	1.32	1.54	0.74
Al_2O_3	4.49	4.4	4.78	4.76	4.52	5.25	4.95	4.64	4.57	4.34	5.26	5.54	5.89	4.47
Fe_2O_3	3.15	3.36	3.13	3.32	3.45	3.57	3.08	2.95	3.2	2.8	2.37	4.07	4.6	3.16
CaO	61.32	62.45	61.26	62.22	60.88	62.58	61.73	64.83	64.47	64.88	63.14	58.58	61.38	63.47
MgO	3.11	2.11	3.85	4.15	2.49	2.37	0.81	1.44	1.28	1.83	1.34	1.54	1.59	2.37
SO_3	2.72	3.12	2.77	2.43	3.12	1.92	3.28	1.21	2.75	2.19	2.56	2.25	3.14	3.00
K_2O	1.02	0.9	0.6	0.52	0.98	0.27	1.00	0.25	0.29	0.58	1.18	0.67	0.2	0.6
Na_2O	0.22	0.17	0.23	0.19	0.21	0.13	0.15	0.13	0.14	0.18	0.23	0.25	0.14	0.24
P_2O_5	0.10	0.03	0.1	0.08	0.04	0.5	0.11	0.22	0.27	0.07	0.16	0.09	0.17	0.13
Mn_2O_3	0.12	0.07	0.03	0.05	0.04	0.11	0.18	0.07	0.08	0.01	0.09	0.06	0.12	0.15
TiO_2	0.21	0.26	0.28	0.63	0.28	0.29	0.25	0.29	0.3	0.2	0.3	0.43	0.39	0.27
Cl ⁻	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cr_2O_3	0.89	0.61	1.08	1.01	0.57	0.58	0.39	0.88	0.92	0.36	0.42	0.52	0.9	4.04
LOI	2.63	2.38	2.45	3.90	4.37	8.23	8.45	7.09	6.92	8.77	6.60	3.45	4.56	2.56
TOTAL	99.43	99.65	100.07	102.39	101.00	105.19	102.43	102.70	103.45	102.91	100.45	100.13	102.95	102.23
F/L	0.82	1.23	1.08	0.75	1.19	1.75	1.45	2.98	0.67	0.86	1.42	0.86	1.13	0.93
LSF	99.14	97.68	101.03	100.22	104.73	110.11	118.25	115.47	117.57	128.33	115.82	82.66	96.65	111.61
C_3S	61.13	58.52	61.96	63.78	67.24	73.96	83.25	82.61	92.50	106.08	82.50	23.26	50.94	82.14
C_2S	7.73	11.47	5.53	5.75	-1.10	-7.57	-19.37	-13.15	-22.97	-36.59	-15.93	43.66	14.09	-13.17
C_3A	6.57	5.97	7.37	7.00	6.14	7.87	7.91	7.30	6.70	6.76	9.93	7.79	7.83	6.50
C_4AF	9.59	10.22	9.52	10.10	10.50	10.86	9.37	8.98	9.74	8.52	7.21	12.39	14.00	9.62

4.2 Physical Tests on Cements

Though all physical tests on cement were carried out, only the results of standard consistency, initial and final setting time, strength test, fineness test and chemical composition were comprehensively discussed because of their significance in both the Nigerian (SON) and international standards.

4.2.1 Standard Consistency test: Though the initial and final setting time do not in any way determine the strength property of cement; it serves to give engineers a guide to water/cement ratio adjustments in mixes. Cements which had high Specific Surface Areas and low ($45\mu m$) residues were found to require more water and vice versa. Cement Sample M had the highest initial and final setting time of

258 and 343 minutes respectively while cement Sample G had the least initial setting time of 171 minutes, Sample C was also observed to have the least final setting time of 203 minutes while it had the least interval between the initial and final setting time. All the cement brands assessed met the SON requirements with regards to initial setting time; ≥ 75 minutes for cements of strength class 32.5 N/mm² and ≥ 60 minutes for cements of strength class 42.5 N/mm². This is illustrated in Figure 11.

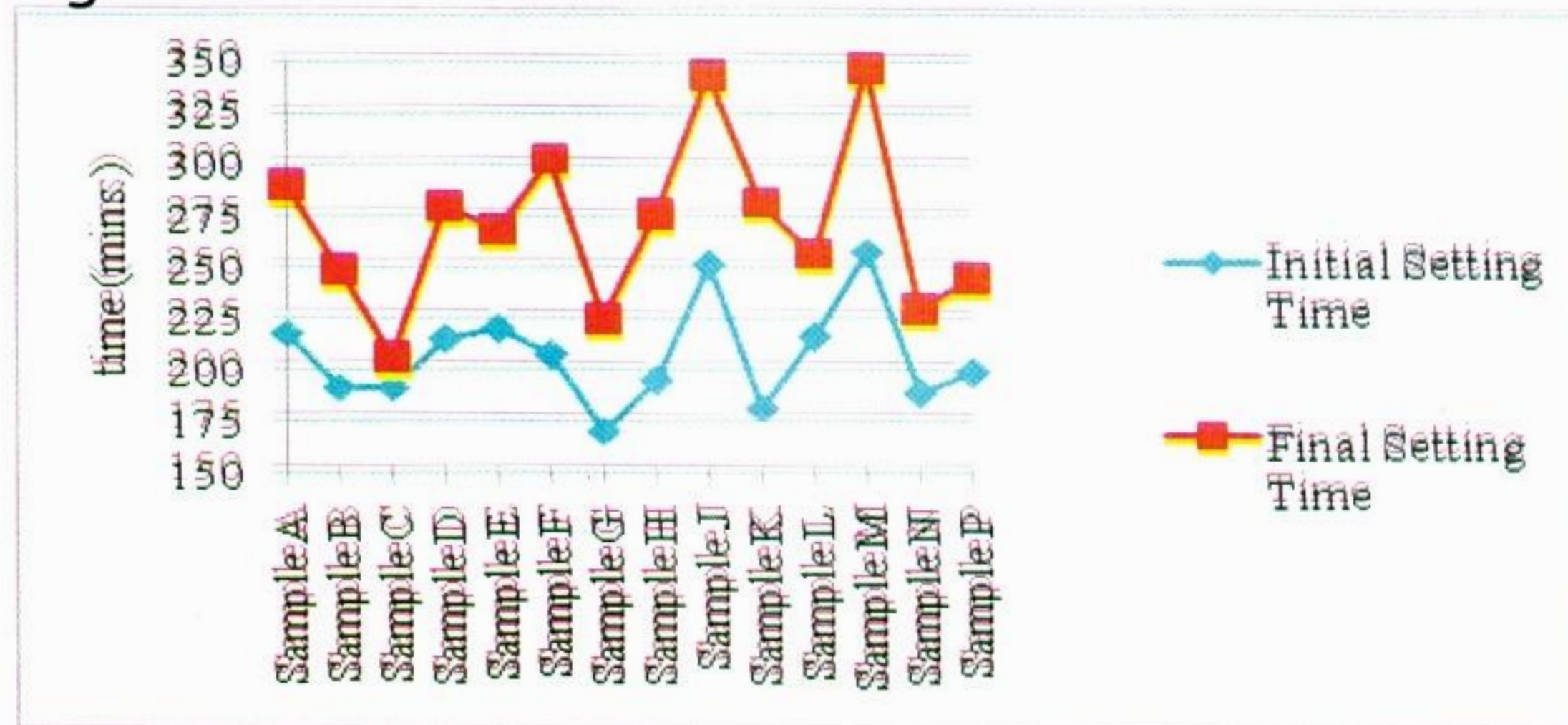


Figure 11: Consistency test results

4.2.2 Strength Test: From results obtained, Sample H was the only brand which failed to meet the required standard strength of ≥ 10 N/mm² at 2 days and ≥ 32.5 N/mm² at 28 days. All other cement brands met the required Nigerian standard.

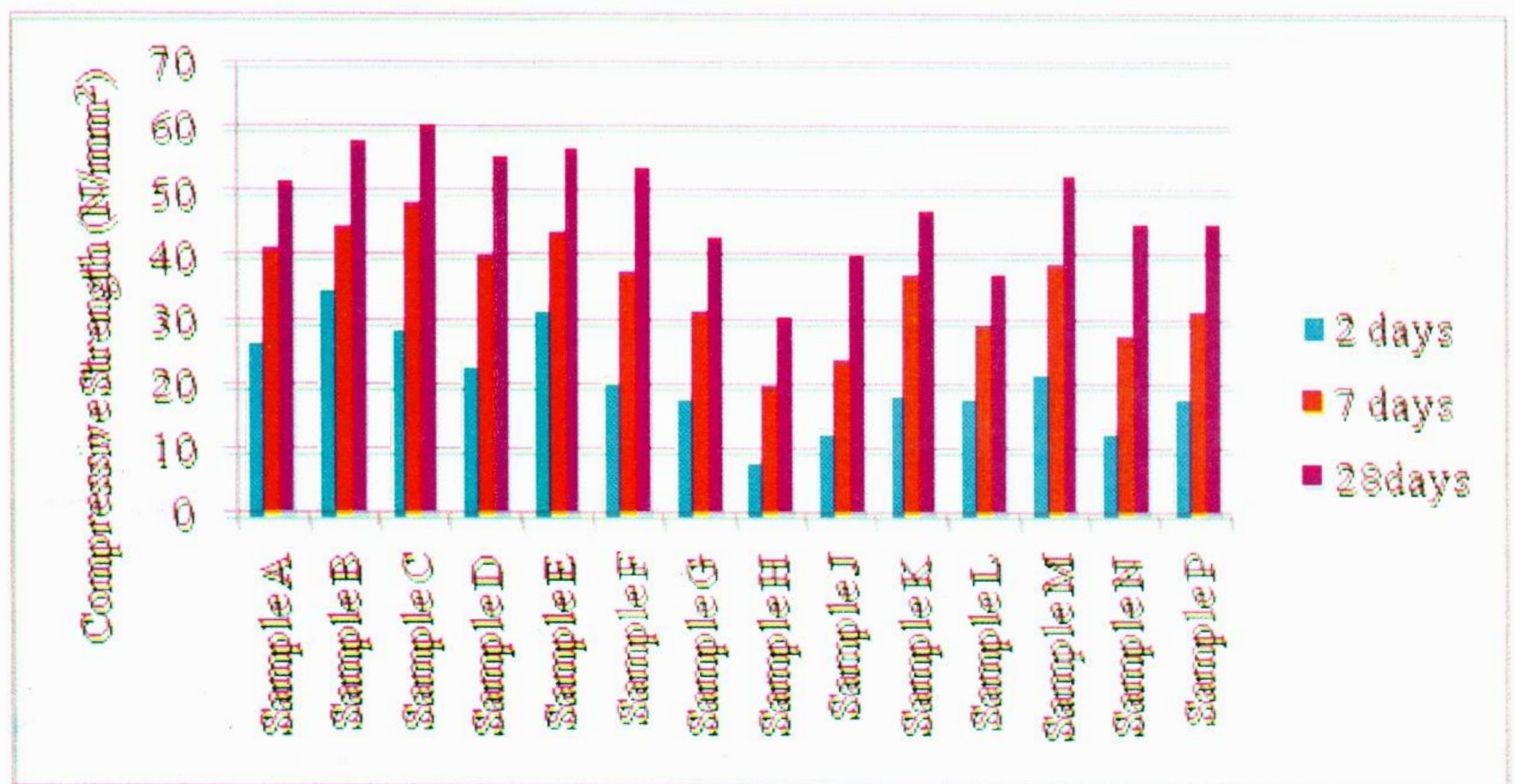


Figure 12: Cement Compressive Strengths.

4.2.3 Fineness test: An inverse relationship was observed between the fineness and 28 day cement strengths with a correlation coefficient of high significance (-0.89). Sample H had the highest 45 μ m sieve residue of 32.4%

and the lowest cement strength of 30.40 N/mm² at 28 days while Sample C had the least 45µm residue of 4.4% and the highest cement strength of 60.01 N/mm² at 28 days.

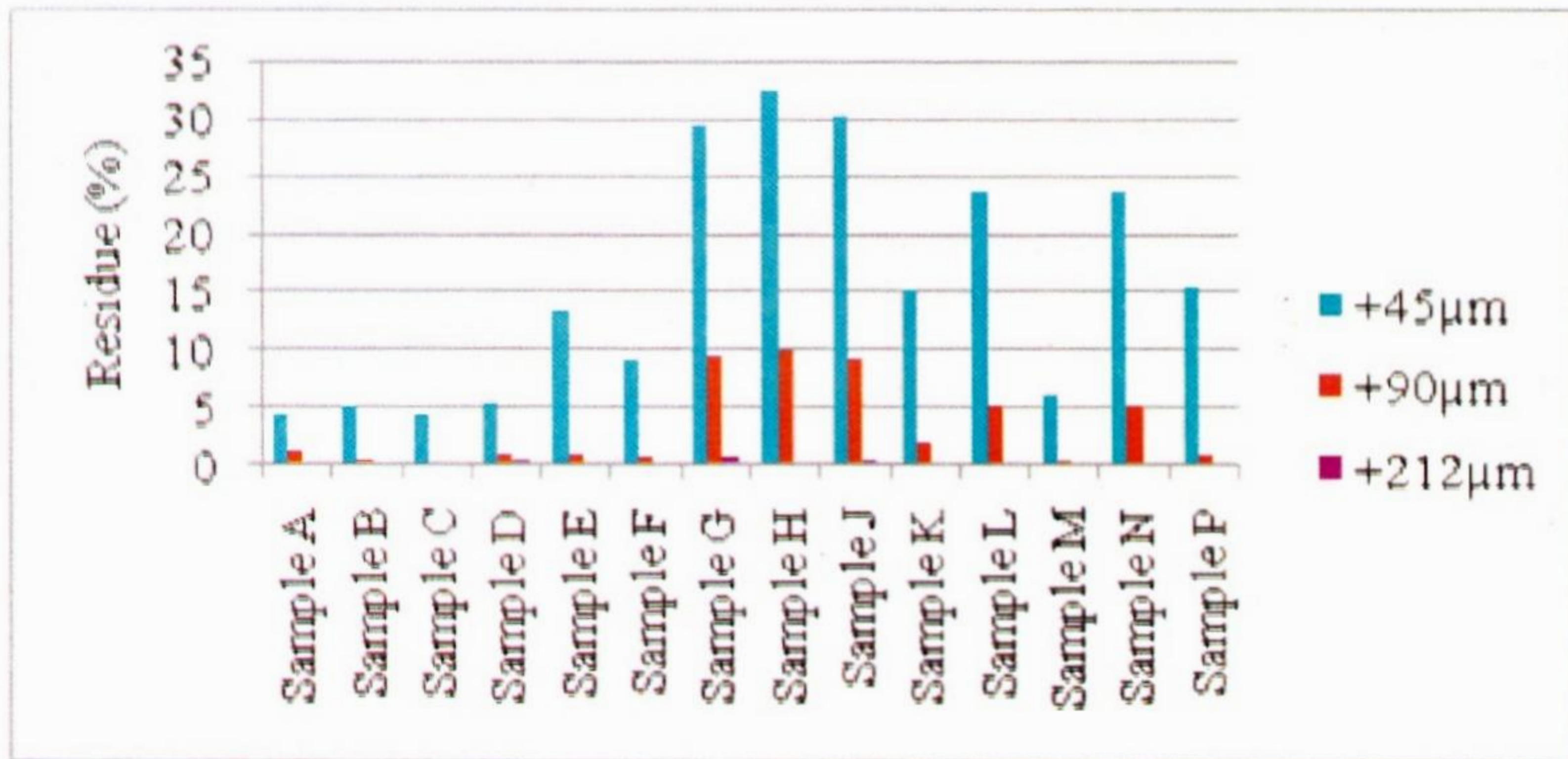


Figure 13: Fineness Test results.

