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PROFESSOR OF STRUCTURAL AND FIRE ENGINEERING

AMBROSE ALLI UNIVERSITY, EKPOMA, NIGERIA

153RD INAUGURAL LECTURE

TITLE OF LECTURE:
TWO WORDS THAT DO NOT FIT-STRUCTURAL COLLAPSE: MY VIEWPOINTS, AND THE PARADOX OF ENGINEERING TRAINING AND PRACTICE IN NIGERIA

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DEDICATION

This inaugural lecture is dedicated to Almighty God alone, the Giver of all good things.

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PROTOCOLS

The Vice Chancellor
Other Principal Officers
Former Vice Chancellors present
Deans and Directors
Heads of Departments
Distinguished Professors
Respected Colleagues
Friends, Parents and Relatives
Greatest Nigerian Students
The Four Estates of the Realm
Ladies and Gentlemen

PREAMBLE

Twenty-six (26) years ago, I was shortlisted to undergo the SHELL Intensive Training Programme (SITP). Providence did not make that happen, instead I decided to accept the offer granted me by the Ambrose Alli University as Graduate Assistant, particularly because I was not so confident SHELL would absorb me after completion of the training. In 2006, barely into the second year of my Ph.D programme under the supervision of Prof. Joseph O. Afolayan at the Federal University of Technology, Akure (FUTA), something very dramatic ensued. I was to be framed up for an unjust disengagement. On that fateful Saturday, I did not know God was redirecting my Ph.D study from FUTA to the University of Manchester, United Kingdom. An individual had orchestrated a way to implicate me in the leakage of examination questions. I was given the question papers, sealed in an envelope two hours before commencement of the examination. The objective, I later discovered, was to provide ample time for me to open the envelope before commencement of the examination. While this machination failed, I was told to my face that I must face the disciplinary committee.

As a young Academic, I was troubled beyond measure. Moreover, the following day was earmarked for my daughter -Mandy's dedication. This spiritual programme was perturbed and nearly marred by this development. I thought the world was mad at me. However, by Monday morning, it was discovered that there was no leakage and I was exonerated. The energy that was devoted for such purpose by the individual was enormous. For this singular reason, I decided to run away by applying to Universities in the UK and US for my Ph.D pursuit. I was offered multiple admissions, which I deferred because of financial constraints. Thereafter, I took loans from ASUU Welfare and Cooperative Society such that my net take-home pay could no longer take me home. That was when God suddenly showed up for me.

In 2008, I was offered the Petroleum Technology Development Fund (PTDF) scholarship to undertake a Ph.D programme at the University of Manchester, England. This was the catalyst of my academic odyssey. However, I decided to make a detour of my odyssey to reflect on a major challenge that confronted me as a young academic. You can imagine the implication if that furtive machination had come to fruition. Without mincing words, the Department of Civil Engineering by now would have experienced Structural Collapse. In fact, the Department would have become a mechanism by now. This is particularly true because today, I am the most Senior Academic and the only Professor in the Department of Civil Engineering. Therefore, let us work in synergy to eliminate its occurrence or better, reduce its effect to as low as reasonably practicable (ALARP).

1.0 INTRODUCTION

Structural collapse simply refers to sudden loss of the load-carrying capacity of elements of construction within a structure or the structure as a whole. This phenomenon can occur when the external stresses and other disturbing forces exceed the structural capacity of the materials, thereby breaking the load path and resulting in a mechanism. In risk analysis, structural collapse becomes imminent when the limit state function is less than or equal to zero as depicted in Equation (1a). The probability of failure can then be determined using Equation (1b).

$$R - S \leq 0 \qquad 1a$$

$$P_f = p(R - S) \leq 0 \qquad 1b$$

Where P_f is probability of failure, R is the material resistance (structural capacity) and S is the load combination effect

Structures will collapse when they are transformed into mechanisms by developing plastic hinges at locations of bending moments. Load redistribution is usually permitted when more than one plastic hinge can be developed. Therefore, the structural engineer should endeavour to reduce all risks associated with structural collapse to as

low as reasonably practicable. In this situation a robust design is required to enable the redistribution of stresses in the event of failure of any structural component.

The goal of a structural and fire engineer is to ensure that this catastrophe does not occur. In fact, the primary objective of all structural designs is to guarantee that the structure will perform adequately during its design life. Structural collapse can be averted if all design and construction requirements are satisfactory, and the design is sufficiently robust to ensure full compliance with the limit state philosophy. Some of the pertinent questions a structural engineer must ask the client before embarking on any design should include the following:

- ✓ How much money does the client have for the building construction to take off?
- ✓ Does the client intend to alter or change the design purpose in future?
- ✓ How long does the client want the building to last?
- ✓ How often does the client envisage to carry out maintenance?

However, with reference to Lagos State Fire Service repository, Nigeria has recorded hundreds of building collapse since 2000, with Lagos serving as the primary epicenter owing to its rapid urbanization, use of substandard materials, weak regulatory enforcement of design standards and proliferation of quackery within the construction industry. Lagos State experienced about 167 cases of collapsed buildings between 2000 and 2021 as shown in Fig. 1. This translates to residential buildings accounting for 78.4%, 12.8% were commercial buildings and 8.8% were institutional buildings involved in the collapse as demonstrated in Fig. 2. In another report, according to data from the Building Collapse Prevention Guild, between 1974 and 2025, Nigeria has recorded about 679 building collapse cases that resulted in not less than 1,639 deaths. Let me categorically aver that building collapse causes more deaths than many other mishaps in the ecosystem. Unfortunately, less attention is given to this very important field. What a paradox!

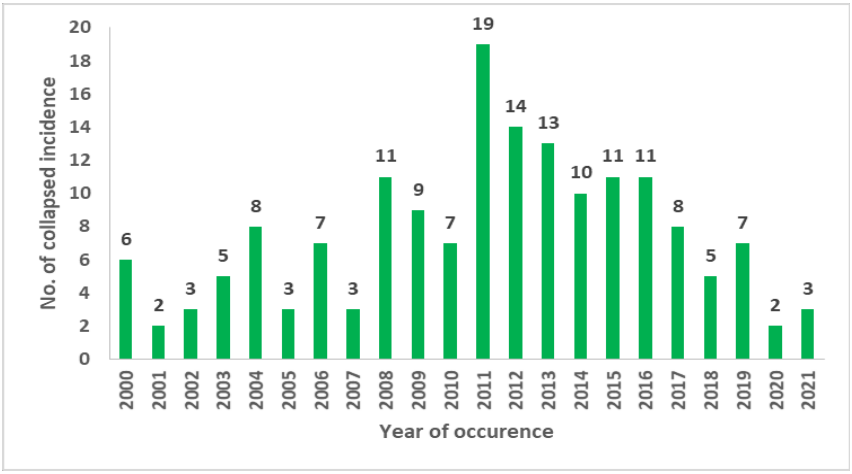


Fig. 1. Statistics of collapsed buildings in Lagos State from 2000 to 2021 as reported by Lagos State Fire Service

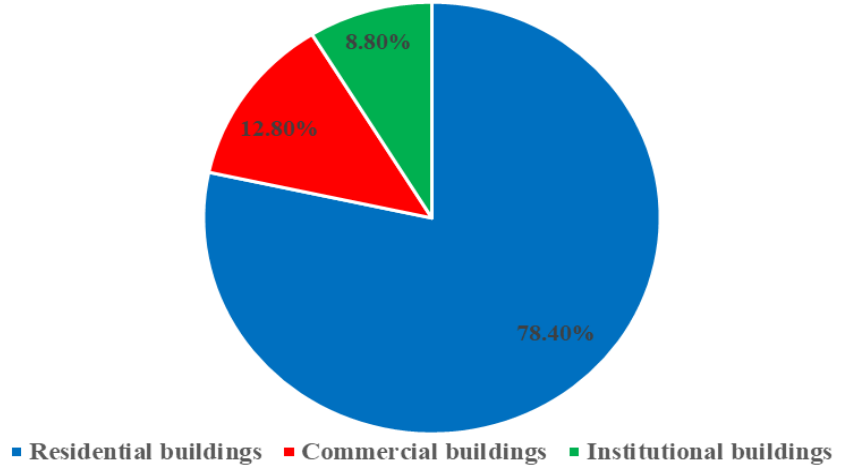


Fig. 2 Pie chart showing percentage distribution of collapsed building cases in Lagos between 2000 and 2021 as reported by Lagos State Fire Service

The 21-storey luxury high-rise building under construction that collapsed in Ikoyi, Lagos resulting in no fewer than 45 casualties was actually designed for fifteen (15) floors. It was later discovered that the approval was fifteen (15) floors, and that poor materials were also used in construction of the collapsed building. Why is it that the construction process was not immediately stopped when this violation was discovered? Therefore, it can be surmised that indifference on the part of the supervisory agencies whose failure to perform their duties and enforce punitive measures on the contractor and owners of private properties probably led to the tragedy. It would have taken appreciable time to construct the six (6) additional floors. However, the Agency responsible for issuing the 'stop work order' disregarded the construction of those additional floors and therefore failed in the implementation of extant building laws. This negligence and apathy on the part of regulatory agencies may kindle the need to drive for the prosecution of culpable officials of Regulatory Agencies.

1.1 FACTORS RESPONSIBLE FOR STRUCTURAL COLLAPSE

There are various factors responsible for structural collapse ranging from natural disaster to man-made factors. The natural factors include earthquake and related seismic disturbances, flooding, wind gust, accidental fire and explosion. The man-made factors include illegal conversion of intended use of structures, lack of supervision by qualified professionals, use of substandard construction materials, developers and clients' undue interference in the construction process, poor maintenance culture, inadequate geotechnical investigation, excessive and accidental loadings, foundation failure, design and construction errors, weak regulatory enforcement processes, rampant quackery, unethical behavior such as bribery and kickbacks, etc.

A structure may become unserviceable without actually collapsing. These serviceability failures such as excessive deflection and cracking usually prelude structural collapse. Most building owners

and developers have persistently failed to engage the services of qualified and registered professionals in the execution of building construction so as to reduce cost. It is unthinkable and an aberration to observe that unqualified and non-engineering personnel are allowed to undertake most construction works. Consequently, there are quite a number of buildings still existing today in Nigeria constructed/supervised by these unqualified personnel that may be at the verge of collapse.

There are cases where a localized failure of a component within a structure can induce global collapse. This phenomenon occurs once a critical element of construction fails and the design or construction is not robust enough to allow redistribution of loadings to other members. It should be noted that before structural collapse can occur, there are usually warning signs such as severe cracking and visible deflection of structural elements, elastic instability, and other serviceability issues. However, use of defective construction materials, alterations of approved building permits and illegal conversion of existing buildings are recurrently observed to be major reasons for building collapses.

Oseghale et al. (2015) asserted that the major causes of building failure were bad design, faulty construction, overloading, and unavailability of approved drawings and use of unqualified personnel in the construction process. Obodoh et al. (2019) studied the effects of building collapse risks on the stakeholders in the Nigerian built environment. They found out that economic/financial risks have the predominant effect on the stakeholders followed by human-related risks, social-political risks, physical risks, environmental risks and law/legal risks.

Moreover, Williams and Rahila (2020) maintained that conversion of intended use of structure without following professional protocol, lack of supervision by qualified personnel, use of substandard materials were some of the causes of building collapse. Similarly, some of the factors responsible for building collapse as revealed by

Kolawole (2018) include overloading, lack of maintenance, illegal conversion of existing buildings, use of unqualified personnel, inadequate structural analysis/design, improper foundation and inadequate supervision by professionals.

However, Odeyemi et al. (2019) claimed that structural defects were mainly responsible for building collapse. Imafidon and Ogbu (2020) went further to classify the factors responsible for collapse of buildings into design and construction-related, policy-related and quality-related. Nevertheless, they discovered that maintenance culture, illegal conversion of building and use of substandard materials were found to be the most influencing causes of collapse for these classifications.

One of the largest and deadliest building collapse in recent time is the collapse of the World Trade Center towers in New York City on September 11, 2001. This collapse was triggered by the impact of the hijacked airliner that plunged into the 110-storey twin towers resulting in not less than 2975 fatalities. A structural collapse can occur due to errors associated with design and construction processes. However, while these factors may account for the root cause of the collapse, they do not necessarily describe the mechanics that cause the structure to fail. Structural failure that leads to a building collapse can be caused by the following:

1.1.1 BENDING FAILURE

The load-bearing elements of construction can undergo flexure or bending if they are subject to excessive loadings. This bending action can induce deformation of the structural supports up to the ultimate limit state. If the moment of resistance becomes less than the ultimate bending moment initiated by external actions, the structure will develop into a mechanism.

1.1.2 SHEAR FAILURE

Shear forces can be induced when a structural element is subject to two or more opposing forces. To every action there is always an equal

and opposite reaction to ensure equilibrium is maintained. However, if the shear forces are greater than the shear capacity of the structure, a collapse will ensue.

1.1.3 BUCKLING FAILURE

All structures have a critical load, which is the maximum amount of load the structure can sustain before failure becomes imminent. Buckling occurs when the critical buckling load is exceeded, resulting in bending, bowing, and other deformation of structural components. Consequently, this leads to elastic instability that can cause structural failure and the resulting collapse.

1.1.4 TENSILE FAILURE

Tensile failure can occur when the tensile capacity of the structural material is exceeded by the tensile loading. Both pin-jointed and rigid structures can fail in tension if the performance function is compromised. Inherently, structural failure and collapse can occur if the material's tensile capacity is less than the tensile force to which it is subjected.

1.1.5 COMPRESSIVE FAILURE

Compressive loading on a structural member can lead to crushing and buckling due to elastic instability. Strut and columns are structural elements that resist compressive loadings. Short columns are likely to fail by crushing whereas slender columns usually fail by buckling, depending on the slenderness ratio. This elastic instability may lead to lateral torsional buckling if twisting effect is involved. A pin-jointed member will fail in tension and compression while a beam-column structural member will fail in tension, compression, bending and shear.

1.2 COMMON TYPES OF STRUCTURAL COLLAPSE FORMATIONS

A structural collapse may have one of two different forms, namely complete and partial collapse. In a complete collapse scenario, the entire configuration of the structure fails and drops down. A partial

collapse on the other hand only involves a part of the structure. One of the most serious concerns with any structural failure is the tendency and potential for a progressive collapse, thus resulting in what is known as domino effect. A progressive collapse occurs when the failure of one or more primary structural elements trigger other elements of the structure to fail. With this development, the localized damage exposes the entire structure to a catastrophic loss. To avert such failure and the eventual collapse of any structure, a robust performance-based design is recommended to guarantee safety and resilience of elements of construction against random external actions. The following are the common types of structural collapse formations.

1.2.1 PANKAKE COLLAPSE

A pancake collapse occurs when the floors or sections of a multi-level structure collapse on top of one another. The simultaneous failure of exterior walls permits the upper floors and the roof to collapse vertically on top of each other in the form of stacks. This collapse pattern is dangerous as it leaves very limited spaces for evacuation of personnel. This is also known as a horizontal collapse, as the entirety of the floors and walls collapse to form heaps.

1.2.2 LEAN-TO COLLAPSE

A lean-to collapse occurs when one load-bearing wall fails while the others remain standing. The floor or roof may drop down on the failed side while resting on the intact wall thus creating a formation of a large triangular void.

1.2.3 V-SHAPED COLLAPSE

In this collapse pattern, the perimeter walls remain intact while the central regions of the floor and roof sag vertically downwards due to overloading or failure of some critical structural elements.

1.2.4 A-FRAME COLLAPSE

This pattern of collapse occurs when the floor or roof assembly loses its continuity around the surrounding walls and collapses inward

while the central region remains intact.

1.2.5 CANTILEVER COLLAPSE

In a cantilever collapse, one or more of the multi-storey structure's walls fail, leaving the floors dangling from the remaining standing walls. This allows the support for the structure to rely on the remaining walls. This is an extremely dangerous situation, as a progressive collapse could occur in the offing if the remaining wall or walls are not promptly reinforced.

2.0 DESIGN CONSIDERATION

2.1 LIMIT STATE DESIGN PHILOSOPHY

The limit state design philosophy simply defines the condition of a structure beyond which it becomes unserviceable. It is a structural engineering approach that ensures structures remain safe and usable within the limits by evaluating conditions of potential failures. The two common limit state design philosophies are the ultimate limit state and the serviceability limit state. Moreover, the probability-based design technique forms the basis for design principles like the Load and Resistance Factor Design (LRFD) method.

2.1.1 ULTIMATE LIMIT STATE

This limit state ensures that the entire structure or any part of it does not collapse under unforeseeable or overloads. The worst condition of loading may be envisioned and accommodated under this limit state by preventing total or partial collapse. It focuses on the maximum load capacity and structural safety by giving consideration to partial safety factors.

2.1.2 SERVICEABILITY LIMIT STATE

This limit state design condition ensures that a structure remains functional and comfortable to the end users during everyday use. It focuses on the normal use and performance of the structure. The essence is to limit service conditions such as excessive deflection, crack widths, vibrations and other forms of discomforts to the end

users.

The usual approach is to design on the basis of the most critical limit state that describes the behaviour of the structure under consideration. For a reinforced concrete beam for example, the critical limit state is the ultimate limit state. On the other hand, a water retaining structure may consider the serviceability limit state of cracking as the critical limit state. However, once the critical limit state is established, the other limit states must be checked to guarantee overall stability and safety of the structure.

3.0 VIEWPOINTS OF STRUCTURAL FIRE ENGINEERS (SFE)

3.1 FIRE DESIGN OF STRUCTURES

In fire design of structures, it is apparent that the probability that these structures can be extremely affected by the assumed maximum accidental loadings is not remote. The performance of steel beam-column members at elevated temperature has been the subject of topical research projects, which have been investigated both numerically and experimentally (Dwaikat and Kodur, 2011). However, a few that have studied the elevated temperature behaviour of steel structural elements using analytical procedure have actually considered simple structures as it is often difficult to carry out analytical calculations in fire conditions. Fire design of structures has been traditionally evaluated using deterministic techniques where the fire loadings are computed based on the simple models described in Eurocode 3, Part 1-2 (2005).

Currently, a new technique that can fully incorporate the likely uncertainties associated with the loadings and responses of the structural members has begun to gain much popularity. This probabilistic method that is often termed "the stochastic technique" has been used by a few researchers such as Hietaniemi (2007) and Eamon and Jensen (2012) to study the reliability of structures. This approach is found to be useful in evaluating critical response

parameters for fire design of structures.

In recent times, the trend of fire design has begun to move from the long-established prescriptive approach to the more robust performance based approach. Moreover, the traditional prescriptive approach to design is based on individual member analysis to determine the strength and behaviour under various loading conditions. This approach has been effectively applied in the design of most of the existing buildings. In the case of universal beam steel sections, the critical element is recognized to be the bottom flange. Nevertheless, Bailey et al. (1996) maintained that the web can be assumed critical for laterally unrestrained sections, which can often result in lateral-torsional buckling under compressive loadings.

Contemporary experimental and numerical studies have also shown that it is possible to protect only the critical structural members of a structure subjected to fire, such as columns while leaving most of the beams unprotected (Bailey, 2004, Li et al., 2007 and Ufuah et al., 2013). This is based on the assumption that under large displacement the reinforced concrete slab will utilize the inherent tensile membrane action as a carrying-capacity to support the load even when the internal beams have yielded completely (Bailey, 2001). Nevertheless, in circumstances where tensile membrane actions do not exist the behaviour will be such that the slabs would yield completely without any significant reserved strength. Hence, it becomes very paramount to evaluate the behaviour of steel beams under fire conditions.

The material properties of steel at elevated temperatures are required to model the behaviour of structures in fire conditions. When a steel structure is exposed to fire, the temperature of the element will increase from room temperature to a high level, thereby leaving the material to degrade in strength and stiffness. The loss of strength and stiffness at elevated temperature introduces material nonlinearities into the model thus leading to a more complex analysis. In assessing the performance of structures at elevated temperatures, both

mechanical and thermal properties are needed to accurately predict their behaviour. The thermal properties that are of interest to the fire engineer include thermal conductivity, specific heat, thermal strain and thermal expansion. Conversely, the mechanical properties that are of concern to the design engineer include the potential yield strength, the ultimate tensile strength, the strain hardening and the stress-strain curve.

For current design methods within the context of the European Union and allied nations, Eurocodes have been adopted as the standard for prescriptive or codified design of structures. Nevertheless, it is imperative that structural designers acquaint themselves fully with the language of Eurocodes for the effectiveness of harmonization of design procedures. In normal design at the ultimate limit state, serviceability conditions are imposed to control the degree of damage while in fire limit state design such conditions are, however not accounted for. The objective in the case of fire limit state will be to assess the fire resistance of structures and check their deflection requirements in maintaining the integrity of fire-stopping systems and compartment walls. A structural steelwork under accidental (fire) limit state is normally designed to either provide the passive fire protection that can resist fire attack for a known specified duration or to assess the fire resistance without applied fire protection or both. However, certain rules must be satisfied in the design of steel structures to resist fire.

According to Eurocode 3, Part 1-2 (2005), the clauses defining such requirements are divided into principles and application rules. Principles are rules such as definitions, requirements and analytical techniques, which must be strictly followed and satisfied without recourse to alternative means. Application rules are, nonetheless, standard rules which should satisfy the principles and their requirements, though other alternative design rules are permitted with the proviso that it can be shown they satisfy the relevant principles and serviceability conditions (Harmathy, 1981 and Law et al., 2011).

Eurocode 3, Part 1-2 (2005) requires that the strength of steel at elevated temperature should be characterized such that at 550°C a maximum load level of 0.6 will be reserved by the structural steel member. This commonly held assumption is based on the concept of allowable stress design, which was adopted prior to the advent of the limit state design method. In the allowable stress method, the maximum stress allowed was about 60% of its room temperature design strength. Hence, the critical temperature of steel is taken as 550°C for a load level of 60%.

3.2 DESIGN METHODS IN STRUCTURAL FIRE ENGINEERING

Structural fire engineering can be examined from the simple prescriptive based approach to the more complex and accurate performance based approach. Generally, it is a requirement in the analysis and design of buildings that elements of building construction so designed should have adequate load bearing resistance under fire condition. However, in the performance based approach it requires a wide range of expertise and competence to numerically model structures that can predict the real structural behaviour according to Eurocode 3, Part 1-2 (2005).

In fact, the trend of design from the simple, traditional prescriptive approach to the more complex performance based approach involves three logical schemes. The first is the prescriptive based approach referred to as deemed-to-satisfy rules. The second approach may be called the "quasi-performance-based" approach, which is partly prescriptive and partly performance based. The quasi performance based approach addresses a particular phase of the design where the deemed-to-satisfy rules become inefficient with the rest of the design following a prescriptive based approach. The third scheme of the design method is the full performance based approach, in which case every component of the design follows the prescribed definitions of the performance based approach.

Indeed, the prescriptive based approach seems to rely more on design codes that provide standard solutions for given sets of structural components. Conversely, the performance based approach involves the determination of structural fire resistance using more robust tools capable of capturing the actual structural behaviour based on the theoretical models derived from accurate tests data.

However, the conventional structural theory is often modified to account for the mechanical properties of the materials at elevated temperatures so as to develop a realistic approach for modelling structural behaviour under fire conditions (BS 5959-8, 2003). For structural steelwork, a fire protection scheme is a significant part of the design process because of the thermal characteristics and behaviour of steel at elevated temperatures. A fire protection scheme comprises the provision of passive fire protection systems such as generic materials, boards and blankets, sprays and intumescent paints to steel members. A simple model for the performance based fire analysis and design of structures is represented in Fig. 3.