4.3 Tests on Concrete

A concrete mix of expected 28 day characteristic strength of 44N/mm² was designed using the British method of concrete mix design and cast in Cube moulds after which they were cured by complete immersion in water and then tested.

4.3.1 Slump Test

The slump values were used to measure the workability of the concrete mixes. The concrete was designed for medium workability of 30-60mm. Cement Sample J had the lowest slump of 20mm while Samples A, K, H, and P had values greater than 60mm. The other cement samples (i.e. B, C, D, E, F, G, L, M, and N) had slump values within the designed range.

4.3.2 Compressive Strength

A correlation between the cement strength and concrete strength of the samples showed a high significance value of 0.91. Sample B had the highest 2 day strength (28.1N/mm²) while Sample H had both the lowest 2 day and 28 day strengths of 8.7 and 24.5N/mm² respectively. Sample D had the highest 28 day strength of 48.6N/mm². Among the cement samples collected, only Sample H did not meet the strength requirements as stated in the SON document for cement production.

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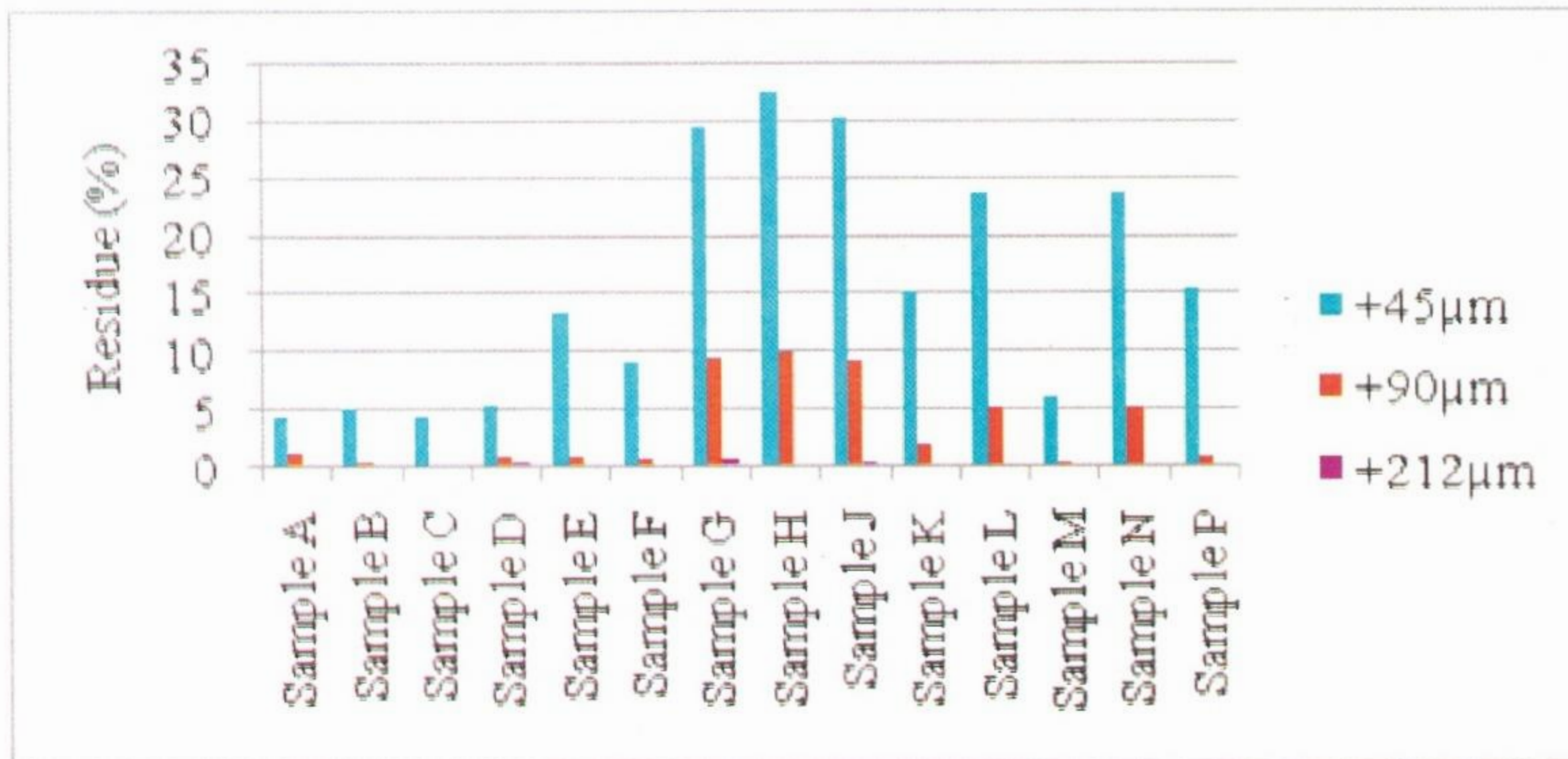


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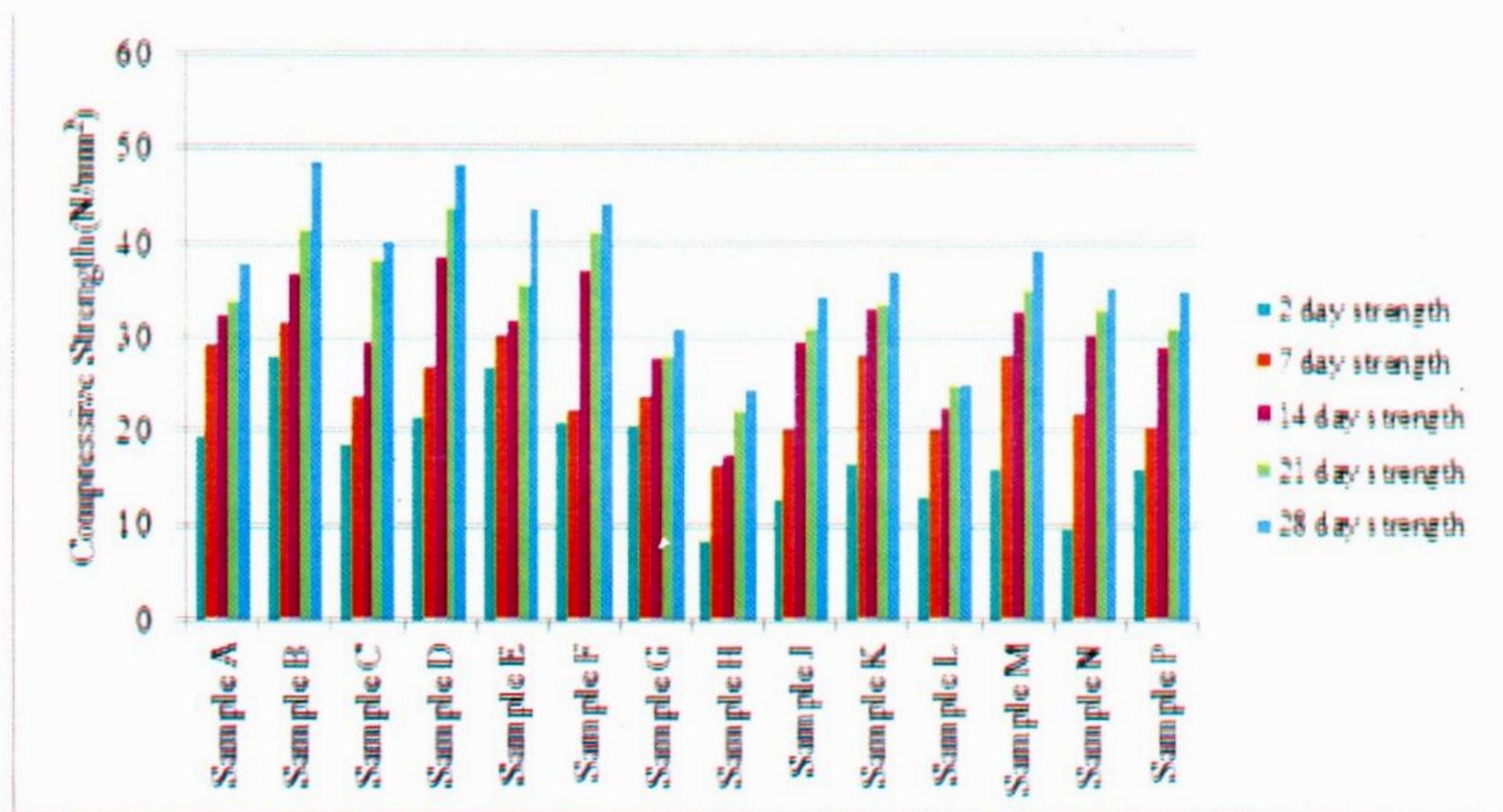


Figure 14: Concrete Compressive Strength.

The research concluded that all the Nigerian cement samples met the Standard Organisation of Nigeria standards with regards to cement products with the exception of cement Sample H. Apart from the chemical composition of cement, its fineness was found to be a major contribution to its strength. It recommended that the SON should enforce the labelling of all cement bags by importers and manufacturers as well as carry out periodic assessment of cement products from retailers so as to detect possible change in the quality of the products which may arise due to adulteration, poor storage conditions, defective bags and/or re-bagging. Other results already used for discussion above are shown below from tables 10-12.

Table 9A: Physical and Mechanical Test Results on Cements .

Sample ID	H ₂ O (%)	Consistency (mm)	SetTime Initial (mins.)	SetTime Final (mins.)	Surface Area (m ² /kg)	Residue +45µm (%)	Residue +90µm (%)	Residue +212µm (%)
A	28.1	7	208	376	420	4.5	1.3	0.3
B	29.4	7	192	245	358	5.3	0.5	0.0
C	27.4	5	192	203	356	4.4	0.2	0.0
D	27.0	6	215	276	346	5.6	1.0	0.5
E	26.2	5	220	265	410	13.4	1.0	0.0
F	32.8	5	208	299	433	9.3	0.7	0.1
G	25.8	5	171	221	390	29.4	9.5	0.9
H	23.0	5	195	272	347	32.4	9.9	0.3
J	24.0	7	251	340	326	30.3	9.3	0.5
K	26.0	7	182	278	336	15.2	1.9	0.1
L	26.4	5	216	253	343	23.8	5.2	0.4
M	28.0	7	258	343	365	6.3	0.5	0.0
N	29.2	7	189	226	371	23.7	5.2	0.2
P	25.8	5	199	241	323	15.6	0.9	0.3

Table 9B: Slump and Compressive Strengths of Concrete Samples

Sample ID	2 day Strength (N/mm ²)	7 day Strength (N/mm ²)	14 day Strength (N/mm ²)	21 day Strength (N/mm ²)	28 day Strength (N/mm ²)	Slump (mm)
A	19.8	29.0	32.2	34.0	37.9	60
B	28.1	31.2	36.7	41.5	48.7	40
C	18.7	23.4	29.2	38.3	40.3	35
D	21.7	26.8	38.2	43.8	48.6	50
E	27.0	30.0	31.6	35.8	44.0	55
F	21.2	22.0	37.0	41.3	44.4	55
G	20.9	23.4	27.6	28.2	31.0	65
H	8.7	16.2	17.4	22.3	24.5	80
J	13.0	20.1	29.4	31.0	34.4	20
K	16.9	27.7	32.8	33.8	37.1	60
L	13.3	20.1	22.4	24.8	25.3	65
M	16.2	27.7	32.6	35.2	39.4	60
N	9.8	21.7	30.0	33.1	35.3	45
P	16.1	20.2	28.8	31.0	35.0	100

Table 9C: Cement Mortar Strength Results

Cement Sample	2 Days			7 Days		28 Days	
	Prism Weight (g)	Flexural Strength	Compressive Strength (N/mm ²)	Flexural Strength	Compressive Strength (N/mm ²)	Flexural Strength	Compressive Strength (N/mm ²)
A	580.4	4.83	26.89	7.15	40.91	8.02	51.45
B	580.0	5.33	35.27	7.12	44.20	8.58	57.47
C	588.3	4.94	29.17	7.72	48.15	8.78	60.01
H	578.8	2.83	8.35	4.04	19.63	5.28	30.40
D	577.0	4.76	23.15	7.21	39.90	8.23	55.02
J	575.9	2.51	12.96	4.65	23.70	6.76	39.74
K	581.0	3.79	18.71	6.60	37.05	7.31	46.70
L	578.8	3.30	18.10	5.36	28.90	6.59	36.73
E	576.4	5.35	31.83	7.16	43.52	8.38	56.26
G	577.7	3.48	18.16	5.64	31.15	6.89	42.56
M	588.5	4.52	22.10	6.89	38.57	8.56	52.20
N	586.8	3.74	12.90	4.70	27.38	6.97	44.92
F	584.3	3.75	20.80	6.31	37.10	7.05	53.48
P	576.8	3.75	18.40	5.79	31.00	7.49	44.78

5.0 DISCUSSION OF THE MEASURES TO BE PURSUED TO CURB THE INCIDENCES OF BUILDING COLLAPSE IN NIGERIA

From all the work undertaken by the Nigerian Building and Road Research Institute and this Author, works which are still on-going, three measures have been identified as necessary to tackle the problem of incessant collapse of buildings in the country and possibly eliminate the occurrences, especially for new construction. These measures have been generally classified as Short-term and Long-term.

5.1 SHORT-TERM MEASURES TO REDUCE COLLAPSE INCIDENCES

5.1.1 Sensitization and Campaign

The general Lay Man's impression is that if a lot of publicity in the electronic (Radio, Television) and Newspaper media is made, the Nigerian public will listen and accept the need for corrections that will go a long way in reducing the incidences of Building collapse. The Institute, NBRRI, has also considered the need for the use of some sensitization bill boards campaigning and sensitizing on the use of quality materials, employment of appropriate technical personnel to design and supervise building construction. The use of the world wide web (www) in this modern age of ICT is also imperative. The Institute initiated some Radio discussions in collaboration with NOA in December 2011 and designed some Radio and television Jingles in English and major Nigerian languages, while Newspaper pages have been used. We acknowledge the continuous positive partnerships of the Leadership Newspapers, the Compass Property News, Channels, AIT and ITV television stations, and the Radio Nigeria programs brokered in collaboration with NOA, in this regard. The fact remains, however, that these measures are expensive and need all cooperation of Government, Professional regulatory bodies, cognate stakeholders, and the Media of this country to be effective and to be able to provide the financial budget required for a massive exercise. It is a challenge that everyone in possession of any peculiar roles in the Building and construction sectors of the economy is expected to take up as a responsibility.

5.1.2 Organization of Conferences, Workshops, Seminars and Training Programmes

When the first meeting of the Professional bodies and cognate Stakeholders was initiated in 2011, the Institute NBRRI was mandated to act as a coordinating Parastatal to organize a conference. Additionally, the need for continuous Professional development (CPD) through short courses, workshops, seminars and annual conferences was highlighted. Like has been identified for the media promotions, this too is very expensive and in addition to tabling recommendations for continuous actions in the future, it is also important to define practical and implementable avenues for sourcing funds for these future activities. Because the mandate of the Institute, NBRRI, also extends into Roads, affordable housing and many other spheres of Life of the economy and the common man, there may be competing responsibilities in the future. It is nothing new underscoring the need for the Institute to also divest its research activities to cover areas of collapsed road pavements, traffic studies and accident mitigation on the nation's road networks. So there must be optimization and critical path decisions as the choice of areas of emphasis are made and resources allocated, accordingly. Professional bodies and other Stakeholders have been doing a lot in their individual responsibilities as

illustrated, for example, by:

- ∅ The Council for the Regulation of Engineering in Nigeria setting up Zonal and State Engineering Monitoring and Regulatory teams to enforce standards and intervene on potentially problematic situations. Nigerian Building and Road research Institute is happy with the complimentary role it has received from COREN and other professional bodies whenever there was a failure of a building. Our technical report has formed the basis for the prosecution of suspicious parties in the few cases brought up in 2011 and in 2012.
- ∅ All professional bodies: Architects Registration Council (ARCON) and Nigerian Institute of Architects (NIA), COREN, and Nigerian Society of Engineers (NSE), Town Planners registration Council (TOPREC), and Nigerian Institute of Town planners, Council for the registration of Builders (CORBON), and Nigerian Institute of Building (NITP), NIQS, etc, all hold annual conferences, Lectures and other forums where these matters are tabled and exhaustively discussed. ARCON just held its annual Colloquium for 2012 in April and it was very successful with a beautiful exhibition on display.
- ∅ In the course of presentation of results earlier, reference was made to SON standards on Cement confirming that there are activities in the areas of standards. What is left is for a comprehensive course of action by SON in collaboration with the professional bodies, NBRRI, Resource personnel from the tertiary education sector and international bodies to evolve indigenous codes of Practices and specifications for Nigerian practice.
- ∅ It is also important that in undertaking individual roles, that the records are properly kept and propagated. As example, the Nation is very much aware that in one of the annual rituals of COREN assembly in the past, the whole session was dedicated to the issue of Building collapse which gave rise to the Engineering Monitoring and Regulatory Teams. Where is this report and why can it not be located on the shelves of libraries in the country?
- ∅ A vital recommendation earlier highlighted is that the SON should enforce the labelling of all cement bags by importers and manufacturers as well as carry out periodic assessment of cement products from retailers so as to detect possible change in the quality of the products which may arise due to adulteration, poor storage conditions, defective bags and/or re-bagging. Since Cements are so critical, it is possible that NBRRI, SON, COREN can organize annual Certification visits to Cement companies by Panels from these organs with resource persons cutting across the academia and industry. NBRRI

is poised to provide the laboratory facilities for these certification tests.

5.1.3 Materials Testing Laboratories

The Institute, NBRRI, will begin to set up a laboratory for the testing of Soils, Cement, Concrete (and Bitumen and Asphaltic concrete products) and other construction products in Abuja this year while improving the National laboratory in Ota as well as contemplate Zonal, even State laboratories in the future. This intervention will provide easy access to testing facilities so that there is no excuse for not supervising any project comprehensively. Already, we are making our own Cube moulds and Slump Cone apparatuses in the laboratories and urge that rather than import these simple items, NBRRI can be empowered to fabricate them for the laboratories in the tertiary education sector and construction industry.

5.2 LONG-TERM MEASURES TO REDUCE COLLAPSE INCIDENCES

The primary long-term measure that must be instituted to check-mate building collapse and, indeed, correct other construction misdemeanours (like Road pavement collapse, Poor plumbing, Scaffolding and Formwork Collapses two massive cases were recorded in March and April 2012 in the central business district, CBD, of Abuja, etc.) is in the area of Training and Continuous Professional Development, CPD. The Institute, NBRRI has made up its mind that it will work towards the establishment of a NBRRI ACADEMY to train and provide skilled labour for the construction sector in the areas of Draughting, Detailing, Iron Bending, Artisanship, Block Making and Laying, Brick, Concrete and Mortar Artisans and workmen, Plumbing, Electrical works, etc. The need for this has already been emphasized by the detailed exposition of Cement and Concrete as critical components earlier made in this paper. While the appreciation OR even learning of many details requires actual formal education, nonetheless, the performance of this category of workers in the Office and field can be improved upon by teaching them some basic common sense details associated to their chosen areas of economic activities. Once the foundation has been laid, the platform would have been firmly established to begin to design courses for Continuous Professional Practice, CPD, in NBRRI, for the Building, Roads and Construction sectors of the National economy. The Institute has to embark on a NEEDS assessment to justify this initiative but advanced discussion with the National Board for Technical Education, NBTE, has revealed that it is an area of critical intervention. The Federal Ministry of science and Technology itself has since realised this when in one of its Management meetings in 2011, it asked that the Ministry's Planning and Research department as well as the department of Technical Acquisition and Adaptation (TAA) should work with NBRRI to produce the curriculum for the training of these skilled workers. The budget and funding for it will be inserted into the 2013

budget along with other Research and Development (R&D) activities of the Institute. It is also important to mention here that the tertiary education sector (Universities, Polytechnics and Monotechnics, Technical Colleges) need to work assiduously to empower the Students with appropriate and practical knowledge to tackle the challenges of the Nigerian technological aspirations in the construction sector. Thus their Institutional Academic contents need to be made more robust and reviewed to meet with global standards, the Physical facilities (Classrooms, Laboratories, Workshops, Studios, etc) improved, the Staffing quality and quantity improved upon (undue inbreeding needs to be avoided), the Library hard and soft holdings upstaged, and undue Strikes eliminated.

6.0 CONCLUSION

Incessant Building Collapses in Nigeria in 2011 and the immediate past have provided a challenge not only to Nigerian Building and Road Research Institute, NBRRI, or its parent Ministry of science and Technology but also to the Nigerian regulatory bodies and stakeholders as well as to the government of the Federal republic. For many experienced practitioners involved in design, construction or regulation, it will be pondered why a matter so simple should elude an immediate solution. Well, some of the reasons have been highlighted in this paper and it appears that while the economy of the nation has grown and the citizens have been empowered, the construction activities have equally increased but the manpower requirements of for the Builders and construction workers to man the activities have not been proportionally attended to. As a consequence, phenomenal construction activities take place using poor construction materials and ill-equipped Site-Workers who can hardly read drawings themselves, let alone detect potential problems and call for help to fix them. Apart from huge Corporate organizations that employ well-trained professionals to design and supervise their constructions, Private Individuals and many Government departments and Arms of Government (like Local and State Governments) don't consult appropriate professionals and where there is design, no supervision is available to ensure that implementation is well done. To complicate the situation, Town Planning and Municipal Regulatory authorities traditionally endowed with the responsibility of checking all plans before approval for development is approved no longer undertake their roles and development is now haphazard not only resulting in Building collapse but also giving rise to many developments without access roads, water supply, sewerage, electricity and vital services. Therefore, while providing suggestions and solutions to the basic problem of Building collapse, all Professionals and academics must also look at associated and allied issues and disciplines that actually complicate the problem.

I thank you for reading through the volume of data in this write-up but it is designed not only to highlight the challenge of a problem, but also as educational material that will assist the Reader take some sane decisions on construction Sites that will help the project. I want to mention that the topic of Steel reinforcement which always forms an intricate component of the composite Reinforced Concrete elements has hardly received any attention in the paper. So far in the country, Steel reinforcement is a Proprietary material that is produced and its specifications, including engineering properties, controlled in a factory set-up. There needs to be tact and precision in cutting, bending, bar curtailment, lapping, etc., but this can be a purely professional matter. However, the major premise for avoiding discussion of Steel bars is that discussion has been focussed primarily on catastrophic failures that take place without warning. No one should make the mistake that under-reinforcement OR over-reinforcement is being encouraged. But the point that has been emphasized so far is that in so far as the strength of concrete and associated properties are properly controlled, there will be adequate bonding established with the steel reinforcement and catastrophic collapses can be avoided. This will save life and property because adequate failure warning can be presented by structure giving time to evacuate before collapse takes place. Students of Physics OR Strength of Materials in engineering know that for ductile materials, failure does not simply take place at the elastic limit but the yield point must be reached when the material will continue to have increased strains at constant or even reducing stresses. The steel, which is a ductile material, will undergo necking before snapping at a residual load and this can take on inordinately long period for all warning to have been presented to the Users of a building. On the other hand, concrete, being a brittle material, simply snaps once it is strained, especially subject to tensile stresses, and it fails with a BIG-BANG especially when the concrete mix is as poor as is the case with a majority of our Structures in the country.

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Case Histories of Building Collapses in Nigeria

By

Dr. Augustine C. IKE Fnitp, Mnse, Mnes
Nigerian Institute of Town Planners

ABSTRACT

This paper examines the case histories of building collapse in Nigeria. A brief history of building collapse or (structural failure) in developed countries were also examined to see the trend, causes and effect of building collapse in such environments. We should note that a building that is properly constructed is expected to be in use for so many years at times up to 50 to 100 year.

Although God has so much blessed us with good weather compared to other climate conditions in the world. One will still wonder why we are allowing man made conditions to give the various arms of government and the people of Nigeria nightmare as to the enormous lose of human life, properties and large investment in housing through building collapse. Cases of building collapse in some of our major cities were discussed. Result of the findings of tackling causes of frequent collapse in Nigeria by "S. A. Olayede; C. B. Owogun and O. A. Akinjara of Department of Estate Management, School of Environmental Sciences, College of Science and Technology, Covenant University, Ota, Ogun State. Nigeria was also tabulated to see the options of different stakeholders. Abuja experience was also cited in this paper to show the concern of the Federal capital Territory Administration of this shameful muster called building collapse. Government as a matter of priority must place Town planning in its rightful place in the constitution to have enough political will to allow the Town planning Authority to perform their duties(functions) and provide enough police power to back the professional planner in carrying out his/her functions.

I INTRODUCTION

Buildings collapse when the structures crumble and fall fully or partially thereby rendering the buildings unsafe for the originally desired uses. The collapse of any building is a manifestation of structural failure. Therefore, to forestall the incidence of such structural failure, due diligence and discipline is required by all persons involved in the construction of buildings to strictly adhere to the relevant professional standards and regulation aimed at addressing the causes of failure. There are various causes and reasons that can lead to the collapse of buildings. A building can collapse due to one or any combination of probable reasons or causes. These include:

- i. Buildings erected on a poor substructure right from the foundation either due to the soil or inadequate structural integrity of the construction

- materials or workmanship or even the details of the design being executed.
- ii. Buildings erected in the superstructure above the substructure that lack structural integrity of either the construction or the workmanship or even the details of the design being executed
 - iii. Professional incompetence of the person(s) involved either at the design and or the supervision of the construction stages thereby leading to structural failure that eventually lead to collapse.
 - iv. Ignorance of the developer who inadvertently use professionally unqualified persons either at the design or supervision of the construction stages.
 - v. Inordinate or deliberate desire by a contractor to maximize profit at the expense of quality and standard thereby exposing the building to the danger of collapse. This kind of situation has been aggravated by the rapid huge urbanization with the huge shortfall in housing, general high cost of building materials leading to the influx of inferior materials in the market and compounded by "quacks" at all level in the construction industry, as well as the overstretched or manpower to monitor development by the constituted authorities.
 - vi. The ugly incidents of bomb blast in the country.
 - vii. All possible loads / forces when not properly assessed will lead to the instability of the structure at the application of such loads / forces. Such loads / forces will include live load, dead load, wind load, temperature load and fabrication stresses.
 - viii. Many structures collapse when design of such structures fails to specify in the drawings the assumed minimum strength of materials to be used in the project.
 - ix. Deviation from the internal use of the structure / buildings after and approval granted by the planning authority.
 - x. Lack of proper monitoring by regulatory authorities during construction activities.

2 HISTORIC VIEW OF BUILDING COLLAPSE

The menace of collapse building is most common is most common in our major cities like Lagos, Port-Harcourt, Ibadan, Kano, Abuja etc. It is however not limited to those big cities even the rural areas share in the menace. The sad event is that the stories in the rural areas are not told like the once in the big cities. It is therefore a difficult task to track down the complete histories of building collapse in Nigeria. Worse more the exact number of casualties is never known or reported. After I chaired a committee on fact findings on what happened with one of the collapsed building in Abuja, I was convinced that the causes of collapsed building in Nigeria

are not hard to find. The use of substandard building materials like cement, iron rod, the quality of sand, sand Crete block immediately came to mind. The use of unqualified professional (quack) is also rampant in the building industry. This is more pronounced among private property developers who always want to cut cost to maximize profit in place of the high lose of human life's and properties.

The rascality of some government officials in over locking the standard of the Town Planning Provision in our cities have led to the allocation of plots in areas providers as green, water logged, made up soil, drainage casements etc. this brings to mind the statement made by the former Minister of Lands housing and Urban Development, Chief Nduose Essien, that the town planning departments were no longer performing their duty as laid down by law. I questioned why Town Planning Department was not given its right place then in the ministry. The Minister said government would revisit the process of approving building plans. Has this being done? (Poster by News Update on May 16, 2011 in Nigeria Crime News by Gbenga Onoklums, Abuja). Here the statement of director of First Group Construction, a property development giant and winner of Arabian Property Award, Amr. Al Baward, "said before they start any project in their country, they comb everywhere and engage specialized property development consultants who do studies on soil, making soil investigations for all the plots. Based on the soil investigation report, it will be decided which way the design will go. Whether we will go with what is called raft foundation design or the palling design. That will be step A. Based on these findings, the consultant will design. Normally in Dubai, the design must go to the Dubai municipality office." He continued as quote below:

"There is a very strict rule about the structure and design. Building in Dubai is about integrity. We are aware that the day a building collapses in Dubai that will be the end of Dubai property industry; whenever you have a tower which is B+ that is above 20 floors. Baward said you need to get a three part approval. The professional resident in the municipal office that specializes in structural design will look through it and approve the design done by the consultant. After that the design goes back again to the client to see through it again to also stamp the drawing and return it to the Dubai municipality office to finally approve the drawing. That is the process and procedure and it is a long one, but it is for the safety and integrity of the country. We are pleased to have this kind of system that always provides stability for the buildings."

The director of First Group revealed that it takes up to eight months to get a building approval. That is the time you can have the contractor on site. He said, "Before you have the building approved, it is a taboo to have a contractor on site to do anything. Building materials must be certified. The contractor normally submits list of materials to be used to the consultant for approval and the consultant who will have to approve it technically and commercially and the client will always want quality for his own good."

He said severe punishment is meted to any developer that tries to cut corners. "It is imposed by the authorities and the clients also. As a procedure here in Dubai, you cannot cast or

pour a cubic meter of concrete without getting the inspection done by the consultants. Then it goes to the inspection of Dubai municipality. "They cannot pour anything without government approval, but if it is discovered that they have done the pouring of the concrete, God forbid, the project will be abruptly terminated, no matter who owns the building, they will be penalized, downgraded and all that stuff."

My professional colleagues, it is sad that despite the importance attached to housing on man's hierarchy of needs and culture, building collapse is becoming everyday affair in our country. The most disturbing of it all is that new buildings and ones under construction are the ones failing. All we do is try to apportion blame to one another. The National concern for sudden collapses of buildings across Nigeria today demand that construction and designs of buildings be carried out with great care. Anyone who is interested in the construction industry must go for proper training.

3 CASE HISTORY OF COLLAPSE BUILDING IN NIGERIA

There seems to be no end to spate of building collapse in Nigeria as report reveals that despite the laws guiding construction of buildings in the country, the problem of substandard equipment and lack of respect for enabling laws have continued to be a source of worry to the nation (Moshood Alade, 2012). Let's update ourselves with some of the cases of building collapse in Nigeria.

According to Oyewande (1992), causes of building failure in Nigeria are attributed as follows; 50 percent of causes being owing to design faults, 40 percent to fault on construction site and 10 percent to product failure. Frederick and Ambrose (1989) suggested that the overturning of structures owing to heavy wind loads, sliding of structures due to heavy lateral loads are major types of failure in buildings. Akinpelu (2008) categoried the following as major causes of structure failure: environmental changes, natural and man-made hazards, improper presentation and interpretation in the design. Richard (2002) opined that deterioration of reinforced concrete could occur as a result corrosion of the reinforcement caused by carbonation and chloride ingress, cracking caused by overloading, subsidence or basic design fault, and construction defect. Falobi (2009) said Nigeria is not yet famous as a country ravaged by natural disasters which are like other counties. However, the country is not without her own share of disaster, which are chiefly man-made. Man-made disaster is simply traced to pure negligence at the point of taking decisions to build.