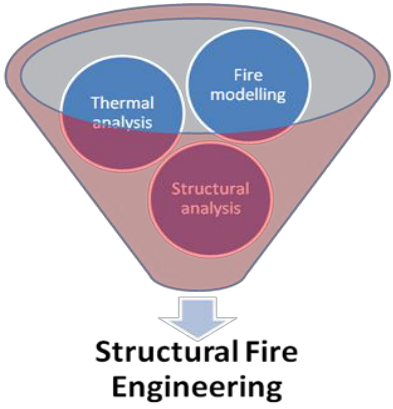


Fig. 3 A model of performance-based method for structural fire analysis and design

3.2.1 PRESCRIPTIVE METHOD

The fire resistance of beams without applied fire protection materials are assessed on the basis of structural stability without consideration made to integrity and insulation. In the case of simple beams the criterion for structural stability at a given load level is that at the end of the fire resistance period the design temperature should not exceed the critical temperature. Hence, the beam will not require any fire protection system, though this approach is only realistic for 30 minutes fire resistance (Eurocode 3, Part 1-2, 2005). This method is also suitable for determining the fire resistance of beam-column members subjected to axial and bending forces.

Furthermore, the prescriptive method specifies the thickness of fire protection to steel members required to ensure a given fire resistance period is achieved. The thickness of fire protection for a given fire resistance period is measured by a suitable parameter called the section factor. A structural member with a high section factor under fire condition will heat up faster than one with a low section factor. The section factor is a measure of the rate at which a steel member will heat up. It is the ratio of the fire exposed surface area (A) of a steel section to the volume (V) of the section (Newman et al., 2000)

3.2.2 PERFORMANCE BASED METHOD

The performance based method is an advanced method of assessing structural performance where the deem-to-satisfy rules of the prescriptive approach become inefficient. It comprises three fundamental components namely the likely fire behaviour, heat transfer to the structure and the structural behaviour. The complexity of the design depends on the extent of simplifications or assumptions and the methods implemented to predict solutions from each of the three design components (Bailey, 2026).

3.2.2.1 FIRE BEHAVIOUR AND MODELLING

Fire modelling forms an integral part of the performance based method in assessing the structural performance in fire. The behaviour of fire in a compartment is different from that in the open. The

modelling of fire behaviour can be considered in several ways depending on the nature and complexity of the fire, the assumptions, type of analysis, amongst others. However, the nominal fire curves are the simplest means to characterize a fire by some arbitrary temperature-time correlations, though they fail to represent as realistic as possible structural configuration, ventilation and boundary conditions. Bailey (2026) maintained that while most research involving experimental testing utilize the concept, the standard fire curves were primarily developed for fire resistance furnace tests of building materials and elements of building construction for the sole aim of defining their fire resistance rating and verification.

The British Standard, BS 476, Part 20 (1987), American Society for Testing and Materials, ASTM E119 (2007) and International Organization for Standardization, ISO 834 (1999) are repositories of the nominal standard fire curves. However, other nominal fire curves may be utilized depending on the nature and type of fire under investigation. A representative standard fire model following the ISO 834 (1999) fire curve is represented in Equation (2), where temperature is expressed in degree Celsius and time is expressed in minutes. The other types of nominal fire curves implemented in fire modelling are defined by the expressions in Equations (3) and (4) as follows (Bailey, 2026):

$$T = T_a + 345 \log_{10}(8t + 1) \qquad 2$$

For external fires, we have the following model expressed in Equation (3).

$$T = T_a + 660(1 - 0.687e^{-0.32t} - 0.313e^{-3.8t}) \qquad 3$$

For hydrocarbon fires, Equation (4) is implemented.

$$T = T_a + 1080(1 - 0.325e^{-0.167t} - 0.675e^{-2.5t}) \qquad 4$$

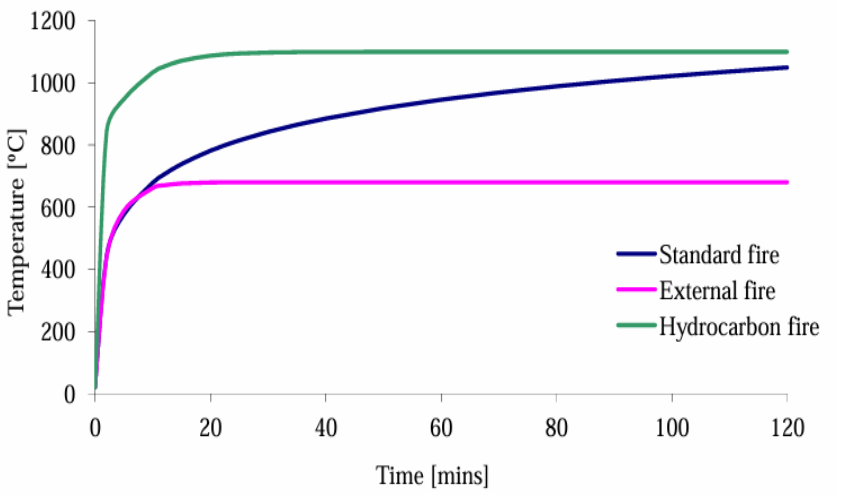


Fig. 4 Time-temperature curves for some selected nominal fires

The parametric fire models are relatively simple design formulae used to estimate the fully developed compartment fire. Since a parametric fire is assessed as post-flashover fire the temperature distribution within the compartment is assumed to be uniform. A parametric fire curve considers the compartment size, fuel load, ventilation conditions and the thermal properties of compartment walls, floors and ceilings. Parametric fires will give more practical estimates of the fire severity for a given compartment than those of standard fires and time-equivalence fires (Lawson and Newman, 1996).

The computational fluid dynamics fire model, often known as CFD fire model, is the most accurate and sophisticated fire modelling method that predicts fire growth and compartment temperatures. CFD models are complex computer procedures that can accurately model fires and the temperature distribution within the fire compartment. They are more practical in modelling all stages of fires in complex geometries such as the non-uniform fire scenarios in pre-flashover and localized fires. In modelling fires with the computational fluid dynamics approach, experience and competence

are adjudged requisite requirements. A comprehensive representative description of fire load modelling is shown in Fig. 5.

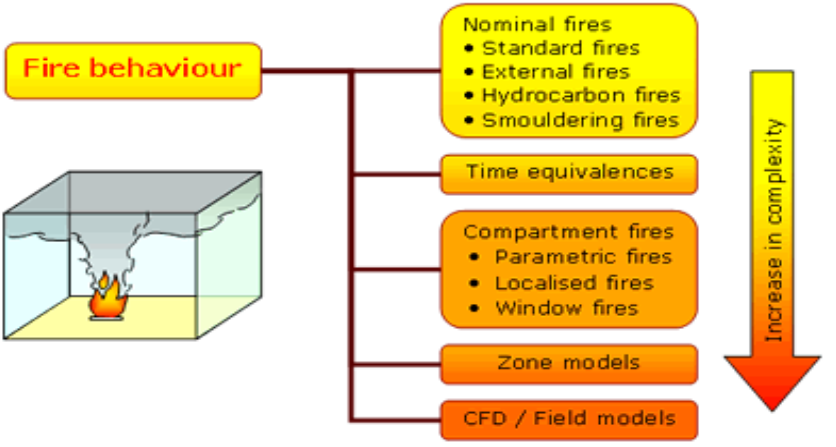


Fig. 5 Performance Base Fire Modelling

Generally, in the limit state definition for fire design of structure, safety of structures is guaranteed when:

$$\sum \gamma_f E \leq \frac{R}{\gamma_M} \qquad 5$$

Where $_f\gamma$ and $_M\gamma$ are the partial safety factors on actions (E) and materials (R) respectively.

Furthermore, the design values of actions, E_d considers the possible load combinations and the resultant effect can then be determined accordingly (Eurocode 3, Part 1-2, 2005, Lawson and Newman, 1996). Therefore, at the ultimate limit state the design value of the actions is:

$$E_d = \gamma_G G_d + \gamma_Q Q_{k,1} + \psi_0 \gamma_Q Q_{k,2} \qquad 6$$

However, at the fire limit state the partial safety factors for permanent and variable actions are put to unity to account for the likelihood of reduced loading in the event of a fire thereby leading to the design value of the actions adjusted as follows:

$$E_{f_i,d,t} = G_d + \psi_1 Q_{k,1} + \psi_2 Q_{k,2} \qquad 7$$

Where $_0\psi$, $_1\psi$, and $_2\psi$ are load combination factors depending on the limit state under consideration, and $_G\gamma$ and $_Q\gamma$ are the individual partial safety factors for permanent (dead) and variable (live) loads respectively.

Meanwhile, the formulation for the design value of the actions at the fire limit state is somewhat similar to that at the serviceability limit state in that the actual service actions in both cases are taken into account. In fact, there is a further reduction in the design value of the actions at the fire limit state by imposing a reduced load combination factor on the variable loads. This reflects the low probability of occurrence of extreme or accidental loading needed to cause structural collapse. Indeed, a parameter that determines the proportion of a member resistance to loading at elevated temperatures is often utilized in structural fire design to account for the degraded material strengthHence, load level at exposure time in fire condition can be expressed in Equation (8)

$$\eta_{fi,t} = \frac{E_{f,d,t}}{R_d} = k_{y,\theta}\left\lceil \frac{\gamma_M}{\gamma_{M,fi}} \right\rfloor \leq \frac{R_{f,d,t}}{R_d} \qquad 8$$

where $\eta_{f,t}$ is load level at exposure time in fire conditions, $E_{f,d,t}$ is the actions effect at the fire limit state, R_d is the design value of resistance, γ_M is the partial safety factor on material, $\gamma_{M,fi}$ is the partial safety factor on material in fire conditions, $k_{y,\theta}$ is the reduction factor for effective yield.

A structure under fire may fail following the collapse of some structural parts or because of the instability of the entire structure as a result of degradation in strength and stiffness of the material. The designer should, therefore, consider the robustness of the structure such that the removal or failure of any critical supports or members does not result in progressive collapse of the structure (McGrattan et al., 2000).

3.2.2.2 THERMALANALYSIS

Thermal analysis in elements of building construction is an area in engineering science that describes the transfer of thermal energy between material bodies as a result of temperature difference. The thermal energy will generally move from a hotter domain to a cooler domain. However, there are three mechanisms by which this phenomenon can take place, namely conduction, convection and radiation. Conduction refers to heat transfer within the elements of structure whereas convection and radiation refer to heat transfer across boundaries from the fires into the elements of construction. Needless to emphasize is the fact that while conduction and convection depend on material media to transfer heat, radiation does not require any medium to allow heat movement from one place to another.

The conductive thermal exchange is analyzed directly by computer programs while implementing the finite element procedures such as those encrypted in the ABAQUS analysis software. However, the analysis requires a transport property known as thermal conductivity, which is a material property of the element. The convective heat transfer, on the other hand, occurs due to the eddy motion of a fluid at a non-uniform temperature due to variation in the specific weight of the fluid at this condition. Similarly, radiation heat transfer analysis may require additional techniques to determine the radiant energy falling on the surface of the structural component.

Conversely, heat transfer can be particularly difficult for materials in which moisture content is an influencing parameter with consequent low thermal conductivity. Heat conduction can be defined as the quantity of heat that transits in unit time through a thickness in a direction orthogonal to a surface of area due to a temperature difference. This results in a temperature gradient allowing heat transfer to occur in the direction of decreasing temperature (SCI, 2009). For heat conduction, the above phenomenon follows the rate equation which is known as the Fourier's law and is represented in Equation (9).

$$q'_{cond} = \frac{-kAdT}{dx} \qquad 9$$

Where q'_{cond} is the rate of thermal conduction (W or Js^{-1}) through a body of thickness, dx in the direction x perpendicular to the direction of transfer.

The Fourier's law can also be more appropriately represented in terms of heat flux density to dimensionally capture the phenomena of convective and radiative heat fluxes as shown in Equation (10). The heat rate by conduction equals the heat flux multiplied by the area of the material across which heat is transferred.

$$q''_{cond} = \frac{-kdT}{L} \qquad 10$$

Where q'' is the heat transfer rate in the x direction per unit area (A) orthogonal to the direction of transfer. The quantity dT/L is known as the temperature gradient, which is always proportional to the heat flux density. The constant of proportionality, k is a transport material property known as the thermal conductivity (W/m.K).