Most builders do not consider the soil type, design type, wind load, choice of materials, estimated load and proper factor of safety. One major reason of negligence is that most building regulations being used for building in Nigeria are

obsolete. Some are dated back to 1970s. Nigerian Engineers, Architects, Builders and Planners should come out with Nigeria design specification codes. (NS in place of BS). Another serious issue that builders tend to overlook in determining their factor of safety in the Nigeria context is the frequent change of use after a building most have been erected. For example, design for residential turn into a church building; multipurpose offices spaces into shopping mall what more, increasing the height of the building without any recourse to the original foundation design.

All these takes place in the building industry when a foreman is addressed as an engineer but find it difficult to read building plans or interpret structural designs. Building owners should engage qualify professionals to erect their buildings. Pay the proper fee and go to sleep with their two eyes closed. Lots of life and property could be saved by engaging the services of appropriate professionals.

Permit me to mention the non-adherence to warning or sign of danger before a collapse takes place. Most owners and occupants tend to under estimate such warning signs. Failure of compliance with repeated warning has been reported in some cases of recent collapse. A case in mind is the three suspended floor that collapsed in Garki, Abuja killing 21 persons. I also have read about similar warning in Lagos before collapse occurs.

Records of some known cases:

LAGOS

In (2006) four cases were recorded. Two of such collapse where in Ebute Metta. 37 persons lost their lives.

March 22 the Nigerian Industrial Development Bank's building collapse killing two persons and injured 23 others.(Adejoney 2006)

November, [2007] a two storey building along Okgbegbe Street. Another two six storey building along Inian Ligali Street in Lagos Island collapsed and affected two other six storey buildings living fifteen (15) people injured and one (1) dead.

July [2011] a three storey building located at 6 Mogaji close, Idumota in Lagos. Over 18 persons lost their lives.

September [2009], Rowland Adewumi posted an article why buildings will keep collapsing in Nigeria; mention the collapse of a four (4) storey building under construction near Ojualegba.

Another multi-millionaire building collapsed in Ajah area. Collapse of Mosque in Mushin and another three (3) storey building awaiting finishing works at Ikeja behind Juli Pharmacy over 40 people trapped.

July [2006], four [4] storey block of flats collapsed killing 25 persons.

October [2011], a five [5] storey structure with a pent house located at Aderibighe street, Mary Land, Nigeria collapsed. Our host today did carry a facts finding investigation. See NBRRI's comments 31st October, 2011.

IBADAN/OYO STATE

July [2011], a building collapsed killing eight (8) people.

Nov [2001] the then past chairman of Nigeria Institute of Architects, Oyo chapter mention of 13 structures collapsed due to quacks.

AKURE

A hotel building under construction collapsed after Oba- Ile Housing Estate, on the way to Oba town in Akure, Nigeria as reported by A. A. Taiwo and J. A. Afolani (2011).

ENUGU

NBRRI team worked on the investigation of three 3 building collapses in Enugu.

BENUE

St. Roberts Catholic Church located in Adambge area collapsed, killing 22 worshippers and injury 31 others, during this year Easter vigil.

ABUJA (FCT)

Abuja experience where the writer has first class information on some of the cases reported below and also the writer chaired one of the numerous committees set up to investigate three of the collapsed buildings.

Raining season of [1992] a four storey hotel building collapsed during construction. The foundation was a simple stripe foundation on a made up soil. The building collapsed because the bearing capacity of the soil could not hold. The developer was allowed to reconstruct but this time removing all made up soil and introducing a basement. Today the Hotel is standing.

July [2005], a three [3] storey building along Aminu Kano Crescent Wuse 2 collapsed after a church service and the worshippers left before the heavy down pore that night. This brings to mind the use of upper floors for activities that create dynamic loads. Remember Hyatt Regency, Kansas City, Missouri, USA.

July (2008) a four (4) storey shopping mall under construction located on plots 230/1101 Utako District, FCT collapsed trapping over 50 persons, principally among whom were construction workers and food vendors.

August (2010) a four storey building located on plot 1007 at No. 2 Ikole street, Garki II, Abuja collapsed killing 21 persons . The building was originally approved as

a three (3) storey building but the contractor convinced the owner to increase to four storeys because the area is a primary location. Stop work notice served; demolish notices served after an integrity test was conducted. Quit notice served to illegal occupants who neglected the warning signs on the structure. Development Control Department tried to remove the upper floor contravening before finally the building collapsed. Findings are in the committee report titled "Final report of the ministerial committee on comprehensive audit of all buildings under construction in the Federal Capital City [FCC]."

One clear unfortunate issue was that the plot was cleared of all debris before the committee visited the site. Building collapse sites should be sealed for proper investigation before clearing of debris

July (2010) a six suspended floors for commercial purpose with a basement on plot 702, Port-Harcourt Crescent, Garki II Abuja, partially collapsed with no one injured. It was a case of substandard materials and the use of unqualified professional.

July (2010), another building located on plot 528, Durumi District, for residential purpose partially collapsed without anyone injured. The developer immediately directed the total removal of the structure to give way for a new one. But for the timely intervention of the field officers the issue was reported to the authority.

November (2009) a building located at plot 1340 Nkwere street, off Muhammadu Buhari Way, Garki II designed for commercial use was said to have suffered failure on the first floor alone. The site Engineer complained of the quality of the reinforce bars supplied. He noted that the irons snapped during bending. The issue was the case of substandard material but the engineer failed to stop work when he observed the snapping of the iron bars. The ground floor earlier built was not affected. The developer demolished and cleared the site before the committee was constituted.

January 2012, a one storey building located at 45rd, 1st Avenue Gwarimpa Estate, Abuja was said to have been commenced by the Nigerian Navy, had some defects. The decision to remove was reached but instead of the use of professionals, quacks were used and the building collapsed.

Our host NBRRI has also at the first half of the year 2011 visited a couple of site in Abuja; one of such site was that of a four (4) storey building at pape, Abuja. Another was a two (2) storey building belonging to Zenith Bank collapsed at Mararaba on the out skirts of the Abuja. (NARRI, 2011).

This is just a wakeup call for us to be the watch dog of our environments. There is

lots of building collapse in our rural areas. Just like Amr. Al. Baward said if only we have our country interest in our hearts we should be very concern about this monster called Building Collapse.

4 REPRESENTATIONS

4.1 PICTORIAL REPRESENTATION

Here are some of the ugly sights of the huge amount of investments wasted and painful loss of lives associated with failures.



PLATE 1: A COLLAPSED HOTEL BUILDING IN AKURE.



PLATE 2: A COLLAPSED HOTEL BUILDING IN AKURE

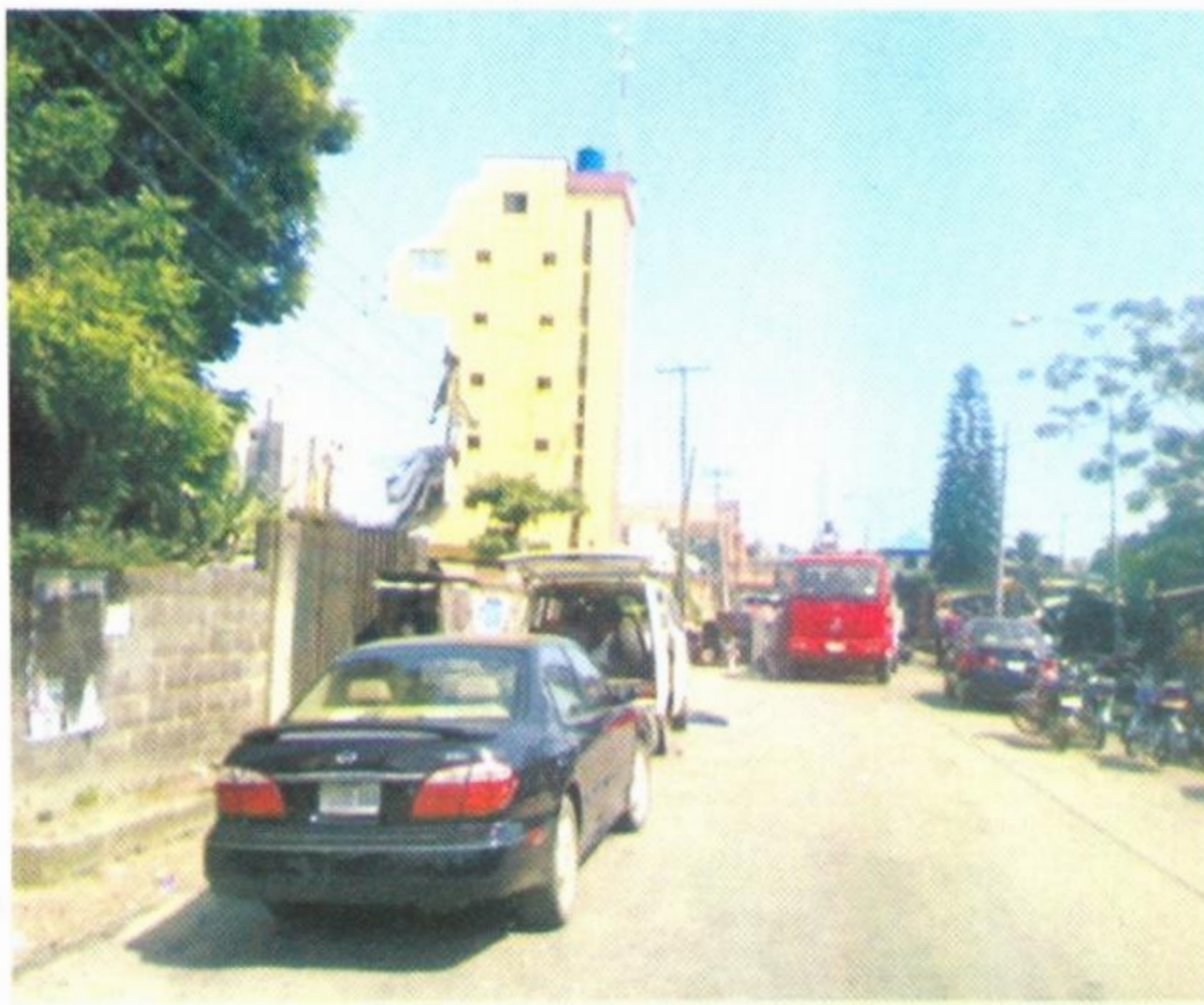


PLATE 3: COLLAPSED 6 (SIX) STOREY BUILDING IN LAGOS



PLATE 4: COLLAPSED 6 (SIX) STOREY BUILDING IN LAGOS



PLATE 5: COLLAPSE OF 6- STOREY BUILDING IN 11 ADERIBIGBE STREET, MARYLAND, LAGOS



PLATE 6: COLLAPSE OF A TWO STOREY BUILDING OWNED BY NIGERIAN NAVY IN GWARIMPA, ABUJA



PLATE 7: COLLAPSE OF A TWO STOREY BUILDING OWNED BY NIGERIAN NAVY IN GWARIMPA, ABUJA



PLATE 8: COLLAPSE OF A TWO STOREY BUILDING OWNED BY NIGERIAN NAVY IN GWARIMPA, ABUJA



PLATE 9: PARTIAL COLLAPSE OF SIX (6) STOREY BUILDING AT PORT-HARCOURT STREET GARKI 2, ABUJA



PLATE 10: DEVELOPER INCREASING THE HEIGHT OF BUILDING WITHOUT RECOURSE TO THE AUTHORITY



PLATE 11: DEVELOPER INCREASING THE HEIGHT OF BUILDING WITHOUT RECOURSE TO THE AUTHORITY



PLATE 12: CRACK ON THE BUILDING DUE TO DIFFERENTIAL SETTLEMENT IN GWARIMPA FHA, ABUJA



PLATE 13: ABANDONED HOUSE OFFERING ILLEGAL ACCOMMODATION, GWARIMPA ABUJA

4.2 CHART REPRESENTATION

Dr. Anthony Nkem Ede of the Department of Civil Engineering, Covenant University, Ota Ogun State, Nigeria in his paper "Building Collapse in Nigeria: The trend of casualties in the last Decade (2000-2010)" said that there have been many papers written on building collapse issues in Nigeria without adequate analysis of death rate involved in the collapses. The result of the analysis of his research is presented here for our perusal.

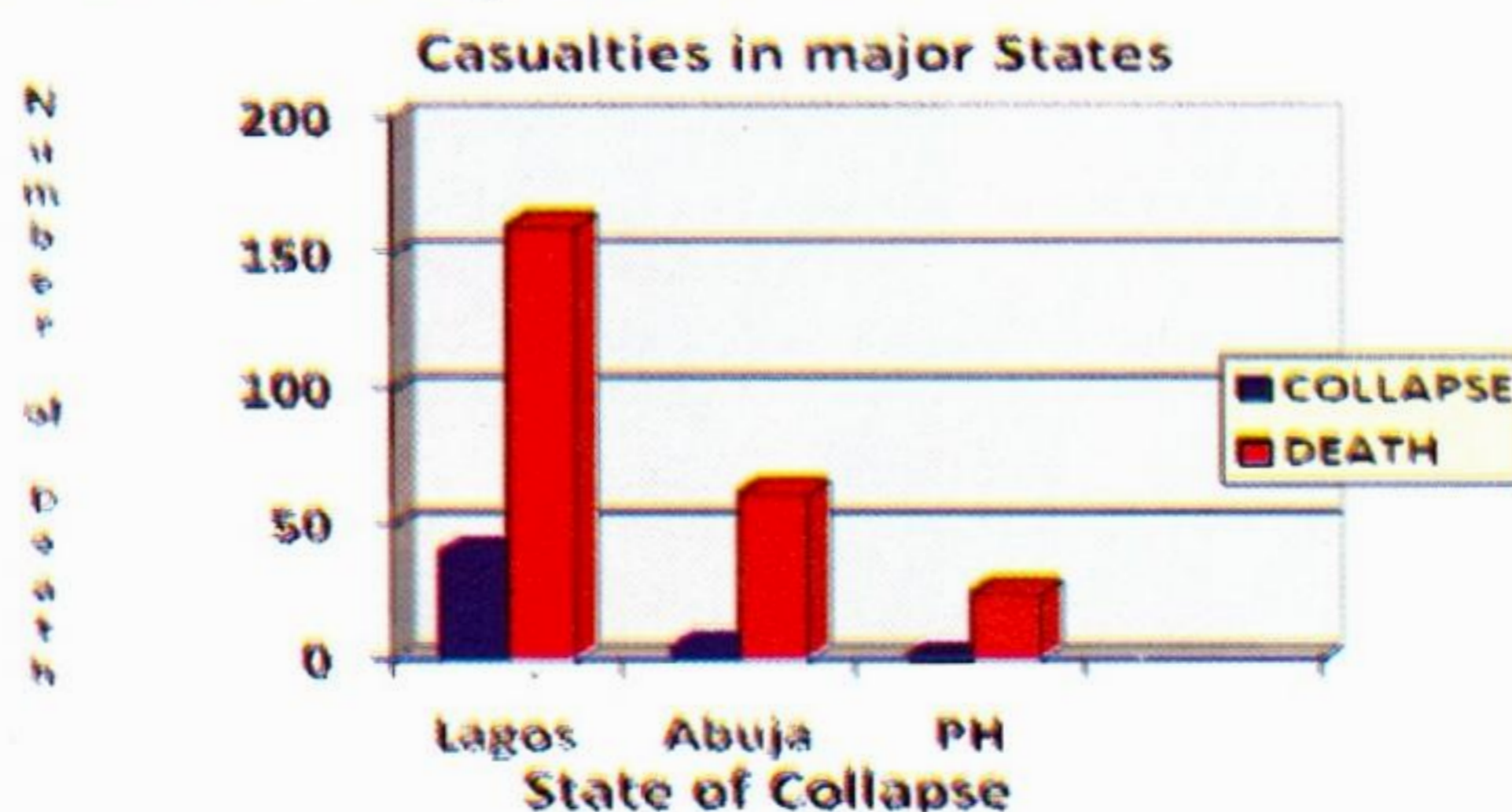


Figure 2: Casualties verified in Lagos, Abuja and Portharcourt
 Source: International Journal of Civil & Environmental Engineering (Dr. Ede A. N, 2010)

4.3 TABLE REPRESENTATION

In their report "Tackling Causes of Frequent Building Collapse in Nigeria" by S. A. Oloyede, C. B. Omoogun, and O. A. Akinjare carried out research through a questionnaire distributed among various seasoned professionals involved in the building industry. Below are their findings.

TABLES 1: Reason from building collapse from real estate professionals

Professionals	Reasons for building collapse					
	Soil type	Poor building design and planning	Use of Low quality building materials	Use of incompetent craftsmen leading to poor workmanship	Weak supervision	Natural disaster
Town Planners	30	10	65	70	55	20
Estate Surveyors & Valuers	10	25	75	65	85	10
Structural Engineers	-	35	55	45	55	10
Electrical Engineers	25	40	60	65	55	10
Civil Engineers	35	45	55	45	55	10
Architects	10	10	55	60	35	35
Builders	25	55	25	15	10	45
Building Contractors	25	65	10	10	15	65
Average score in %ages	160/800 =20	285/800=36	400/800=50	365/800=46	365/800=46	205/800=26
Ranking	6 th	4 th	1 st	2 nd	2 nd	5 th

Table 2: Public Opinion on Factors influencing the Collapse of Buildings

Factors	Public Perception					Aggregate score	Ranking
	Strongly agree	Agree	undecided	Disagree	Strongly Disagree		
Incompetent contractors	66	18	6	3	7	331	2 nd
Faulty construction methodology	45	20	6	13	16	282	5 th
Improper design	-	35	15	47	3	202	7 th
Poor town planning approval/development monitoring process	-	6	4	-	90	108	8 th
non-compliance with specification /standards by developers /contractors	85	5	-	10	-	375	1 st
Use of substandard materials and equipments	35	45	6	14	-	323	3 rd
Inadequate supervision or inspection/monitoring	51	13	6	18	2	281	6 th
Economic pressure	-	11	19	4	66	107	9 th
Incompetent conversion, change of use, poor maintenance culture	85	5	5	5	-	285	4 th

Table 3:Opinion of the Academic on Remote Causes of Building Collapse

Remote Cause	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree	Aggregate score	Ranking
Falling Standard of Education	0	33	26	01	31	150	5 th
Lack of continuing professional development	0	27	32	41	0	163	4 th
Non-enforcement of existing laws	88	12	0	0	0	388	1 st
Endemic poor work ethics	61	11	9	19	0	315	2 nd
Bribery and corruption	4	7	4	42	43	164	3 rd

5 EFFECTS and REMEDIES

5.1 EFFECTS

The ugly sight of a collapsed building is one that carries along with it tremendous effects that cannot be easily forgotten by any of its victims. At times, the phobia to sleep in a building after such collapse is so much that the movement of cockroach in the closet increases the adrenaline in ones system. Like Dr. Anthony Nkem Ede puts it, "that the consequences are usually in the form of economic and social implication", which includes loss of human life, injuries, economic waste in term of loss of properties, investment, jobs, incomes, loss of trust, dignity, and exasperation of crises among the stake holders and environmental disaster. Dr. Ede went ahead to say that the quantification of the complete effects of any collapse is extremely difficult as there are so many factors involved. There are also some socio-economic effects to the entire system.

5.2 REMEDIES

I call on all here today to join us the Nigerian Institute of Town Planners (NITP) to urge the **Federal Capital Territory and all state Government to implement the provisions of Nigerian Urban and Regional Planning Law No.88 1992;**

- i. Setting up the FCT Urban and Regional Planning Board
- ii. Proper constitution of Department of Development Control
- iii. Strengthening the FCT Urban and Regional Planning Tribunal
- iv. Improving the planning approval processes
- v. States Government should adapt the law to suit their uses.

Planning Process and Procedures must be adhered to. Developer must get approval before entering site. All site analysis must be carried out and sealed and stamped by a registered Town Planner.

Capacity building is a must for our artisans to expose them to the basis of construction works.

Co-ordination of Development activities on site by all stakeholders. The enforcement of the building code to prevent conflict in site development by professionals.

One area that is crucial to forestalling the collapse of building is always placing time table for building developments. This will eliminate the issue of abandonment of buildings for so many years, then come back to resume without integrity test of the abandon structure.

The quality of materials used is a factor in building collapse. We observed that many developers do not take time to check the quality of sand, block, iron bars and the grade of concrete mixture on site.

It will be advisable to allow natural completion of fill materials during the raining season before the "German Floor" to allow proper settlement of the fill material. Also the soil type must be properly investigated.

One very important thing the Governments of all levels must do is to build a material testing laboratory in every locality where building material are sold. The Standards Organization of Nigeria [SON] is to facilitate the commencement of the sites selection with immediate effect. This can start with the big cities like Lagos, Abuja, Pot-Harcourt, Enugu, Kano etc.

Finally, contractors should try to achieve grade strength than using the ration system that is not accurate a times.

6 CONCLUSION

I reviewed a few typical collapses which have been documented to show that the issue of collapsed building is not only a third world problem but the difference is that each time such collapse occurs the developed world take time to study the cause of failure and learn a lesson from it. Below are three typical examples;

- i. In 1981, Hyatt Regency walkway collapsed in Kansas City, Missouri, USA killing 114 persons and over 200 people sustained different degrees of injury. The National Institute of Standard and Technology (NIST) investigated the failure.
- ii. In 2008, Petioville School collapsed in Haiti. The story sounds like that of a

- Nigerian developer. A reverend gentleman who was the proprietor of the school claimed to be a builder and constructed the three storey building that collapsed killing 94 pupils of the school and had 154 people seriously injured.
- Iii. In 1968, Ronan Point Apartment Tower collapsed in London Britain. The cause of collapse was attributed to gas explosion on the nineteenth floor of a 22 storey block of flats. This was cited to show the effect of bomb blast on buildings in our society today.

Based on the committee work we served here in Abuja, I concluded that buildings collapse is a man-made issue in Nigeria. You could imagine where a cement bag of 50kg is 75% fine stone dust and 25% cement. This was one of the confessions by cement sellers to the committee. The use of substandard iron rods like 11.5mm for 12mm high tensile iron or 14.5 for 16mm. Building collapse can be put under control if all building design must be carried out by qualified **Professional Planners, Architects, Engineers, etc** and ensure that certified Builders are fully involved in the construction of building (Rowland Adewumi 2009).

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Causative Factors of Building Collapses In Nigeria

By

Engr. Felix ATUME, FNSE, mni

Registrar of Council for the Registration of Engineering in Nigeria (COREN)

1.0 PREAMBLE

The incidence of Building collapses in Nigeria has taken an alarming dimension owing to the frequency of its occurrences. It is on record that hardly a month passes by without a case of collapse building being recorded. Each of these collapses carries along tremendous effect, socially, economically, psychologically and environmentally, that cannot be easily forgotten by any of its victim.

Most of the causes of these collapses have been attributed to non-adherence to the building codes, poor supervision, lack of adequate information on applicable code, use of unskilled labour, poor material, lack of maintenance, overloading, conflict among professionals; and the tendency of some professionals cross-carpeting to lucrative technical fields without appropriate skills, corruption and tendency to cut corners among others.

While the rest of the World has advanced technologically and have been able to surmount the present challenges we are facing, we are yet to address these problems holistically.

There is therefore, the need for an urgent call on all stakeholders to view this challenge with all the seriousness it deserves, so as to confront it boldly, by putting all hands on deck to nip it in the bud.

2.0 BUILDING COLLAPSE

Buildings are structures that serve as shelters for man, his properties and activities. They must be properly planned, designed and constructed to obtain desired satisfaction from the environment.

The factors to be observed in building construction include durability, adequate stability to prevent its failure or discomfort to the users, resistance to weather, fire outbreak and other forms of accidents.

Failure in a building is an unacceptable difference between expected and observed performance. A failure can be considered as occurring in a component when that component can no longer be relied upon to fulfil its principal functions. Limited deflection in a floor that causes a certain amount of crack/distortion in partitions could reasonably be considered as defect but not a failure, whereas excessive deflection resulting in serious damage to partitions, ceilings and floor finishes could be classified as a failure.

Building collapse is therefore the failure of all or substantial part of a building, where full or partial replacement may be needed.

All over the World, the failure of a building structure is not a peculiar thing in the construction industry, and the developing countries are not exempted. The collapse of Buildings in Nigeria is no longer news to an average citizen, as it can happen to any kind of building. The casualty of a multi storey building is usually more devastating in comparison with other low rise buildings (Taiwo, A. A., et al 2011).

2.1 Types of Failures

Failure in buildings could be of two types, namely: **cosmetic failure** that occurs when something has been added to or subtracted from the building, thus affecting the structure's outlook. On the other hand, **structural failure** affects both the outlook and structural stability of the building.

Major structural failures of buildings are currently well known in Nigeria because many are described in the print media. These failures become known to the public, because someone is killed or seriously hurt, not just to discredit the structural engineer, the builder and the other professionals involved in the case of the collapsed buildings (Taiwo A. A., et al 2011).

2.2 Factors Causing the Collapse of Buildings

From engineering perspective, buildings, like all structures, are designed to support certain loads without deforming excessively. The loads are the weights of people, wind, snow, rain and other objects occupying the structure referred to as **live loads**, and the weight of the building itself, also referred to as **dead loads**.

Structural engineers are responsible for engineering design, analysis of the loads and the integrity of the entire structural system of the building. However, buildings are susceptible to catastrophic collapse due to many causes as summarized below;

2.2.1 Poor Structural design: - the structural engineer may make errors in computation, and fail to take into account the loads the structure will be called upon to carry. He may also adopt erroneous theories and rely on inaccurate data, ignore the effects of repeated or impulsive stresses, and make improper choice of materials to be used during construction. The engineer is responsible for these failures, which are created at the drawing board.

2.2.2 Faulty construction and poor workmanship: - This is usually the most important cause of structural failure. The engineer or the supervisors on site are also at fault here, if inspection has been lax. This includes the use of poor quality aggregates to produce concrete, non-adherence to the mix design, lack of quality control of the work, substitution of inferior steel for that specified, inadequate curing of concrete and other practices well known to the construction worker.

2.2.3 Foundation Failure: - Even an excellently designed and constructed structure will not stand on a bad foundation. Although the structure will carry its loads, the earth beneath it may not. The Leaning Tower of Pisa is a famous example of bad foundations. Detailed geotechnical investigation should be undertaken by the Engineer to design foundation.

2.2.4 Extraordinary loads: - These are often natural, such as repeated heavy snowfalls, or the shaking of an earthquake, or the winds of a hurricane. A building that is intended to stand for some years should be designed to withstand these challenges.

A flimsy flexible structure may avoid destruction in an earthquake, while a solid masonry building would be destroyed.

2.2.5 Unexpected modes of failure: - This is yet another reason why buildings collapse. This is the hardest category to deal with as it is indeed unexpected. For any structure constructed, there are properties that are unique to it and affect it its own way. Until all these properties are assessed and understood they remain unexpected and fall under the unexpected failure modes. Finally a building could collapse due to more than one of the above reasons hence a Combination of causes (Cherono, D S 2011).

2.3 Why Buildings Are Collapsing In Nigeria

Structural collapse occurs all over the world, but the rate of occurrence in Nigeria is beyond bound. The causes of building collapse in Nigeria can be traced to **abnormal factors** not obtainable in many other developing nations.

In addition to the generally known factors of building collapse such as design flaws, ageing, material fatigue, extreme operational and environmental conditions, accidents, terrorist attacks and natural hazards, **the Nigerian factor** is another prominent issue to contend with (Ede, A N 2010).

The Nigerian factor in the building industry appears in different forms such as:

- Corruption.
- Lack of supervision
- Bad governance.
- Misuse and abuse of authority by those in authority especially some of the professionals.
- Insufficient quality control and standards.
- Lack of sanctions against erring professionals and landlords.
- Lawlessness and our presumptions that any engineer or professional in the built environment can assume all forms responsibility in a building process without the basic skill required for it.
- Illegal conversion of buildings which often lead to structural deficiencies
- Nonadherence to approval regulations.
- Lack of soil investigation and improper interpretation of site conditions
- Negligence.
- Unethical dealings between project promoters and the relevant Planning Authorities.
- Non-involvement of registered professionals in one or more stages of the project.
- Poor and bad construction practices
- Incompetent and low quality workmanship
- Greed
Corner cutting by client or the contractor
- Hasty construction
- Use of poor quality materials/poor or inadequate form and false work.
- Construction by all-comers due to the perception of Engineering as an easy access window to make quick money.

2.3.1 Corruption is made manifest in greed and tendency to cheat in virtually every aspect, starting from poor materials and quality of work to the quantities we adopt. As disobedience to civil laws is common in Nigeria, the case in the building industry cannot be different. For this, lawlessness finds a fertile ground in our **non-adherence to the building codes and hasty construction.**

The patronage of unskilled labour, inexperienced professionals for the purpose of saving cost, tendency of some professionals to cross-carpet to lucrative specialist duties where they lack the skill, and the abundance of quacks in the building industry are all facts to contend with.

2.3.2 Drainage Systems pose a serious problem to structures along the Nigerian coastlines. It is not uncommon to see sinking old building around Lagos and within the coastal areas due to water related problems and deficient foundations, yet not all the stake holders pay adequate attention to this problem as many new structures manifest the same problem while the structures are still under construction. In fact, most of the collapses verified in the recent years occurred during construction stage (Ede, A N 2010).

2.3.3 Cases of unregistered engineers and other professionals operating in the field are very rampant. Even people without formal training in any of the trades needed in the construction industry often sneak themselves into the system to perform important tasks.

The Council for the Regulation of Engineering in Nigeria (COREN), in 2006 recommended the persecution of a pharmacist who supervised a collapsed building in Port Harcourt. If these issues are put under control, then the adverse effects to which our citizens are subjected to will be drastically reduced.

Most of the facts high-lightened above were confirmed by one of the collapses verified in Abuja. On the 11th of August 2010, thirteen people died in a building, which collapsed at Ikole Street, Abuja. About 35 persons are believed to be trapped in the debris while 10 persons were rescued (Bukola, A. 2010). That was the third collapse case in the year 2010.

The three storey building hotel has been under construction since 2001 and was later marked for demolition by the Federal Capital Development Authority (FCDA) because the owner added an extra floor thereby making it a four-storey building as against the specified three-storey building. When the agency discovered this, the developer was issued a "stop work" order on the 12th of December 2009.

The agency enforced the mechanical removal of the additional floor and subjected the entire structure to Schmidt Hammer and Structural Integrity Tests on the 29th July 2010 and the structure failed the tests. All the occupants were asked to move out of the building while legal backing for the demolition was sought but never obtained till the collapse. As some people illegally made the uncompleted structure their sleeping place at night, they became the victims of the collapse.