The modelling of heat transfer involves the application of heat energy to a surface. Obviously, the transient temperature field shows both temporal and spatial variations in which the three mechanisms of heat transfer are involved. However, the thermal conductivity value of steel does not show significant spatial variation so that a homogeneous thermal conductivity *k* can be adopted as follows:

$$k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) + Q(x,y,z,t) - \rho c \frac{\partial T}{\partial t}(x,y,z,t) = 0 \qquad 11$$

The correct boundary conditions necessary to solve Equation (11) relate to initial temperature *T*, internal heat generation $Q = f(q)$ and heat fluxes q_r as given in Equations (12) and (13).

$$T(x,y,z,t=0) = T_0(x,y,z) \qquad 12$$

$$k(\frac{\partial T}{\partial x}N_x + \frac{\partial T}{\partial y}N_y + \frac{\partial T}{\partial z}N_z) + q(x,y,z,t) + h_c(T_s - T_\infty) + \sigma\varepsilon VF(T_s^4 - T_f^4) \qquad 13$$

where T is the current temperature, $Q(x,y,z,t)$ is the rate of internal heat generation, t is the time, ρ is the density and c is the specific heat; N_x, N_y *and* N_z are the direction cosines orthogonal to the boundary surface, h_c is the film coefficient, T_s is the surface temperature assumed uniform through the thickness, T_f is the fire temperature, T_∞ is the temperature of the surrounding medium, ε is the surface emissivity of the material, σ is the Stefan Boltzmann constant (= $5.667 \times 10^{-8} Wm^{-2}K^{-4}$) and VF is the configuration factor.

3.2.2.3 STRUCTURALANALYSIS

This component of the performance based design in itself considers the mechanical loading imposed on structures and its effect on structural behaviour. Basically, structural analysis and design can be carried out at ambient conditions and the solutions envisioned based on the assumptions that small variations occur in material and geometrical properties, which can be neglected. However, in the event of a fire these simplifying assumptions no longer hold thereby presenting challenging options to the structural fire engineer. It may be more challenging than simply incorporating into the design the material reduction factors that regularize the reduced strengths at elevated temperatures. For instance, in localized regions within a structural assembly such as connections, a more rigorous methodology is required in order to capture the actual structural behaviour in fire (Qian et al., 2009).

The material model often adopted in the analysis of steel structures is assumed to follow the von Mises yield criterion and the associated flow rule (Teng et al., 2003). Isotropic bilinear (elastic-perfectly plastic) stress-strain curve with isotropic or kinematic hardening is

utilized in most calculations. According to Brickstad and Josefson (1998), the kinematic strain hardening model is assumed to be most suitable in simulating time-independent plasticity. The well-known Newton-Raphson method is used to estimate the incremental stress in nonlinear elasto-plastic problems. The validity of the mechanical analysis will, however, depend on the accuracy of the solution to the thermal problem. The transient heat transfer problem is, therefore, considered critical in the finite element algorithm for the prediction of residual stresses and strains. Depending on whether second order effects are considered in the analysis, the following algorithms can be implemented (Eurocode 3, Part 1-2, 2005):

1) First order linear-elastic analysis with redistribution;
2) First order non-linear analysis;
3) Second order linear-elastic analysis and
4) Second order non-linear analysis.

First order non-linear analysis is implemented in one of the following ways, namely elasto-perfectly plastic, elasto-plastic or rigid plastic. On the other hand, second order non-linear analysis is either elasto-perfectly plastic or elasto-plastic. The equilibrium equation and the corresponding constitutive model that have been used to determine the mechanical strength and performance of structures are respectively given in Equations (14) and (15) as follows (Ufuah et al., 2013).

$$\sigma_i = \mathrm{E}\varepsilon_i \qquad 14$$

$$\{\Delta\sigma\} = \{D^{ep}\}[B]\{\Delta U_e\} - \{C^{th}\}[M]\{\Delta T_e\} \qquad 15$$

where σ_i is a stress tensor, E is the flexural stiffness, ε_i is strain, $\Delta\sigma$ is the incremental stress, D^{ep} is the elasto-plastic stiffness, B is strain-displacement relation, U_e is nodal displacement, C^{th} is thermal stiffness, M is temperature shape function and ΔT_e is nodal incremental temperature

In non-linear stress problems, the variation in stiffness beyond the elastic regime necessitates iterative means in the calculation

procedure. As earlier mentioned, most analysis codes adopt the Newton-Raphson approach to incrementally solve the resulting differential equations.

4.0 SOME OF MY RESEARCH CONTRIBUTIONS

My research contributions to knowledge focus on both ambient and fire design of structures. The knowledge of the behaviour of structures in fire condition is paramount to enable safety of personnel and installations under accidental loading conditions. The ultimate and serviceability limit state philosophies become insufficient to understand the behaviour of structures subjected to accidental actions. Therefore, the accidental limit state philosophy becomes necessary to assist in unravelling the intricacies associated with this category of loadings.

Typically, the behaviour of a reinforced concrete slab supporting lateral or transverse loads is practically seen to develop out-of-plane deflection whereby the concrete in the tension zone cracks and the reinforcement in this zone is extended. As the load is further increased, more cracks in the slab will occur leaving the concrete to lose its compressive capacity. Redistribution of loads takes place within the reinforced concrete section and the reinforcements are made to sustain the load. This mechanism is known as membrane action. To understand this phenomenon, I conducted a numerical study which demonstrated that at large deflections, the carrying-capacity of thin reinforced concrete slabs can be enhanced due to tensile membrane action. The mechanism for tensile membrane action is shown in Fig. 6.

For horizontally restrained slabs, I discovered that the carrying-capacity of the slab is over 4 times the collapse load. In a similar trend, the available deflection in horizontally restrained slabs was found to be more than 3 times the maximum deflection for the case of horizontally unrestrained slabs (Ufuah, 2017). The stress profile for the reinforced concrete slab is shown in Fig. 7 while the material and geometric descriptions for the stress pattern implemented in my

analysis is shown in Fig. 8.

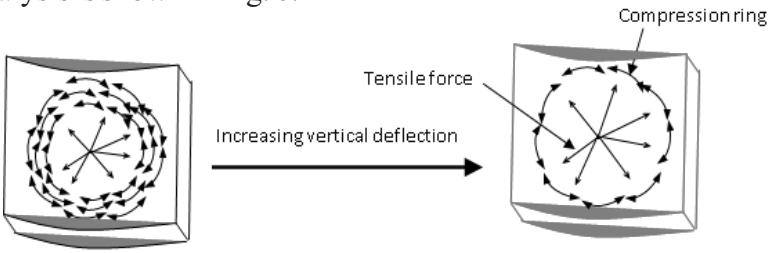


Fig. 6 Tensile membrane action mechanism in thin reinforced concrete slabs

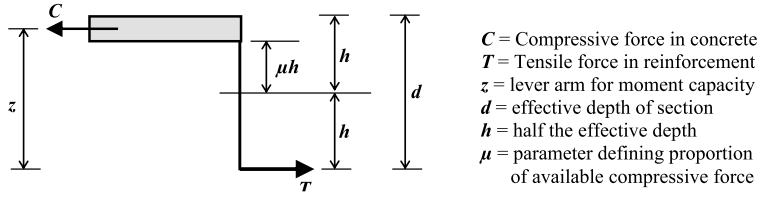


Fig. 7 Stress profile for the reinforced concrete slab

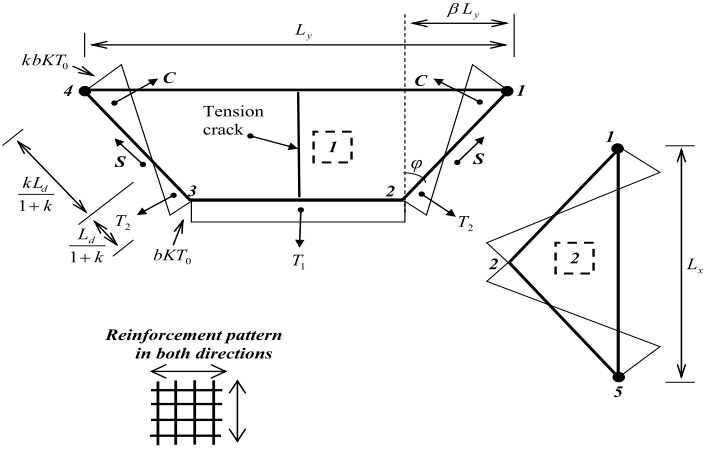


Fig. 8 Material and geometric descriptions showing the in-plane stress distribution, in-plane forces and dimensions for stress pattern (Bailey and Toh 2007)

The various symbols used in the analysis are defined as follows:
C = Compressive force induced near the edges
T_1= Tensile force in element 1
T_2= Tensile force in element 2
T_0= Force in steel per unit width in the longer span
k = Parameter defining magnitude of membrane force
β = Parameter defining yield-line pattern
L_x = Short span
L_y = Longer span
KT_0 = Force in steel per unit width in the short span
φ = Angle defining yield-line pattern
S = Shear force parallel to the yield
L_d = Length of the diagonal yield-line
b = Parameter defining magnitude of membrane force
λ = Parameter defining extent of central tensile membrane force

The in-plane tensile and compressive forces induced in the slabs can be determined by multiplying the appropriate force per unit width with the corresponding length of crack or yield-line. Thus,

$$T_1 = bKT_0 * (1-2\beta)L_y \qquad 16$$

$$T_2 = \frac{bKT_0}{2(1+k)} L_d \qquad 17$$

$$C = \frac{k^2 bKT_0}{2(1+k)} L_d \qquad 18$$

$$L_d = \sqrt{\left(\beta^2 L_y^2 + L_x^2 / 4\right)} \qquad 19$$

In Nigeria today, quacks have infiltrated the construction industry giving rise to incessant structural collapses. One of the common construction errors is misalignment of structural members such as beam-column interface. Eccentric loadings are principally known to induce bending stresses in compression members, which results in unexpected instability before reaching its deformation and load-carrying capacities. Buckling of framed and plated structures has

been a great concern that researchers try to handle over the past decades. In most developing nations such as ours, fewer or no experimental trials are available to obtain requisite information for the proper understanding of this phenomenon.

It is on this premise that I conducted a preliminary study to numerically evaluate the buckling of steel columns under eccentric loadings. To achieve this, I performed a static, linear perturbation analysis on a pin-ended steel column using the subspace Eigen solver for the different buckled mode shapes to illustrate the likely behaviour of the column when subjected to compressive actions. Then, the static, general analysis was conducted with the column subjected to varying magnitudes of eccentric loadings. I discovered that 10 % of the Euler's critical buckling load can alter the stiffness of the column when loaded eccentrically. I further observed that the steel column finally failed at a load greater than 20 % of the Euler's critical buckling load and 40.1% of Rankine's critical buckling load (Ufuah, 2021). The stress-strain curve of Fig. 9 describes the mechanical properties of steel used in modelling the column. The elastic constant was 200 GPa while the yield value was 460 MPa. Fig. 10 shows the loading and boundary conditions implemented in the analysis.