The causes of the deaths verified in this collapse include among other things, **greed** (the owner had the courage to seek redress from court against the demolition), **non compliance with building rules and regulations**, disturbance of

the structural equilibrium during the removal of the illegal fourth floor, exposure of construction materials to deterioration (due to the infiltration of water and steel corrosion over the past 9 years in which the structure was under construction) low quality materials, use of quacks and unskilled personnel, disobedience and poverty. In spite of all the forewarnings and the efforts made by the agency, many deaths still occurred in the building.

3.0 EFFECTS OF BUILDING COLLAPSE

It can be rightly stated that any pursuit of human endeavour has its attendant cost, but the cost being paid in the Nigerian building industry cannot be justified.

Each collapse carries along with it tremendous effects that cannot be easily forgotten by any of its victims and neither can it be fully quantifiable. The resultant consequences are usually in the form of economic, psychological, environmental, and social implications. These include loss of human lives, injuries, economic waste in terms of loss of property, investments, jobs, etc.

4.0 Efforts Made So Far to Address the Problem

Over the years, the government had put in place measures aimed at the provision of sustainable engineering infrastructures as follows:

- Provision of enabling environment.
- Provision of legislation.
- Codes of Practice and standards.

5.0 THE WAY FORWARD

What then is the way forward?

5.1 COREN's Approach

COREN as a government Regulatory Body in engineering has put forward the following measures in place to check the menace of the failures of engineering infrastructures in the country as follows:

- Setting up the Engineering Regulation Monitoring (ERM), and appointment of inspectors in over 40 inspectorates in the six geo political zones in the country.
- Establishment of Investigating Panel and Tribunal to handle cases involving engineering personnel.
- All engineering personnel from clients, contractors and consultants are held accountable on all projects handled by them.
- Non-engineering personnel involved in the failure of any engineering

infrastructure project are handed to the police for prosecution.

All engineers in the departments of Development Control are held accountable for their roles in the procurement of buildings.

5.2 The Role of Engineering Regulation Monitoring in the provision of Housing in Nigeria

The Council for the Regulation of Engineering in Nigeria was established as a statutory organ of the Federal Government of Nigeria by Decree No. 55 of 1970 as amended by Decree 27 of 1992, now Engineers (Registration etc) Act, CAP E 11, 2004, which empowered it to:

- Ø regulate and control engineering practice in Nigeria in all its aspects and ramifications;
- Ø ensure that engineering is practised by industry, government and professionals according to acceptable and prescribed standards and abiding by the ethics and cannons of the profession;
- Ø ensure appropriate training and use of engineering personnel and execution of engineering jobs etc etc.

The provision of housing is an engineering operation requiring the services of engineers. COREN has therefore a major role to play in this regard. To ensure sanity in the practice of engineering, COREN established the Engineering Regulation Monitoring (ERM). Through the machinery of ERM, Council monitors and enforces the compliance with COREN Act.

5.2.1 Establishment of the "Engineering Regulation Monitoring" (ERM)

- To Regulate and Control the practice of Engineering and ensure sanity in the profession, the Council established the Engineering Regulation Monitoring, ERM in 1997 with the following objectives.
 - Monitor and enforce compliance with COREN Act.
 - Ensure that Engineering is practised to the desired standards as contained in the codes of practice.
 - Enforce Ethics of the profession.
 - Foster speedy acquisition of relevant skills by Nigerians.
 - Minimize and eventually eliminate the over dependence of Nigeria on other countries technologically.
 - Minimize the enormous foreign exchange leakage from Nigeria.

In Simple Terms

ERM is

- A tool for the implementation of the Regulation and Control mandate of COREN.
- A tool to promote Ethics in the Engineering profession.
- A tool for engineering personnel to reclaim their space taken over by other professionals.
- A tool to hold all engineering personnel accountable.
- A tool to promote professionalism.
- A programme to hear the voice of the Engineering personnel.
- A programme that engineers in the public service in particular can use to resist external pressure.
- A programme to promote value for money in engineering projects.

5.2.1.1 Implementation of ERM

5.2.1.1.1 Selection of Inspectors

- Experienced Engineers, Technologists, Technicians, Craftsmen (usually chosen by NSE, NATE, NISSET and NAEC).
- A chief Inspector is selected among the Inspectors.
- Identity Cards are issued.
- Other items such as vests bearing ERM.

5.2.1.1.2 Modalities of Implementation

- The Chief Inspector determines the establishment to be visited and informs the COREN Headquarters.
- ERM visitation should not be confrontational. It should be to correct wrong practices, point out omissions or violations of the Act.
- Preceding the visitations, there should be a Workshop for the Chief Executives of the Organizations.
- A questionnaire should be sent to the Chief Executive to complete and return at least one week before the visit.
- After the visit, the Chief inspector submits a report to the Registrar scoring the organization.

5.1.1.2 Instruments of ERM

A. Board Membership Form (BMF)

- To eliminate false declaration of membership of Boards of engineering Companies.
- To ensure that only registered engineers are appointed on the Boards of engineering companies.

COREN inspectors are to demand for the completion and submission of this form before the visit.

B. Project Control Form (PCF)

- To ensure that only qualified Engineering Personnel are used for the execution of engineering projects for public safety and value for money.

C. Questionnaire (CP11) and Score Sheet CP 12

- Used to provide useful information and to create a databank.

5.3 Collaboration with other professionals in the Built Environment

In June 2011, COREN organized a meeting of Presidents and Registrars of professional regulatory bodies in the built environment comprising of Architects Registration Council (ARCON), Council of Registered Builders of Nigeria (CORBON) and the Town Planners Registration Council (TOPREC). The aim of the meeting was to address the seemingly intractable problem of building collapse in Nigeria. At the end of the meeting a joint press statement was issued. It was recommended that henceforth government should hold responsible any minister, commissioner, head of establishment and relevant professionals responsible for Development Control, of any building that collapsed within his or her jurisdiction.

On their part, the regulatory bodies will continue to deal decisively with any erring member found culpable on any case of building collapse in any part of the country.

The meeting also agreed to set up a joint inspectorate in all the states of the federation beginning, with Abuja, Lagos, and Port Harcourt to monitor building construction activities

5.4 The Role of COREN in the Development Control Departments

COREN ensures that only registered engineers are allowed to vet and approve engineering designs in the development control offices. It also ensures that registered engineers are also involved in the designs and supervision of buildings.

Development Authorities are expected to get engineers to sign an undertaking to supervise the construction before approval is granted. This approach is working well with the Development Control in Abuja. It should be applicable to all Development Control authorities across the country.

6.0 PUBLIC'S RESPONSIBILITY

In addition to the above, Nigerians have a collective responsibility to be ready to move the nation forward as follows:

- We need to develop a national consciousness.
- Must be ready to serve our nation wholeheartedly and diligently.
- As professionals, we should have passion for our profession and be ready to put in our best.
- To be ready to fight corruption collectively.

7.0 RESPONSIBILITY OF OTHER REGULATORY AGENCIES

Furthermore, all the Regulatory Agencies in Nigeria, especially those in the built environment should work in synergy and be sharing relevant information. They should also be able to complement each other. The security agencies should also close ranks and work in unison with the professionals in the built environment. Nigerians should also be able to raise alarm whenever they observe any foul performance.

8.0 CONCLUSION AND RECOMMENDATION

The cases of Building failures and consequent collapses in Nigeria have attained an alarming and lamentable proportion.

So many factors have been identified as the possible causes, some of which are; design flaws, ageing, material fatigue, extreme operational and environmental conditions, accidents and prominently the Nigerian factor. The resultant negative effects of the incidences on Nigerians in addition to high casualty are summarized as economic, social, psychological and environmental. Therefore, the time to face this intractable challenge is now.

In an attempt to address some of these challenges, the following recommendations are made;

- a) Every construction site must have an official COREN Project Control Forms (PCF) that provides formal records of the Engineering personnel (engineers, Technologists, Technicians and Craftsmen) involved in the supervision of the project. A copy of the completed form (Form PCF B) must always be available at the site for inspection. The use of these forms is to ensure that only COREN registered engineer is in charge of such a site.
- b) Owners of collapsed buildings should always be identified and sanctioned. The various Professional bodies to sanction any of their member(s) that is found to have been negligent or criminally implicated in the violation of ethics and professional codes. A huge amount of Public enlightenment will be required to draw attention to the dangers of sub-standard building construction. The press has a large role to play in this.
- c) Only Structural Engineers are trained to do Structural Engineering jobs, and as such, they are the only ones who should be entrusted with the responsibility for executing Structural Engineering projects, especially site supervision of construction works.

- d) Relevant Planning Authorities should not approve structural drawings that do not bear the COREN stamp to indicate that such drawings have been made and or checked by a registered Structural Engineer
- e) The relevant Planning Authorities should formally engage the services of practicing Engineering firms to vet designs and drawings. They must also be involved in project supervision, monitoring and control from inception to completion
- f) The relevant planning authorities must not compromise on the standards established for the approval of drawings
- g) Government must, through the appropriate standard organizations, ensure availability of only good quality materials for the construction market. Cost reducing measures need to be employed to reduce the cost of construction. Dealers in poor quality construction materials should be prosecuted.
- h) Government must demonstrate adequate interest in project safety by prosecuting, with all seriousness, offenders whose activities result in the collapse of structures.
- I) No Engineer or related construction professional should carry out work in a specialty of which he is not qualified
- J) That Government and the professional bodies should organize more awareness seminar and courses to enlighten all the operators and the general public on the risk in the building industry. Particular emphasis should be placed on the period of heavy rainfall, so that everyone will play his/her appropriate role in reducing the incidence of building collapse and save precious human lives round the nation.
- k) The high rate of casualties verified for high rise buildings is directly related to the difficulties involved in realizing such edifice which can only be adequately handled by highly skilled professionals. Adequate measures need to be taken to upgrade the safety awareness of all the operators in the sector. The presence of certified safety professionals should become mandatory in every building site.
- L) That law enforcement agencies be mandated to enforce eviction in houses marked for demolition, as that could have save the lives that were lost in the most recent case.

Finally, if the above recommendations were adhered to, the incidence of frequent building collapse with attendant the high casualty will be reduced drastically.

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Estimating the Cost of Building Collapse in Nigeria

By

Agele J. ALUFOHAI, MPM, MRICS, FNIQS
President, Nigerian Institute of Quantity Surveyors

1.0 INTRODUCTION

Neolithic man, during the Stone Age, had his abode in caves which being God's designed shelters, naturally offered protection from the elements and predators. The progress of civilization enabled man to produce tools and equipment that enabled him to design and erect shelters to his taste, using assorted natural and artificial materials.

Modern construction is generally believed to have commenced with the erection of the Great Pyramids of Giza in Egypt about 6,000 years ago. Relics of these early projects are still in existence and later ones such as the Great Wall of China, the Coliseum in Rome, and many others in different parts of the globe.

It is instructive to note that despite the absence of technical skills, sophisticated machinery and materials at the time of their erection, these structures have with little or practically no maintenance, defiantly withstood the harsh and ravaging effects of the weather, various natural disasters, and pillaging by treasure hunting thieves over the centuries. They still stand out proudly with their imposing aura that continue to lure and attract thousands and millions of tourists, from different parts of the globe, generating income and contributing to the growth and sustenance of many local and national economies.

2.0 BUILDINGS AND THE NATIONAL ECONOMY

Infrastructure is the principal driver of any economy, especially developing countries. The state of existing infrastructure and the rate of maintenance and addition of new stock strongly influence rate of economic growth. All buildings therefore, no matter their sizes, are economically important, whether in the private or public sector; from the owner occupied residences, hotels, factories, shops and commercial houses, social and sports centers, places of religious worships, to public sector facilities which include administration buildings, educational institutions, hospitals, etc.

The economic significance of any building lies in the fact that it is either

- Ø A source of direct income to the owner through the collection of rents; OR
- Ø It is a capital or factor (i.e. input resource) for the production of goods and services in the economy.

Construction is such an important sector; the scale of construction activities is influenced by policymakers to regulate the economy. There is a strong link between the mortgage sector and economic growth, especially in the advanced economies. The global recession which started in the USA in 2008 has its roots in the massive expansion of sub-prime mortgages (for low-income citizens with poor credit history) and the subsequent high rates of default and losses in the mortgage industry and capital market.

3.0 THE SIGNIFICANCE OF COSTING IN BUILDING PROCUREMENT

Conventional economic and popular microeconomic theories for price determination are mainly based on the dynamics of production and demand of consumer goods. However, buildings and all other construction goods have some unique attributes that make them radically different from those of manufacturing sector as follows:

- a) Buildings are bulky and except for housing estates, no two buildings are the same.
- b) Buildings are erected in a fixed location and cannot be moved from one market to another.
- c) The production time for a building, which could be from six months for the very small ones, to several years for a large and complex one is very long whereas consumer goods are turned out in hundreds in a minute or hour or in a day.
- d) The price (or cost of erection) for buildings is usually determined before the commencement of production, but in the case of manufactured goods, prices are usually fixed after production.

Production of buildings is usually a two stage process:

- i. The first stage is budgeting and design of the building; and tendering and award of the contract. A number of different professionals in the construction sector (architects, engineers, quantity surveyors, surveyors, etc.) are usually involved in this first stage.
- ii. The second stage is the erection process on site, where a duly selected builder undertakes the erection of the project, subject to supervision by the professional team. Modern buildings are technology-heavy; they are constructed and supported by a variety of complex technology products.

Buildings are expected to remain stable at all times. Apart from their own structural weight, they bear the weight of the occupants and users and furnishings etc. and the impact of external natural forces, such as, wind, small earth tremors, etc.

From the foregoing, we can see that a lot of risks are associated with the process of design and erection of buildings. These risks are aggravated in a context where there is scarcity of funds. The function of the various consultants earlier mentioned is to analyze and evaluate all risks associated with any project, and produce an implementable or budget friendly design solution.

There are also risks associated with the execution of the project, especially with respect to cost and competence, and in this regard, a robust procurement process must be applied to ensure that the right builder or contractor is appointed to ensure effective execution of the design on site.

4.0 ECONOMIC CONSEQUENCES OF BUILDING COLLAPSE

Any manufactured product has a life span. The product is guaranteed to be valid or effective for use according to the specified standards for a period of time after production. Technically and otherwise, a product is not and should not be utilized after its expiration date. It is an offence to put up expired products for sale or consumption. In some sectors of the economy, regulatory and monitoring authorities are empowered by the laws establishing them to track, collect and destroy any expired products, and prosecute offenders.

Buildings also have life spans, otherwise known as building life cycle, which commences with the design and terminates at the end of the projected period of validity. Fig. 4A above shows a graphic illustration of the profile of a typical building's life cycle.

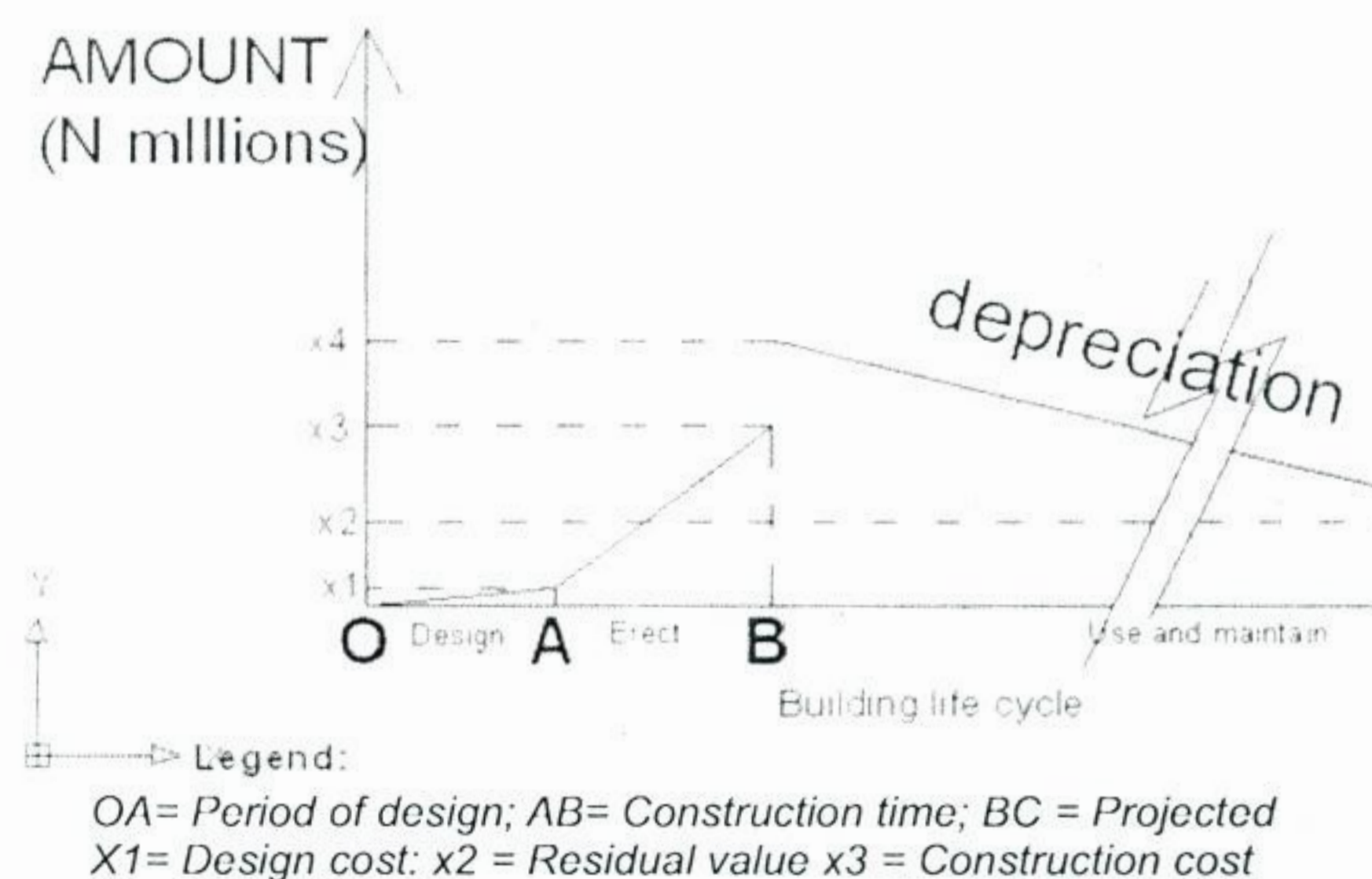


Fig. 4: A Profile of the life cycle of a typical building.

While the life span of a manufactured product is dependent largely on the shelf life of the degradable components, a building's life cycle may depend on:

a) The physical life span

Buildings are constructed of different materials, such as reinforced concrete, timber, steel, aluminium, clay, etc.; the physical and chemical properties of which alter over time, especially after continuous exposure to the weather leading to their deterioration

b) The economic life span

A building is always an economic asset, meaning that it is always subject to the play of economic forces of supply and demand. A building that is erected strictly as an investment asset to yield a certain minimum percentage of return, would have lived its economic life span once it no longer yields the said minimum return. For example, a block of 4 flats erected in location say "A" would be said to have reached its economic lifespan if after 15 years of fetching good rents for its owner, it stopped yielding the desired minimum rent.

c) The statutory life span

Buildings are erected on lands with "C of Os" (Certificates of Occupancy) and other similar titles, issued by State Government;s which vary from 30 to 99 years in duration. Any building(s) existing on a piece of land after the expiration of the period in the "C of O" has expired statutorily.

d) Technological life span

Buildings are hi-tech products and are also liable to become obsolete due to technological changes. Modern intelligent buildings, with large components of engineering services installations are liable to expire due to rapid technological changes of electrical and mechanical installations. This life span is the most unpredictable of all.

Since buildings are investment assets, which yield income directly or are used to assist the process of income generation, through the production of goods and services, a collapsed building may be potentially an asset lost. This is more so where the collapse leads to loss of lives and damage to other adjoining property. The impact on the personal, corporate, state and national economy is obviously negative, and the level or extent would depend on the outstanding useful life of the building. From the foregoing observations, it can be presumed that a building that collapses after its expiration date (where it does not lead to loss of life or damage to other property), is technically, not an economic loss.

5.0 ESTIMATING COSTS ASSOCIATED WITH COLLAPSED BUILDINGS

The stability of all buildings depends on:

- a) The strength of the sub-soil, and
- b) The strength of the structural components which are the foundations, columns and beams, stair, floor slabs, and load bearing walls.

The two principal stages in the life cycle of a building during which collapse may occur, as shown in fig. 4A, are:

- i) During erection, and
- ii) Post-erection

5.1 Collapse during Construction Stage

A building under erection is not a complete product and cannot be deployed yet as economic asset. It is not generating any income and does not have a real market value. Aside from any lives and property, the material loss at this stage is principally the aggregate cost of construction resources (materials, plant, labor, and management) that have been expended on the building on site, etc.

Under the typical contract conditions for erection of new buildings, there are provisions for an insurance cover typically called Contractors All Risk (CAR) policy, to be taken out by the contractor on behalf of the client which spells out the items for which claims could be entertained, which apart from the works include:

- i. Claims for restoration of any damaged third party property
- ii. Claims for any loss of lives of operatives and other authorized persons on the site.

The cost of the said works loss at this stage will technically be the valuation of work done on site up to the time of the collapse, and cost of removal of the debris.

5.2 Collapse at Post-Construction (use and maintain) stage

A completed building has market value and being an investment asset, it is subject to depreciation. Normally the market value of a newly completed building is usually higher than the cost of erection; the difference in value is the profit that keeps estate developers in the business.

The costs associated with the collapse at this stage would be

- i. The replacement cost and
- ii. The potential market value at the time of the collapse

The significance of these figures is to establish the net effect of the asset on the economy and also to enable a proper and wise management decision to be taken on appropriate further actions.

A simplified example is as follows:

Disregarding the cost of land, if a building which cost N100 m to erect collapses 5 years later, would it be wise to re-erect the building to the same standard and specifications; assuming an average annual inflation of say 7% and an annual depreciation of 3%?

Cost of new similar building = (N100m x 7% x 5) + N100 m	=N135.00 m
Add Removal of debris @ 2.5%	=N 3.375m
Total	=N138.375m

Meanwhile, the notional market value of the collapsed building = N138.375 m - (N138.375 m x 3% x 5) =N117.619m

Assuming the collapse occurred 10 years after completion, the figures would be

Cost of new similar building = (N100m x 7% x 10) + N100m	=N170.00 m
Add Removal of debris @ 2.5%	=N 6.75m
Total	=N176.75m

Meanwhile, the notional market value of the collapsed building = N176.75 m - (N176.75 m x 3% x 10) =N123.625m

From the foregoing, there is an indication that the nearer a building gets to the end of its life cycle, the much less its economic value, hence it is a waste of resources to redevelop such a collapsed building to the same specification and standard.

Some of the reasons why the market value lags behind were discussed in section 4.0. However, historic buildings and similar structures of cultural significance that are preserved as national or international monuments usually are not equated to any market value and are usually carefully redeveloped to their previous standards before collapse.

6.0 SUMMARY

All buildings have an economic value; they either represent a source of income to the owner or are used as inputs in the production of goods and services. The construction and mortgage industries are so important to economic growth that Governments influence activities in the sectors to control the rate of economic growth. Unlike consumer goods, the cost of a building has to be rigorously calculated by different professionals before the "production" i.e. construction is commenced. Risks have to be managed from this design stage, taking care to provide a budget that is sufficient to engage builders who have the appropriate skills to execute the project. Buildings have four types of life spans; a building that collapses after the expiration of its lifespan has technically not caused any economic loss. In an economic sense, the cost of replacing a collapsed building must be greater than its residual economic value which depends on the stage of its lifecycle.

Roles and Obligations of the Statutory Regulatory Authorities, Consultants, Contractors and Artisans in Mitigating Building Collapse

By

Arc. Umaru ALIYU, ficiArb, fnia, ppnia

President, Architects Registration Council of Nigeria (ARCON)

1.0 INTRODUCTION

There are many dimensions to this topic and the time available to us at this forum will only permit a general overview of the many factors that contribute to this disturbing phenomenon - even within the confines of our heading - which focuses on the statutory regulatory authorities, consultants, contractors and artisans. In our discussions we would like to highlight the roles and obligations of each of these parties within the industry and then discuss how their actions or otherwise can contribute to building collapse. I will not be going into the technical modes of building failure - indeed such detailed reports have been produced on specific building collapses by NBRRI - we shall focus instead on the activities of the named parties. I would then like to suggest some measures that may be applied to reduce or, indeed, prevent the incidence of building collapse.

Without expanding our scope unduly, let us at least mention some of the other parties that play a critical role in the collapse of buildings, and so, we start by asking; why do buildings collapse?

2.0 WHY DO BUILDINGS COLLAPSE?

Failure is the one word that summarises the cause of building collapse. Failure is also the word that broadens the contributing causes beyond the actions of the parties mentioned in the heading of our discussion. Building collapse is often as a result of a cascade of failures. These failures may originate at any point, from any one of these parties and then, without timely intervention or compensation by another party, the

failure progresses to building collapse. The critical parties, in no particular order, include:

- a) Clients and building users
- b) Planning Authorities
- c) Statutory Regulatory Authorities
- d) Standards Organisation of Nigeria (SON)
- e) Building Materials Manufacturers
- f) Building merchants
- g) Consultants
- h) Contractors
- i) Artisans
- j) Research Institutions

This net could be further spread to include our policy makers and many others, but let us focus on this core group of actors.

3.2 ROLES AND OBLIGATIONS

Before returning our focus fully to the statutory regulatory authorities, consultants, contractors and artisans as defined in our topic, let us briefly touch on the other parties mentioned above, namely, the client, planning authorities, SON, building materials manufacturers, building merchants and research institutions.

3.1 Clients and Building Users

Buildings are 'common' because we see them around us every day and unfortunately we can sometimes start to think that they are also 'simple', just because our grandfathers were able to build their huts and house the family without needing a university degree. With the building owner, this simplification can lead to a number of dangerous assumptions

- i. That they do not require the expertise of trained building professionals to plan and produce their buildings.
- ii. That the remuneration of the building design professionals is the first place to start the cost-saving process, followed quickly by the structural materials and the quality of the contractor or labour force.
- iii. That they can disregard the advice of these professionals with regards to the need for soil tests, materials tests and materials storage and handling before and during construction.
- iv. That buildings once completed, can be chopped and changed at will, without regard to the designed pathways for live, dead and dynamic loads.
- v. That buildings, in use, can be loaded infinitely; only limited by the space available to load them and that the weight and distribution of that loading has

no significance.

- vi. Planning building and zoning laws are optional and a minor inconvenience to be subverted by corruption and outright disregard.
- vii. That buildings once constructed do not require any maintenance to remain safe and functional.

Needless to say, all these assumptions are wrong. Paradoxically, when you need to save money on a building project you need more, not less, input from the design professionals to optimise your space, structural and services options and to work, safely, close to the permitted scientific limits of structural safety. The aggregate fee of the professional is such a small proportion of the overall cost that you reap a considerable profitable return on that form of investment. Competent professionals will build safely on poor soil, will optimise the use of materials by design and by quality control in the handling, storage and placement of materials and will provide the required functionality with less cost. Their advice will ensure that buildings are located and situated in a manner that obeys the law and ensures long term health and safety; whether from natural phenomena such as flooding or man-made hazard such as exposure to radiation.

Each or a combination of the factors mentioned above can start or contribute to a cascade of failures.

3.2 Planning Authorities

In the administration of planning laws, the Planning Authorities interface with the building procurement process at a number of critical choke points that give them ample opportunity to pre-empt or arrest the cascade of failures--from the communication of planning requirements, the inspection and approval of planning drawings, the monitoring (at requisite stages) of the construction process and the application of fairness, honesty and diligence in carrying out these functions. Mistakes made by other parties could easily be identified and corrected at any of these choke points.

3.3 Building Materials Manufacturers, Building Merchants and Standards Organisations

When a building materials manufacturer deliberately manufactures an 'A' standard and a 'B' standard where there should only be one standard then he has, potentially, started a cascade of failures. When a building merchant knowingly orders the 'B' standard in addition to or in place of the 'A' standard then he has propagated that cascade. These failures create an opportunity for unjustifiable

'cost savings' on the structure of a building - something that should not pass the quality control processes of the project consultants (if they are present) or the inspection of the planning authorities if inspection milestones are involved.

Unscrupulous building merchants will often mix the good with the bad quality materials to try and beat batch tests, say for reinforcement bars, making the quality control duties of the supervising consultants less effective.

The Standards Organisation of Nigeria (SON) has the responsibility of ensuring that our country does not become a dumping ground for substandard materials. We should also not become users, producers or exporters of substandard goods. Unfortunately it would appear that not just the people of Nigeria, but our international trading partners have come to see us as a nation that accepts the second rate.

3.4 Statutory Regulatory Authorities

Building projects are realised as a planned, structured and regulated combination of money, materials and manpower and the statutory regulatory authorities assure the quality of the high level trained manpower in that equation. The seven statutory regulatory bodies in the building industry - the Architects Registration Council of Nigeria (ARCON), the Council of Registered Builders of Nigeria (CORBON), the Council for the Regulation of Engineering in Nigeria (COREN), the Estate Surveyors and Valuers Registration Board of Nigeria (ESVARBON), the Quantity Surveyors Registration Board of Nigeria (QSRBN), the Surveyors Registration Council of Nigeria (SURCON) and the Town Planning Registration Council of Nigeria (TOPREC) - have the joint responsibility of ensuring that our building industry gets the correct calibre of manpower we need to produce safe and effective buildings today and in the future.

Statutory Regulatory authorities have the responsibility of establishing the standards for training; monitoring and ensuring compliance with the standards in training institutions. They carry out the licensing of qualified professionals and firms eligible to practice the respective professions in the country and continuously monitor compliance with practice standards. This role continues to expand to incorporate the latest best practices in the industry - including emerging considerations such as sustainability and energy efficiency.

The capacity of the building professionals to work effectively and with integrity is dependent upon the standards of training, the thoroughness of the registration

process that licenses them to practice, and the monitoring of professional standards and conduct that takes place post- registration by the Statutory Regulatory Authorities. This is a dynamic thing, as the society is not static and professionals must be trained and empowered to operate in the current scientific and socio-economic environment.

Any inadequacies in these tasks will produce substandard professionals and create the potential for building failure, increasing the likelihood of building collapse.

Statutory Regulatory Authorities are the structures globally used to regulate the building industry; therefore neglecting them is most inappropriate as it will spell doom on all physical development.

3.5 Consultants

The consultant is an expert who provides enlightened and considered professional advice and renders service in an area of certified training. Procedure is essential for effective consultancy work. Failures, as always can start from any one of the consultants in the building industry in ways that we can only summarised here.