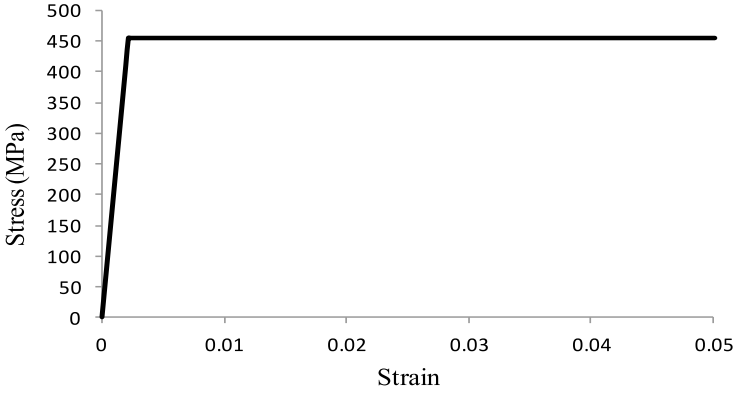


Fig. 9 Stress-strain curve for carbon steel

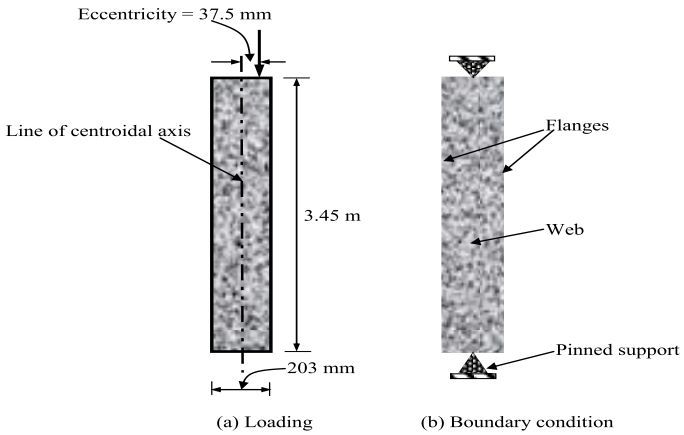


Fig. 10 Two dimensional represention of loading and boundary conditions of the column

The conventional prescriptive method applied to fire design of structures has become obsolete and does not essentially represent the real behaviour of structures when subjected to thermo-mechanical actions. To demonstrate the application of performance-based approach to steel-framed assembly, I numerically examined the effect of fire type on the response of steel structure by identifying the most critical thermal loading from a selection of fire types to enable the most economic and efficient fire design of structures (Ufuah, 2014). The elevated temperature mechanical properties were characterized using the model of Fig. 11 as described in Eurocode 3, part 1-2 (2005). The two-dimensional steel-framed structure previously analyzed by Bailey et *al.* (1996) is shown in Fig. 12. It comprises internal beams of sizes 610 x 229 x 101UB and columns of sizes 254 x 254 x 132UC, with the connections assumed to be rigid and the entire structural assembly restrained horizontally. The beams were subjected to a load level of 0.6 whereas the internal columns in the fire affected region were subjected to a load level of 0.45. The external columns were loaded with point loads of 475.2 kN each while the internal columns were made to resist 950.4 kN as shown in Fig. 12.

The columns were assumed to remain at room temperature and the beams under consideration were heated with the top flanges having 80% of the web and bottom flange temperatures. The room temperature yield strength and modulus of elasticity used were 275 MPa and 210GPa respectively. The thermal properties adopted in my study are as described in Eurocode 3, Part 1-2 (2005).

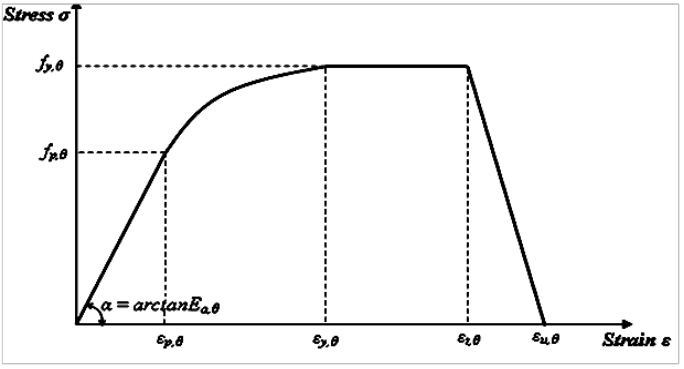


Fig. 11 Stress-strain model for carbon steel

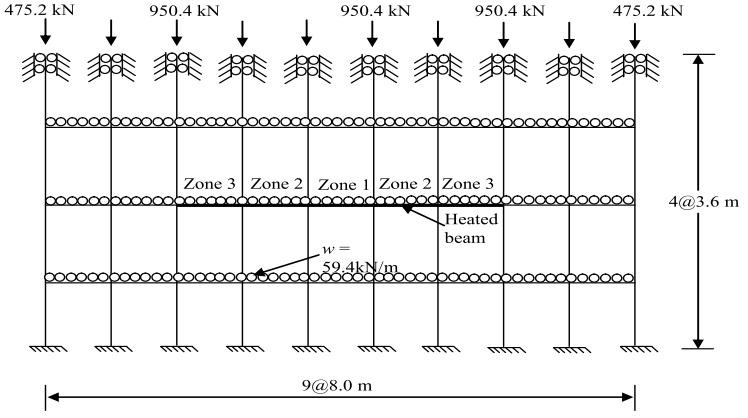


Fig. 12 Two-dimensional frame structure under travelling fire

What is more worrisome is that the correct batching of concrete mix in most construction sites is hardly ever practiced. Therefore, it was

necessary to determine the effect of changes in the volume of coarse aggregate and water-cement ratio on the compressive strength of concrete. It was established that by reducing the volume of coarse aggregate in the mix, the compressive strength can still be enhanced whereas an increase in the volume of water used will result in loss of the compressive strength (Ufuah, 2017).

The high cost associated with experimental works has limited a lot of research activities. However, the Box-Cox transformation regression analysis is currently being employed to circumvent the rigor of experimental trials. For that reason, Iyeke and Ufuah (2021) carried out a study which shows that the variations of compressive index with liquid limit can be represented by a cubic power transformation law. This model is useful during preliminary design stage of site investigation and validation of laboratory test results.

In fire design of structures it is necessary to provide active and passive fire protection materials to enhance the fire resistance period in the event of a fire. These fire protection materials are costly. Therefore, economic fire protection systems applied to structural steels are essential to permit safe evacuation of personnel in the event of an accidental fire. On the basis of this, we conducted a numerical investigation that provides a cost effective scheme whereby the bottom flange of a structural steel may be protected while leaving the web and top flange unprotected (Ufuah et al., 2013). This shows that it is not necessary to protect the entire element against fire attack thereby saving cost and providing a guide to fire design of structures requiring passive protection systems. The thermal and mechanical properties of carbon steel used in our study are presented in Figs. 13-15. The deflection profiles of the beam investigated are shown in Figs. 16 and 17.

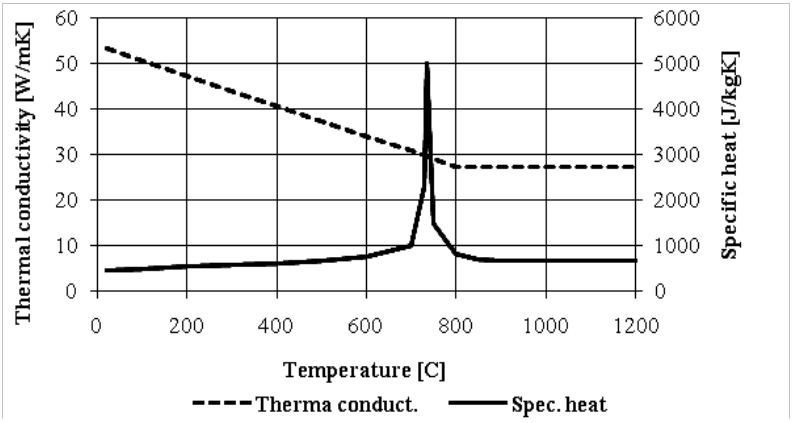


Fig. 13 High temperature thermal properties of carbon steel

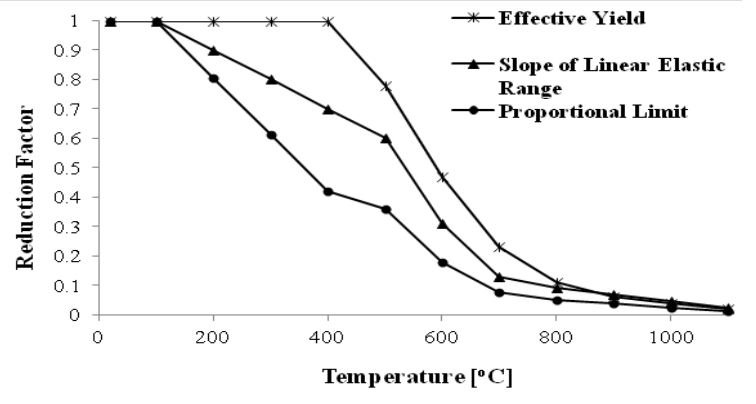


Fig. 14 Mechanical properties reduction factors for carbon steel at elevated temperatures

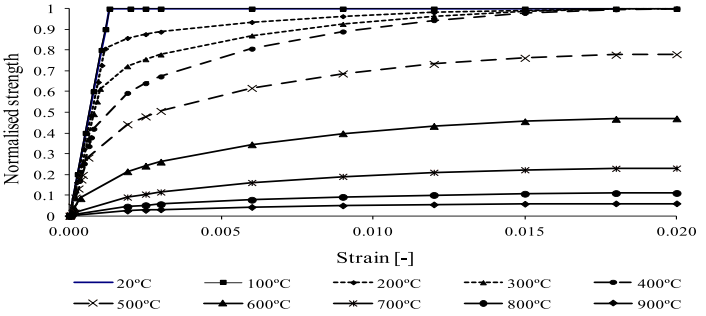


Fig. 15 Stress-strain-temperature curves for carbon steel

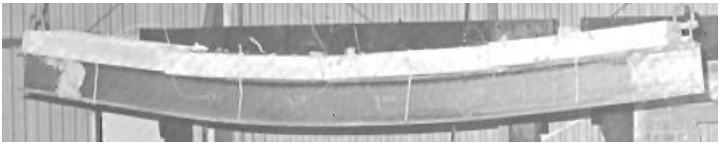


Fig. 16 A 4.5 m long beam tested at the Warrington Research Laboratory (Wainman and Kirby, 1988)

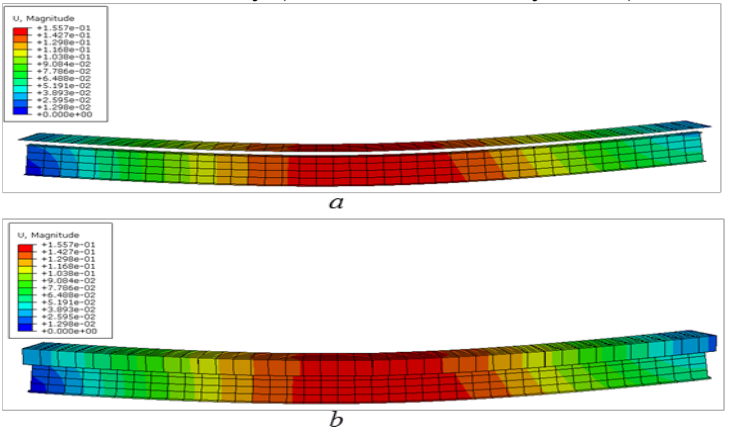


Fig. 17 Deflection profile for the numerical calculation of test beam 1 (*a*) Shell element (b) Rendered shell element thickness

In the offshore environments accidental actions are likely due to the hazardous nature of activities. The probability of occurrence of explosion and fire may be remote. However, our work demonstrates

that in an event of accidental loadings, an initial blast can alter the behaviour of the steel deck coupled with the degradation of strength and stiffness of structural steels at elevated temperatures. We discovered that spreading fires can have major implications on the integrity of welded connections (Ufuah and Tashok, 2013).

Fire design of structures emphasizes that requirements for strength, stiffness and robustness are satisfied to ensure safety of personnel and installations. In our investigation, we discovered that the current design methodology described in Eurocodes 3 for fire design of connections is misleading, and therefore cannot be applied to model welded connections made with high strength steels (Ufuah & Ikhayere, 2013). The experimental programme adopted the steady state and transient tensile test methods.

Tensile tests were conducted on coupon specimens of high strength steel grade S420M for Butt-welds to determine the mechanical properties at elevated temperatures. It was discovered that Butt-welded connections in fire will begin to degrade in strength at a temperature above 100^{o}C as against the 400^{o}C described in Eurocodes 3. Hence, strength and stiffness reduction factors for Butt-welds made with high strength steel grade S420M were established. The indication is that the strength factors defined in Eurocode 3 are not applicable to steel grade S420M, and therefore should not be used to model welded connections in this class of steel (Ufuah, 2012b). Consequently, the design methodology defined in Eurocodes 3 for fire design of connections needs to be revised. An elevated temperature tensile testing device was used to study and measure the load-deflection and stress-strain data from the test coupons.