- a) Town planning and zoning failures may contribute to an increased tendency for buildings to fail. Location of building developments in potential flood plains could create unpredictable seasonal surges that weaken building foundations and structures.
- b) Improper site investigation - weather, topography and subsoil considerations - will provide insufficient information for safe building design.
- c) Improper design response to the peculiarities of the site and the applicable planning regulations and/or a failure to meet the functional needs prescribed in the design brief could ultimately lead to a cascade of failures. Architectural and structural engineering designs are critical in this area.
- d) Inadequate construction documentation - whether as incomplete or inaccurate specifications and drawings - can disrupt the communication of the design intention to the contractors, resulting in their inability to correctly realise the building as designed.
- e) Inadequate design management can result in a lack of design coordination amongst the design professions, creating a need for late corrections 'on site', (which can be costly and dangerous) or a tendency for compromise that hides critical faults.
- f) Inadequate, improper, negligent or the total lack of supervision can make the best drawings, specifications and construction planning fail.

- g) Lack of professionalism, experience, or indeed the courage and guts to point out potential faults, no matter what the sources may be, can contribute to the failure of a consultant's role in preventing building collapse.

Procedure is a key part of achieving all these - did you put it in writing as and when required? Have you followed the required checklists? Have dotted the i's and crossed the t's?

3.6 Contractors

Contractors contribute to building failure largely due to incompetence or to compromise. Compromise can arise from unethical conduct (unethical professionals or outright non-professionals) or where contract quotations are insufficient to carry out the works to meet the requirements of the design specifications, resulting in a desperate attempt to hold down construction costs. Incompetence can involve the placement of the wrong calibre of staff for the specific requirements of the building project. These failures can manifest in so many ways:

- a) Improper analysis and deliberations on the viability of a contract at the tendering stage - including a critical assessment of funding.
- b) Improper project execution planning.
- c) Poor execution of the contract in the management of materials, labour and processes.
- d) The use of substandard materials
- e) The employment of improper construction methods.
- f) The mishandling of materials in terms of storage and preparation.
- g) Failing to follow the design drawings or seek due clarification from the design consultants.
- h) Deployment of unqualified staff on building projects.
- i) Dishonesty of staff or management in the execution of projects - leading ultimately to false records of work done.

3.7 Artisans

Most of the failure at this level is due to the lack of initial and continuous training of artisans, often compounded by a poor background for the proper acquisition of knowledge-on-the-job. Most often the proper equipment is not provided for doing work and, frequently, artisans are poorly paid - greatly increasing the tendency towards dishonesty.

4 RECOMMENDATIONS - Towards Prevention of Building Collapse

Do not be deceived by the short recommendations that follow - the fact is that getting just a few fundamentals right will go a long way towards achieving a considerable correction.

- i. Resuscitation of the Building Code Advisory Committee to achieve full implementation of the National Building Code, as an industry-wide guide for safe and effective building delivery. The guidelines for a properly structured construction industry have been set out in the National Building Code and its implementation will greatly help to tackle the problem of building collapse.
- ii. Funding and proper support of the regulatory bodies by the federal government. As a developing economy, infrastructure development is critical to a future of our nation and such critical elements of nation building should not be left to international 'market-forces'. We have the opportunity to develop world-class professionals and then export them to the world one day.
- iii. Effective regulation, in all its ramifications, by the regulatory bodies.
- iv. Effective education of clients as well as secondary service providers within the building industry on what their true roles should be on building development projects.

Generally the benefit from the application of these measures will radiate to the various parties that contribute to the problem, causing them to improve their specific performance while mitigating the impact of their specific failures.

Building Collapse Phenomenon Sanctions, Liabilities and Legal Implications

By

Bldr. Dachollom Dalyop JAMBOL, FNIOB
Department of Building, Faculty of Environmental Sciences,
University of Jos

1 INTRODUCTION

The frequency of collapse of buildings in Nigeria in the recent past has become vexatious, menacing and embarrassing. The incidences have become an issue of concern to all stakeholders in the construction industry and indeed, the built environment, as its sustainability is increasingly and greatly threatened.

The impact of building collapses have affected the entire fabric of human endeavour, ranging from psychological trauma on those affected to the economy of the nation. Lives and property are lost, revenue to government in tenement rates and taxes are lost, investments and subsequently jobs are lost, victims suffer permanent disabilities, homelessness, among others.

The phenomenon certainly deserves attention, if only to curb the menace and up the economy especially in this transformation government. This paper examines this issue from a legal angle for the effects or liabilities, legal implications and sanctions required to tame the monster, Building Collapse.

It is necessary to appreciate the Nigerian Building and Road Research Institute (NBBRI) from the onset, being a key stakeholder in the built environment for spearheading the search for a lasting solution to this problem. NBBRI, being a research organization, has also selected an apt theme for this National Conference: **'Curbing the Incidences of Building Collapse in Nigeria'** and brought in the appropriate critical stakeholders: professional bodies and stakeholders in the construction industry to deliberate on this issue. These constitute a critical mass for policy inputs and formulation. It is the case of "Physician heal thyself."

2 DEFINITIONS, CONTEXTUALIZATION

It is important to define key terms/phrases that will be used in this paper and appropriately contextualize them.

Phenomenon of Building Collapse

Levy and Salvadori (2002) in their book "Why Buildings Fall Down" brought a metaphoric analogy of the building to the human body. They pointed out that "a building is conceived when designed, born when built, alive while standing, dead from old age or an unexpected accident (such as a collapse). It breathes through the mouth of its windows and the lungs of its air conditioning system. It circulates fluids through the veins and arteries of its pipes and sends messages to all parts of its body through the nervous system of its electric wires. A building reacts to changes in its outer condition through its brain of feedback systems, is protected by the skin of its façade, supported by the skeleton of its columns, beams and slabs, and rests on the feet of its foundation. Like human bodies, most buildings have full lives, and then they die." Sometimes naturally, and at other times untimely, as in collapses.

The accidental death of a building they concluded is "always due to the failure of its skeleton, the structure." This happens when the structural system e.g. steel frame of a shopping mall, the materials used in construction and forces acting on the building caused by gravity, wind, earthquake, temperature changes or even settlement of the soils react by being "pulled or pushed." These are the natural technical reasons for a structural failure, which is not unusual or abnormal for any building. It could also happen at the end of its designed physical life (life-cycle). It can be recalled that there were once celebrated "Seven Wonders of the World." Today, only one, the mountain like pyramid of Khufu in the Egyptian desert of Cairo has survived. All the others have fallen (collapsed). Therefore, the phenomenon of building collapse is natural, inevitable and universal, but controllable. It can to a large extent draw analogy to human death.

3 BUILDING COLLAPSE.

A building is said to have collapsed when its structural and component states have failed and are not only unserviceable requiring some level of maintenance, but unable to adequately support intended loads or lacks stability due to excessive deformation. It has gone beyond the failure of either material or structure, or both (Iyagba, 2005; Adegemi, 2002; Ogunsemi, 2002; Odunlami, 2002; Taiwo, 1988). Such a building is no longer safe as a structure to live in and therefore a nuisance (Jambol, 2010). Building collapse could be complete or partial.

What therefore is of concern, is the situation that makes collapse, which ought to be a phenomenon (i.e. something that strikes as strange or uncommon, an exceedingly remarkable thing or something extra-ordinary), an issue of **incidence**

becoming one too-many or a menace that requires curbing (restraints or control). A collapse can be equated to an accident or an untimely occurrence, an exception rather than the norm. It therefore does not just happen, as in failure, but it is caused. It needs control.

4 THE BUILDING CONSTRUCTION INDUSTRY.

Jambol (2010) described the Building Construction Industry as one with the following characteristics.

- ∅ Responsible for the delivery of goods and services such as buildings and housing. It consumes raw materials in the production process.
- ∅ Knowledge driven (process and technology). The drivers of the industry for its performance are: committed leadership, focus on clients, integration of process (devoid of fragmentation), quality focus getting operations done right first time and with a commitment to people providing quality services and value, safe and healthy site conditions, employment, etc.
- ∅ In agreement with Sir John Fairclough (2003), industry's delivery mechanisms are driven or characterized by a construction culture, integration of design with production, delivery chain management (production networks), a focus on innovations secured/driven by adequate R&D and an acceptance of standardization in design, components and assembly across building types and processes. These tally with the philosophy and provisions of the National Building Code (NBC), 2006.
- ∅ When above is successful, the industry will be known for:
 - a) **Productivity** characterized by
 - i. Reduction in cost of production (capital costs)
 - ii. Reduction in construction time.
 - iii. Fewer defects in products and services (quality production)
 - iv. Fewer accidents during productions (Health and Safety)
 - v. Increased productivity (developed technology, serviceable products)
 - vi. Increased turnover and profits, profitable ventures, contribution to the economy, etc.
 - b) **Quality Workforce**(People) that
 - i. Have conducive work environment for operations,
 - ii. Health and safety provisions and practices.
 - iii. Improved working conditions.
 - iv. Improved care development and life-long learning, job security and satisfaction.
 - v. Sound professional behavior: attitudes, values, ethics and law abiding.

c) Sound Practices which promote:

- i. Learning by doing
 - ii. Best practices, defined as "The adoption and development of ideals, systems and methods in a way that measurably improves a business or enterprise so that it continually offers best value for money" (Ashworth, 2005).
- It adopts the Construction Best Practice Cycle:
Awareness → Commitment → Action → Sharing.
 - Uses Construction Best Practice Action Plan where all Performance Measurement actions go through a system that:
Measure → Diagnose → Plan → Do → Review.

Therefore, accountability is the watchword in practice.

Innovations are encouraged through networking (both within and between organizations). Practice promotes integration, bench marking, partnering, delivery chain management and innovations management. This kind of practice in the UK led to the achievements of lean-construction, design management and knowledge management, which resulted to drastic reduction in cases of collapsed buildings. Indeed, even building failures have been greatly reduced, leading to developments like deconstruction instead of demolitions, sustainable construction, building information management and Green Building developments to tackle global environmental problems of sustainable developments. It also eliminated quackery, promoted professionalism and productivity, efficient and effective sustainable service delivery, value (quality products) and therefore healthy and safe buildings.

d) Construction Excellence.

The UK Researchers have been able to advance the objectives of construction excellence to include:

- i. Improving performance through productivity and competitiveness.
- ii. Improve industry image through developing a culture of construction that develops people, enhances engagement with the community and customers promoting popular participation in the development of a suitable environment.
- iii. Engagement- actions with individuals, businesses, organizations and industry associations through integration. It requires a system such as the Construction Industry Development Board being advocated by the NIOB/CORBON. This when established, will promote:
 - Innovations that continue to identify and promote tomorrow's best practices.

- Productivity with products and services that improve competitiveness of the Construction Industry.
- Best Practice Knowledge sustaining continuous improvement through exchanges of best practices.
- Integrated engagement Working with people, business organizations to change the culture of the construction industry.

Innovations, productivity and Best Practice Knowledge adequately address the technical issues in building collapse. It is in engagement that the **humanerror** element is critical. This is the critical delivery mechanism that is fundamental to Constructing Excellence, which can be achieved through a Systems Approach delivery mechanism where delivery is seen and accepted as **teamwork**, based on the rule of law for equity and accountability.

e) Safety

The Construction industry has been adjudged as the second worst of any industry for safety accounting for 3.6% of total project costs from accidents (Egan, 1998). Building laws and regulations such as Health and Safety Codes of Practice, Quality Management Plans, Planning Control Laws, etc provide guidance to understanding, compliance with the law, and definite "dos" and "don'ts" to be obeyed on all aspects of building production for healthy and safe buildings. The health and safety checklist as produced by HSE has 17 key items to be observed.

- | | |
|-------------------------------|--------------------------------|
| 1. Access to site | 10. Hoist |
| 2. Welfare | 11. Emergencies |
| 3. Scaffolds | 12. Fire |
| 4. Ladders | 13. Hazardous substances |
| 5. Roof Work | 14. Noise |
| 6. Excavation | 15. Hand warm vibration |
| 7. Manual Handling | 16. Electricity&other services |
| 8. Traffic, Vehicle and Plant | 17. Protecting the public |
| 9. Tools and Machinery | |

In implementation for safety, the industry is guided by:

- i. **Employers' Responsibilities**, to ensure health, safety and welfare of employees on site. These include safe use of mechanical plants and equipment, safe work methods, provision of instructions, supervision and staff training, and all others working on site, the public and third parties. Building production management must therefore plan, coordinate and control health and safety throughout the stages of the project, input quality and ensure that all managers are competent to manage and adequately allocate all resources. The welfare of the workers and clients are paramount.

- ii. **Employees Responsibilities** must comply with all organizational and statutory requirements for health and safety operations for themselves and co-workers.
- iii. **Operation Documents**
All relevant sections of the building laws, regulations etc for safe and healthy operations must apply and be enforced. This is universal and an age-old tradition of all civilizations dating back to Hammurabi's Building Code.

The Legal Imperatives: Liabilities, Implications & Sanctions.

Causes of Building Collapse

Going through several reports on cases of Building Collapses have left one with several speculative factors said to be responsible for building collapse. Scientific thinking however, informs us that failure has other more fundamental causes. Three causes have been identified as critical. They are Designs, Human error and Risks inherent in the management of the production processes of buildings, and all are liabilities that have significant legal implementations.

5. DESIGNS.

Design decisions for structures are usually based on the following:

a. Structural Theories in Design

Designers often take design decisions based on structural theories that have their bases traced to Galileo and Isaac Newton's Mechanics as against more recent and abstract theories of relativity of Albert Einstein or quantum mechanics. The mathematics of today's structural theory is essentially based on the calculus of Newton and G.W. Leibniz's differential equations, a derivation of calculus. These are relatively new and yet to influence Engineering practice significantly.

When complex structures are designed using exceptionally strong materials, calculations can be reduced to methods of successive approximations instead of nonlinear equations. Thus, structural theories employed in structural designs, should as much as possible be based on and supported by experimental research using less complex scientific methods, as the approximations could be and have been a source of error leading to failure and higher costs from over design, for example George IV Bridge in Edinburgh, NBRRI Reports Nos 22 and 23.

b. Calculation Techniques

The revolution in the tools for structural calculations from the slide rule, log and trigonometric tables, hand calculators and now computers, is breath taking both in time and cost. Yet, there is need for caution. Solutions from computers according to Levy and Salvadori (2002), are "successive approximations of complex equations

appearing in the dynamics of structures." This field has not been thoroughly investigated and it is important that these approximations are understood to avoid failure. The findings of NBRRI Reports affirm this position for caution.

c. **Material Properties**

Natural building materials used for structural purposes must solve the issues of tensile and compressive forces. Developments in this area for bigger and complex structures are phenomenal. Designers and constructors need to check what the markets provide/supply by Chemists and material engineers). The market is so wide and growing. Inductive incentives for patronage are complex and sometimes confusing as users seek to balance and take maximum benefits of the economics for modern inexpensive, stronger and safer materials. The choices are now more difficult to make for the variety of structures which range from iron, steel, and aluminum to wood, plastics and even hybrids of these. Experimental researches on the application of materials become more suitable than choices based on purely scientific methods. Wrong choices do result in failure and even collapses as have been experienced in Nigeria.

d. **Communication Procedures**

The developments in the production, accuracy, speed and costs of communicating architectural and structural designs aided by ICT developments are great and exciting. Designs can be fully and graphically viewed, analysed and understood before they are produced. Software have been developed for aesthetics, cost indications and structural details for strength and stability.

All these can be comprehensively organized into information components relevant to the members of the construction team. However, while this enables effective communication among designers (Architects and Engineers), it often ignores other critical participants: designers, builders, contractors, developers and labour leaving out an important component of supervision and management of the production process, which involves the "less experienced members" in designs both in the office and field. This is a source of human error, a liability, too dangerous to be ignored. These are however being addressed using computers in construction programmes, quality management plans, health and safety management plans and buildability and maintainability analysis reports.

5. **Economic Factors**

These factors of costs that range from raw materials, processing, and transportation to installation, use and maintenance are of the greatest importance in structural designs. Their applications are compounded by the operating