The test setup is an Instron electromechanical testing system with a load capacity of 250 kN as shown in Fig. 18. The high temperature extensometer was fitted internally to the specimen and supported by a string as shown in Fig. 19. The design of the test specimens was carried out in accordance with BS EN ISO 6892, Part 1 (2009). A typical test specimen showing the section dimensions is illustrated in

Fig. 20. Adequate care and precaution were ensured during welding to eliminate the possibility of fluxes remaining following each welding run. The un-machined test specimens that were cut out of a typical test piece for the transverse test are shown in Fig. 21 while the machined specimens are shown in Fig. 22.

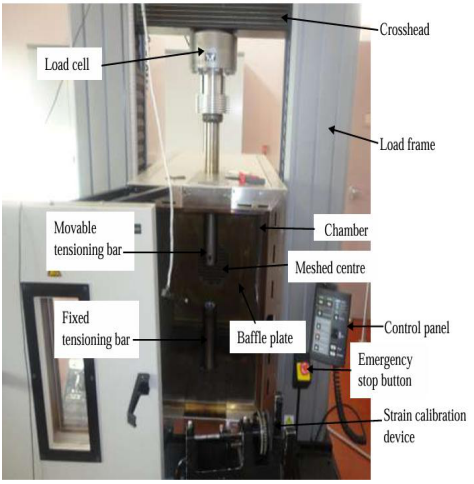


Fig. 18 Elevated temperature tensile testing device

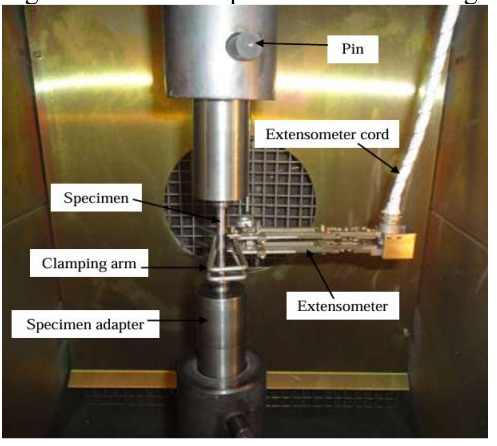


Fig. 19 Test specimen arrangement when using high-temperature extensometer

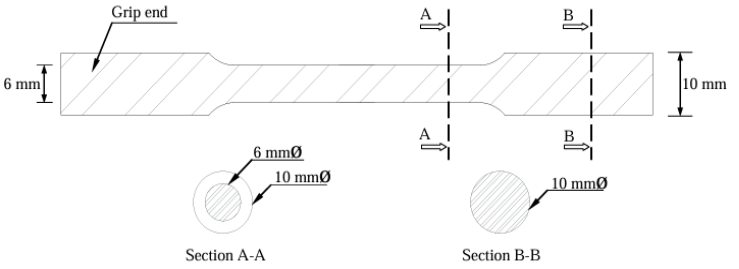


Fig. 20 Typical test specimen showing sections dimensions



Fig. 21 Un-machined transverse test specimens for the base-weld metal joint



Fig. 22 Machined transverse test specimens

A large scale fire experiment conducted at the Health and Safety Laboratory, UK revealed that structural integrity of unprotected steel-plated deck may not be achieved within the fire resistance period. It was noted that unconfined pool fires can induce alternating tension and compression in the deck thereby resulting in possible cracks in the welded connections. Consequently, I decided to investigate if spreading fires that ensue from the unconfined pool fire can induce forces that cause crack in the welded connections. It was demonstrated that slenderness ratios for plate and stiffener web can notably affect the axial and deformation capacities of a stiffened steel-plated deck subjected to unconfined pool fires (Ufuah, 2012a).

The fundamental subject of fire research with problems involving hydrocarbon pool fires focuses on thermal radiation from the flame surface. Smoke obscuration and pool fire size are parameters of influence. The object is to establish the temperature and heat flux profiles, and assess the hazard consequences that may arise from these fire actions. Our investigation (Ufuah and Bailey, 2011), therefore, provides a correlation for the surface emissive power of flame based on observed data taken from five (5) different experimental studies. The thermal radiation models implemented in our study are shown in Fig. 23 and the shape factor between the flame source and the target was determined from Equation (20).

$$F_{12} = \iint_S \frac{\cos\theta_1 \cos\theta_2}{\pi R^2} dA_1 \qquad 20$$

where $_1\theta$ and $_2\theta$ are the angles between the normal to the surfaces and the line of sight for the emitter and the receiver respectively, R = distance between the flame source and the target along the line of sight, dA_1 is the elemental surface area of the emitter viewed by the receiver.

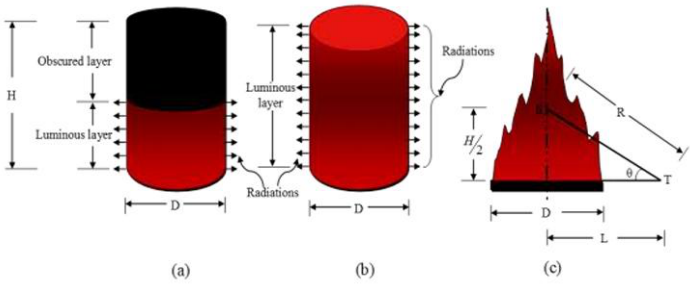


Fig. 23 Pool fire thermal radiation models (a) modified cylindrical flame model (b) classical cylindrical flame model (c) point source model

The model we developed (Ufuah and Bailey, 2011) is shown in Equation (21), and it provides a better prediction for liquefied natural gas and aviation fuels as shown in Fig. 24. Most building constructions incorporate simple beam-column members designed to carry both axial and flexural loadings. These elements can exhibit different behaviour under fire conditions. Large displacements are often experienced by these elements when subjected to elevated temperatures making the analysis to become more nonlinear. On the basis of this, I carried out a performance based thermal and structural analyses of simple beams carrying non-structural concrete slabs. Consequently, I developed numerical as well as simple theoretical models, and a comparison was made using the experimental results from tests conducted at the Warrington Research Centre, UK (Wainman and Kirby, 1988; Ufuah, 2011). The computed maximum coefficients of variation (COV) of about 2% and 6%, are achieved for mid-span deflection and temperature distribution respectively, demonstrates that the numerical model and trial results are in good agreement.

Moreover, correlation coefficients of 99% can be achieved by implementing the theoretical models in predicting the deformation behaviour of the beams. Since experimental studies are normally difficult to execute due to high cost of requisite facilities, the findings

in my work provides accurate numerical and semi-empirical models that can predict the deformation capacity of a structural steel beam subjected to thermo-mechanical loadings. It is shown here that due to spatial and temporal variations associated with trials conducted at different times and locations on free-burning pool fires, model predictions for surface emissive power of flame can be very different.

The result above highlights the need to exclusively utilize a given methodology, which gives a clear description of all sub-models used in the derivation of surface emissive powers of free-burning hydrocarbon pool fires. It is noted that the significance of thermal radiation model also broadens the means by which the acceptable separation distances between radiation source and targets –people and structures can be determined. Hence, a new and semi-empirical model was developed to enable the prediction of surface emissive power of flames that can likely impinge on surfaces of structures.

$$SEP = 70 * \exp(-kD) \qquad 21$$

Where k = average flame extinction coefficient, 0.00165m^{-1}. D = equivalent fire diameter, m

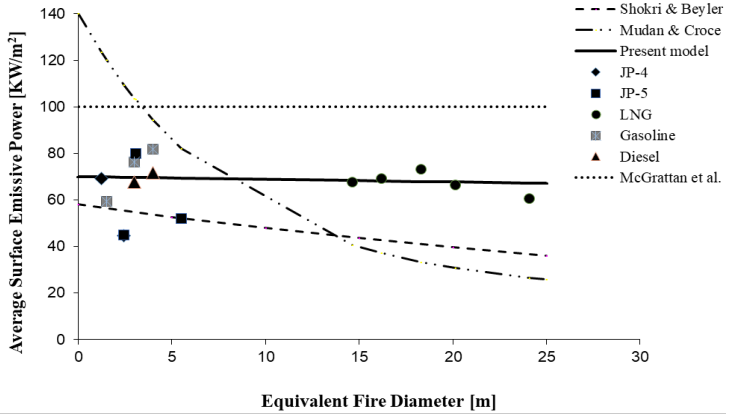


Fig. 24 Surface emissive power models as a function of fire diameter

4.1 STOCHASTIC INTERPRETATION OF (FIG 1)

Buildings have incessantly collapsed over the years with the attendant loss of lives and properties. Despite the fact that different studies have revealed the causes and offered possible remedies, there are still cases of building collapse. Consequently, it is important to have the knowledge of the mechanisms of structural collapse. It is noted that loads and resistance of a structure are associated with some uncertainties and therefore change with time. The conventional deterministic approach may not exactly represent the behaviour of the structure. A more realistic method that can access the variability in the random variables is the stochastic analysis. Therefore, reliability analysis of the existing structures should be carried out to access the probability of failure. This can circumvent any impending collapse of these structures.

As a preliminary analysis, data for the number of collapsed buildings from 2000 to 2021 were obtained from literature to determine the likely number of building collapse in any given year. The Monte Carlo simulation technique was adopted. To do this, the expected value (mean) and standard deviation of the total number of collapsed buildings shown in Fig. 1 were determined to be 7.59 and 4.30 respectively. To implement the Monte Carlo simulation technique, ten thousand random numbers were generated in Excel spreadsheet and the probability of occurrence of building collapse in any particular year was computed accordingly. The probability of occurrence of building collapse in Lagos State is therefore depicted in Table 1 and Fig. 25. A fifth degree polynomial depicted in Equation (22) is used to represent the stochastic analysis of Fig. 1 based on the results obtained using the Monte Carlo simulation method.

$$N_{CB} = 7*10^{-10}X^6 - 2*10^{-7}X^5 + 3*10^{-5}X^4 - 0.0018X^3 + 0.0552X^2 - 0.9474X + 18.382 \quad (22)$$

Where N_{CB} is the expected number of collapsed buildings in any particular year, X is the probability that collapse will occur (in percentage).

Table 1 Results of Monte Carlo simulation of collapsed buildings in Lagos (2000-2021)

No. of collapsed buildings	1	2	3	4	5	6	7	8	9
Probability of occurrence (%)	94	91	86	80	73	65	56	47	38
No. of collapsed buildings	10	11	12	13	14	15	16	17	18	19
Probability of occurrence (%)	29	22	16	11	7	4	2	1	1	0

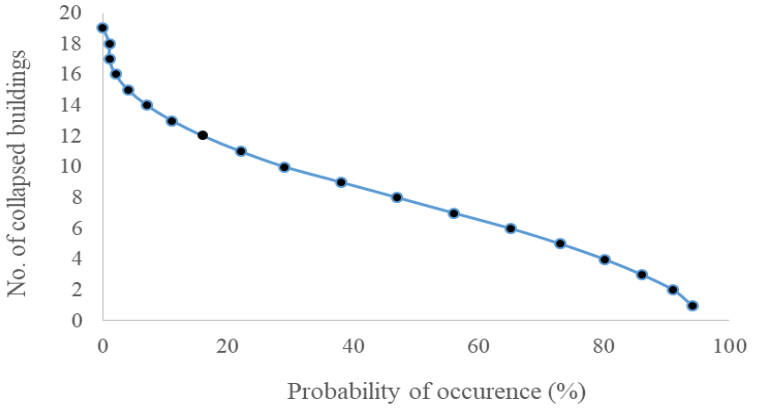


Fig. 25 Building collapse projection in Lagos State in any particular year based on risk analysis

The different types and classification of steel cross sections, various failure mechanisms and a number of structural collapse examples are presented in the appendices.

5.0 THE PARADOX OF ENGINEERING TRAINING AND PRACTICE IN NIGERIA

The paradox of engineering training and practice in Nigeria simply represents the logical inconsistency that exists between the vast majority of highly trained, intelligent and qualified engineers in the country and its scientific, infrastructural and technological underdevelopment. There is a pain in my heart that as a country, we speak with our tongues in the cheek. The much touted outcome-based education (OBE) in engineering that is currently trending in our institutions is theoretically powerful and fundamentally lacking in implementation. Non-linkage between industries and academia in engineering practice is a bane militating against technological development in Nigeria. The poor implementation of policies is also a major evil that must be surmounted without compromise.

I have sat down a number of times to cogitate and cudgel my brain. I realize one recurring trend in engineering training in Nigeria. We teach fantastic topics in the classroom without adequate pragmatic follow-up. This inadequacy has become a systemic error that appears like a virus in the Nigerian university system. The basic laboratory and workshop facilities and equipment required for learning are either obsolete or nonfunctional. For instance, most of the installations in our laboratories are incomplete to permit their proper utilization for effective learning. This is one reason our unions embark on strikes to drive home their demands in drawing the attention of the government and relevant agencies to these inadequacies. It is obvious that the population size of engineering graduates that have the opportunity to learn practical skills on the job is highly insignificant. Those that have the opportunity to undergo training overseas know very well that in engineering, teaching without adequate practical research is only a mirage in its own sense. It is glaring that the educational institutions and research centers in Nigeria lack modern laboratories and equipment required for training future engineers.

There is no gainsaying that teaching can impart knowledge and trigger innovation among students. Unfortunately, these innovative ideas are only imaginary in the mind. A few Nigerians who are fortunate or privileged to have access to practical research exposition are making waves in their respective fields. However, some promote the claim that teaching without conducting active academic research can still drive development. Of course, this assertion is true. In engineering, this practice only imparts knowledge of existing technology and drives innovative ideas that cannot readily transform into reality that brings about meaningful development. This school of thought argues that while research is essential for innovation and expanding the boundaries of knowledge, high-quality teaching, even in the absence of original research, can foster development through the dissemination of existing knowledge. This approach often leads to a different type of development compared with research-based training. The expectation of scientific and technological development in such climes is better imagined than otherwise.

Despite a strong academic base, engineering practice in Nigeria is plagued by proliferation of quacks in the construction industries, reliance on foreign expertise for critical infrastructure and failure to turn engineering knowledge and skills into economic development. Nigerian engineering education places more emphasis on theory, leaving graduate with limited hands-on, practical knowledge. The very weak Industry-Academia linkage creates a skills gap and hinders the ability to apply academic knowledge to solving real-world problems. Similarly, in spite of available local talents, major government projects are undertaken by foreign firms thereby limiting the growth of local content in the construction industry.

The non-key actors in engineering are empowered to undertake critical engineering projects. This is possible through political manipulation and influence. The engineering profession is inundated with impostors and quacks who use fake engineering credentials to secure contracts, thereby leading to poor infrastructure and building failure. Even more perturbing is the case where highly qualified

Nigerian engineers are often supervised by foreign technicians assumed to possess more practical competence. This is a high degree aberration that must be corrected.

The limited interaction between the universities and industries creates an extensive gap that inhibits the ability to apply academic knowledge to practical engineering problems. There is also this lack of focus on specific and advanced engineering applications whereby engineers are commissioned to handle projects that are outside their scopes. Quackery and lack of effective regulatory and institutional policies have also contributed to the rampant incidences of structural collapse. A major challenge is the lack of reliable workplace policies and rights for engineers. The brain-drain syndrome has permeated the nation's engineering workforce as qualified engineers often relocate to countries with better enabling environments and standard of living.

6.0 THE WAY FORWARD AND CONCLUSION

Structural collapse is the end result of structural failure. The panacea to this structural quagmire is embedded in proper implementation of policies that guide the construction industry. An advocacy to ensure this vision and expectation come to fruition must be driven with sincerity of purpose. We have to effectively harness the knowledge garnered from training by promoting and enforcing academia-industry-government linkage in the curricula. Standardized workplace policies and protections for engineers should be instituted.

Educational institutions and research establishments should have their laboratories and ICT center equipped with state-of-the-art facilities for effective training of our future engineers. Good remuneration and incentive should be given to highly talented and qualified engineers to discourage them from emigrating thereby limiting the effect of brain-drain syndrome. An effective maintenance culture with emphasis on “build and sustain” should be promoted to enhance sustainable development of infrastructure rather than “build and abandon”. Research and Development investment strategies should be encouraged by defraying sufficient fund for research and

development that have the propensity to bring about meaningful innovation and technological advancement.

The current drive for OBE in engineering is fundamental since the emphasis is now on what the students are able to garner from the training. Practical skills, project-based training, real-world simulation via computer applications and emerging technologies like machine learning/artificial intelligence (AI) must be fully captured in the curriculum. However, the integration of AI into the curricula should be regulated to avoid dwindling of mental sagacity. The government should fulfill its obligation by providing facilities and the enabling environment.

COREN should be strengthened to be able to combat quackery, maintain professional standards and implement stricter local content laws and policies that promote the prioritization of Nigerian engineers in project execution. COREN should promote the establishment of functional partnership between universities and industries to be able to realize our objective of bridging the practical skills gap. To reduce structural collapse to as low as reasonably practicable, institution managers and regulatory bodies must up their games to ensure full compliance with requisite rules, regulations and standards.

In construction, quality is a responsibility that must be achieved by the structural engineer. Every robust structure begins with proper material testing and other quality control measures. To ensure the adequacy in load-carrying and deformation capacities of any sub-structure, proper geotechnical investigation, provision of adequate drainage systems, engineered backfilling methods, correct compaction procedures, and strict quality and safety control measures during construction must be implemented without compromise.

The Vice Chancellor, Ma permit me to connotatively illustrate structural collapse at this juncture. It can be defined as any structural

system that is unable to fulfill its intended purpose, mission and vision. In other words, it is a system that is unable to support itself and the actions imposed on it. The following instances exemplify this description:

- If the structure of a political party is weak, the party is likely to experience structural collapse.
- Churning out graduates who are not fully equipped with the knowledge and technical know-how that can lead to scientific and technological innovation and development is tantamount to structural collapse.
- The aftermath of the activities of the Special Intervention Team (SIT) in AAUE culminated in structural collapse. Fortunately, the rebuilding process is currently ongoing.
- Furtive or open machinations targeted at people without justifiable objectives can lead to irreparable structural collapse.

7.0 RECOMMENDATIONS

- The Council for the Regulation of Engineering in Nigeria (COREN) should ensure that buildings are designed, constructed, supervised and maintained to high standard of safety in order to avert loss of lives and properties.
- Reliability analysis of existing and new structures should be conducted to ascertain their safety levels.
- Appropriate development authorities in Nigeria should ensure that only qualified and registered professionals undertake both design and supervision of all building construction and infrastructure projects.
- Building laws violators must be prosecuted accordingly to dissuade others. Building codes and regulations should be strictly adhered to for safe design and construction. Moreover, non-compliance with construction procedure by developers and contractors should be resisted without compromise.
- Federal, state and local development authorities should

ensure all unauthorized building developments are prohibited.

- Professionals in the construction industry must continually undertake personal development programme to enhance their skills.
- In addition to proper soil investigation, the appropriate foundations should be utilized in accordance with design standards.
- Soil and material testing should be effectively carried out in accordance with quality control and compliance measures.

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APPENDIX A

Table A1: Selected structural collapse cases in history between 27AD and 2016

S/N	Structure	Place	Year	Casualty	Cause
1	Fidenae Amphitheatre	Fidenae, Rome, Italy	27 AD	20,000	Economically constructed with wooden materials (timber) and overloading
2	Circus Maximus	Rome, Italy	140 AD	1,112	Overloading
3	St. Servatius Bridge	Maastricht, Netherlands	1275	400	Overloading
4	Eitai Bridge	Tokyo, Japan	1807	1,400	Lack of regular maintenance
5	Ponte das Barcas	Porto, Portugal	1809	4,000	Overloading
6	Angers Bridge	Angers, Maine-et-loire, France	1850	226	Dynamic loadings from storms and humans
7	Pemberton Mill	Lawrence, Massachusetts, USA	1860	145	Defective or flawed design and overloading
8	Dale Dike Dam	South Yorkshire, England, UK	1864	244	Reservoir overspill/flooding
9	South Fork Dam	Johnstown, Pennsyvania, USA	1889	2,209	Failure due to heavy rains
10	Maddur Railway Bridge	Maddur, India	1897	150	Over-flooding of river below the bridge
11	Eden Railroad Bridge	Eden, Colorado, USA	1904	111	Natural disaster - Thunderstorm
12	St. Francis Dam	Santa Clanta, California, USA	1928	431	Design flaws and lack of maintenance

13	New London School	New London, Texas, USA	1937	300	Accidental loading caused by explosion from gas leak
14	Whangaehu River Rail Bridge	Tangiwai, New Zealand	1953	151	Collapsed dam triggered collapse of the bridge
15	Malpasset Dam	Cote d'Azur, France	1959	423	Pressure of heavy rainfall and tectonic fault in the impermeable rock base
16	Vajont Dam	Friuili Venezia Giulia, Italy	1963	2,000	Unstable basin that led to landslide
17	Buffalo Creek Dam	LoganCounty, West Virginia, USA	1972	125	Heavy rain initiated collapse of dam
18	Corralejas Bullring Stadium	Sincelejo, Sucre, Colombia	1980	222	Poor design and foundation failure caused by excessive rain
19	Hyatt Regency Hotel	Kansa City, Missouri, USA	1981	114	Overloading and change in design consideration
20	Val di Stava Dam	Stava, Italy	1985	268	Poor /lack of maintenance work
21	Dzhrashen School	Spitak, Amenia	1988	400	Earthquake and poor design concept
22	Royal Plaza Hotel	Nakhon Ratchasim, Thailand	1993	137	Faulty design and violation of safety regulations
23	Alfred P. Murrah Federal Building	Oklahoma City, Oklahoma, USA	1995	168	Bombing attack

24	Sampoong Department Store	Seoul, South Korea	1995	502	Change of purpose from residential to commercial without adequate design consideration
25	World Trade Centre	New York, USA	2001	2,996	Struck by hijacked airliner
26	Canterbury Television Building	Christchurch, South Island, New Zealand	2011	115	Quackery and earthquake
27	Rana Plaza	Savar, Dhaka, Bangladesh	2013	1,134	Lack of maintenance
28	Synagogue Church of All Nations (SCOAN)	Lagos, Nigeria	2014	115	Insufficient structural members and lack of rigid joint and ductility
29	Dharahara Tower	Kathmandu, Nepal	2015	200	Natural disaster - earthquake
30	Weiguan Jinlong	Tainan, Taiwan	2016	116	A combination of substandard materials and earthquake

Source: https://en.wikipedia.org/wiki/List of_building_and_ structure_collapses

Table A2: Selected 2025 building collapse cases in Nigeria

S/No.	Building Type	Address	Date of Occurrence
1	3 Storey Building Under Construction	Aboga along Igwuruta-Etche Road, Ikwerre LGA, Rivers State	4th January, 2025
2	3 Storey Building Under Construction	No. 4, Agarawu Street, Lagos Island	13th April, 2025
3	A Block of Classrooms	Mayigi Community Copmprehensive High School, mIlase, Ipokia LGA, Ogun State	20th March, 2025
4	1 Storey Building Under Construction	Agarawu Street, Off Aroloya, near Central Mosque, Idumota Bus Stop, Idumota, Lagos	14th April, 2025
5	2 Storey Restaurant Building	Oremeta Street, Ojodu-Berger, Lagos	19th April, 2025
6	2 Storey Building Under Construction	Ikota, Lekki, Lagos State	28th January, 2025
7	2 Storey Building Under Construction	Ishaga road, Oppt Idi Araba Central Mosque, Mushoi, Lagos	18th May, 2025
8	3 Storey Building	Adeniji Adele Road, Behid Sasi Palace, Sasi Lane, Isale Eko, Lagos Island	3rd July, 2024
9	4 Storey Building	Enugu-Onista Express Way, Oppt. Five Star Restaurant, Awka, Anambra State	29th January, 2025
10	1 Storey Residential Building	Unity Estate, Alagbole-Akute, Ogun State	3rd June, 2025
11	5 Storey Building	Ahmadu Bello Way, Behind A.A Filling Station,	25th July,

12	3 Storey building under construction	Kado, Abuja	August 02, 2025
13	2 Storey building	Prince & Princess Estate , Abuja	September 06, 2025
14	4 Storey building under construction	333, Borno Street, Alagomeji, Yaba, Lagos	September 12, 2025
15	2 Storey building	Prince Chinedu Akwuaka Street in Akpaka GRA 33, Onitsha, Anambra State	September 23, 2025
16	5 Storey building	Behind Anambra State House of Assembly, Off Ekwueme Square, Okpuno Awka, Anambra State.	September 25, 2025
18	3 Storey off -campus student hostel building	Pentagon Lodge in Izamgbo, Abakaliki, Ebonyi State (Off Campus Student Hostel)	July 25, 2025
19	2 Storey build ing under construction	Obafemi Awolowo Road, Ota-Ona Area, Ikorodu, Lagos State	May 27, 2025
20	1 Storey hotel building under construction	Uromi, ENE LG, Edo State	July 31, 2025

Source: https://coren.gov.ng/building-collapse-record/

APPENDIX B

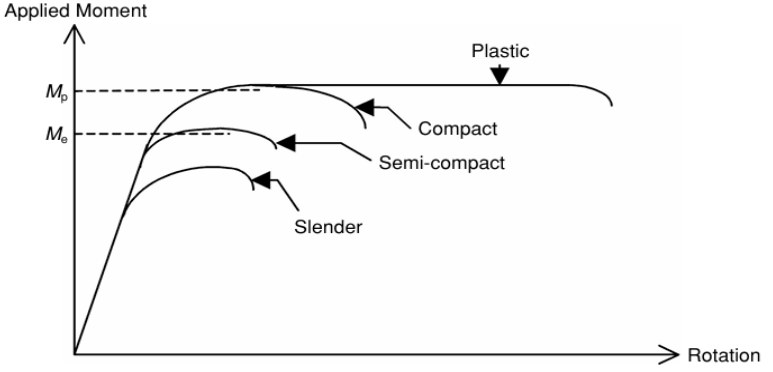


Fig. B1 Typical moment/rotation characteristics of different classes of section

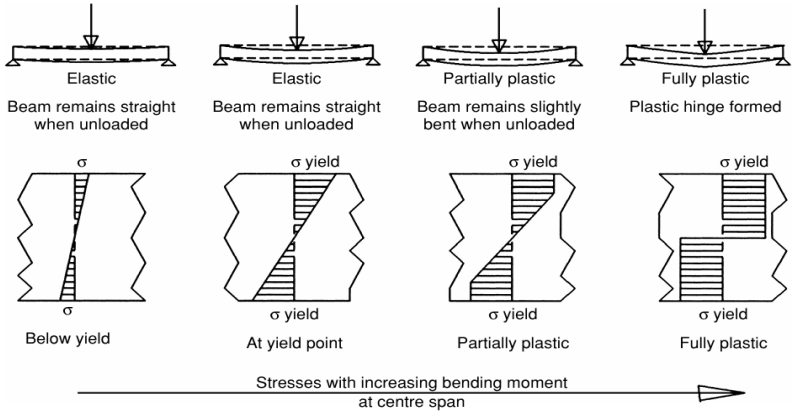


Fig. B2 Bending failure of a beam (Chanakya, 2009)

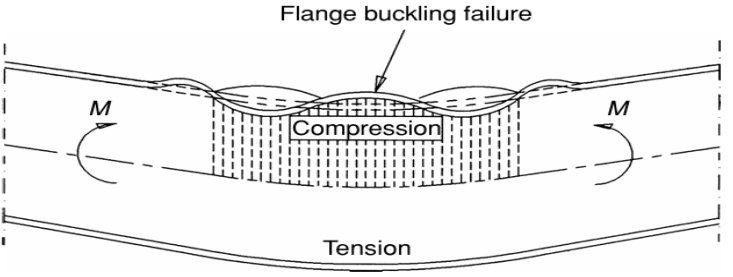


Fig. B3 Local flange buckling failure

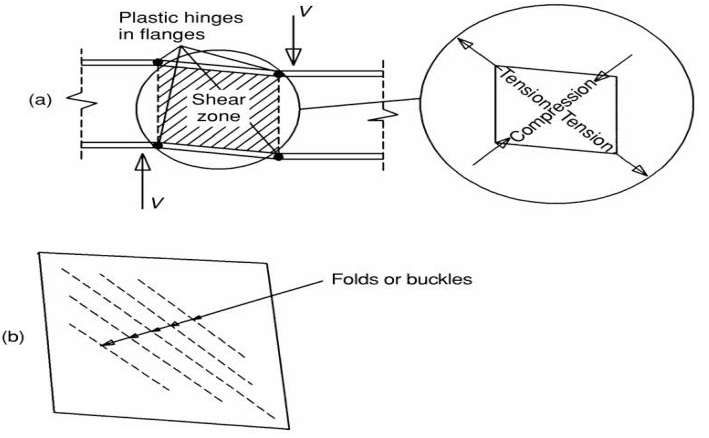


Fig. B4 Shear and shear buckling failures: (a) shear failure, (b) shear buckling (Chanakya, 2009)

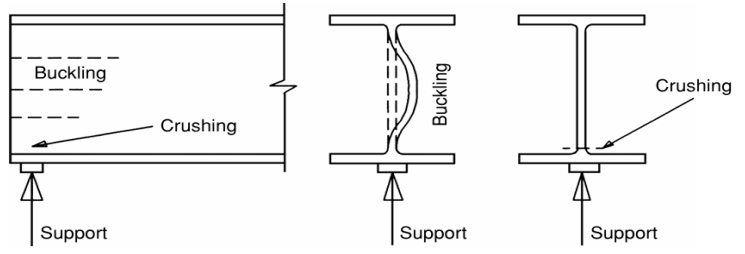


Fig. B5 Web buckling and web bearing failures

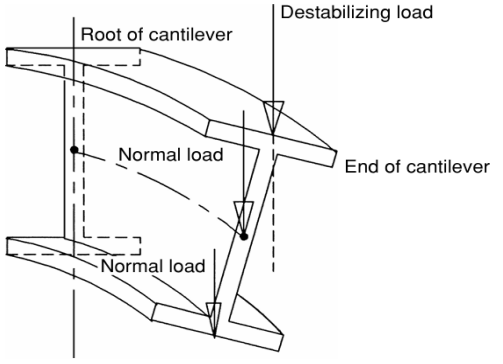


Fig. B6 Lateral torsional buckling of cantilever

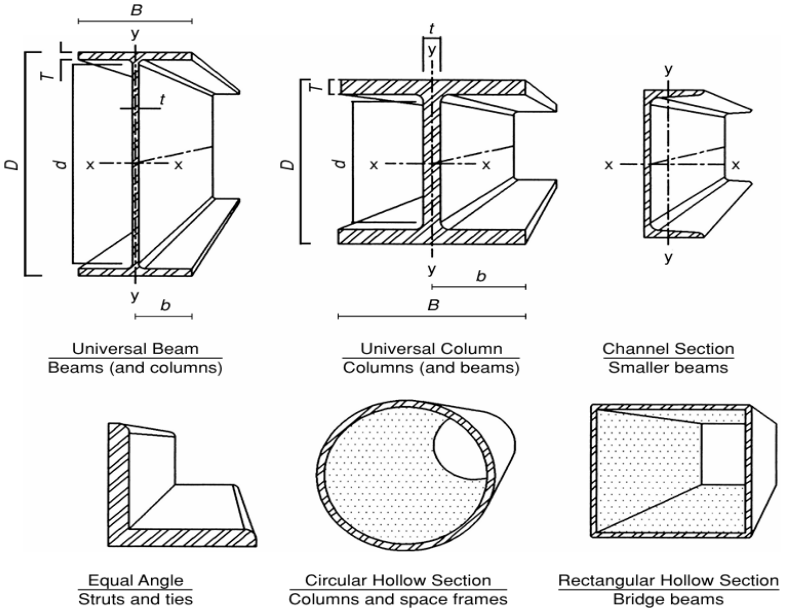


Fig. B7 Standard rolled steel sections (Chanakya, 2009)

APPENDIX C



Fig. C1 Selected collapsed building examples

PROFILE OF INAUGURAL LECTURER

Engr. Prof. Emmanuel Ehioriaze Ufuah was born to the family of Late Pa Michael Stephen I. Ufuah and Mrs. Margaret E. Ufuah at the St Camilius Hospital, Uromi in October 9, 1973. He attended Okpujie Primary School, Uromi from 1979 to 1985. In 1986, he briefly joined the well-known Esan Grammar School, Uromi and later transferred to the prestigious Annunciation Catholic College, Irrua where he began his JSS 2 in 1987. He graduated and had his SSCE from the Annunciation Catholic College, Irrua in 1991. In 1992, he was admitted to the pedigree programme, Edo State University, Ekpoma, which he never accepted. He eventually got admitted in 1993 to study Civil Engineering in the then Edo State University (now Ambrose Alli University), Ekpoma. Engr. Prof. Ufuah is a highly accomplished academic, researcher, and administrator specializing in Structural Fire Engineering (SFE) and design of Civil Engineering Infrastructures. He currently serves as the Dean of the Faculty of Engineering and Technology, Ambrose Alli University, Ekpoma.

Engr. Prof. Ufuah's academic foundation is remarkable, having earned his Ph.D. in Civil Engineering with a focus on structural and fire integrity of structures from the renowned University of Manchester, England in 2012. Prior to this, he obtained an M.Eng in Structural Engineering with Distinction from the University of Benin and a B.Eng in Civil Engineering (Second Class, Upper Division) from the Edo State University (now Ambrose Alli University), Ekpoma.

Engr. Prof. Ufuah's professional journey spans over two decades, marked by impactful teaching, cutting-edge research, and extensive consultancy services. His research contributions cover structural stability under fire conditions, behaviour of reinforced concrete structures, performance of steel and composite structures, soil mechanics, and sustainable engineering practices. He has published over 30 scholarly works in reputable international journals and conference proceedings. These publications reflect his unwavering commitment to advancing civil engineering knowledge, solving real-

world problems, and improving environmental and structural safety. His works are widely cited, contributing significantly to academic scholarship and engineering practice globally. He has delivered papers on topical research areas at the University of California, Berkeley, San Francisco; Imperial College, London; University of Naples Federico II, Italy; Budapest University of Technology and Economics, Budapest, Hungary, just to mention a few.

A passionate teacher and mentor, Engr. Prof. Ufuah has impacted countless undergraduate and postgraduate students, fostering innovation and problem-solving skills in the fields of Structural Analysis, Fire Design of structures, Structural Dynamics, and Finite Element Modeling. He has successfully supervised numerous research theses and served as an external examiner for undergraduate and graduate programs to several universities, upholding academic excellence.

Engr. Prof. Ufuah's administrative proficiencies are equally commendable. He was Acting Dean of Students, where he officiated in a critical university-wide student management role and multiple terms as Acting Head of the Civil Engineering Department. He has also served as Sub-Dean of the Faculty and Head of AAU Water Unit, a component of the AAU Consultancy Services. Engr. Prof. Ufuah's leadership prowess has driven significant achievements, including infrastructure improvements, committee reforms, and enhanced academic programs. He has chaired strategic committees on housing allocation, revenue generation, curriculum reforms and structural stability, contributing to the university's growth and operational efficiency. Moreover, Engr. Prof. Ufuah's administrative acumen, coupled with his visionary approach, has earned him the trust and admiration of his peers, students, and the broader university community.

As a licensed professional engineer, Engr. Prof. Ufuah is registered with the Council for the Regulation of Engineering in Nigeria (COREN) and is a proud member of the Nigerian Society of

Engineers (MNSE). His international recognition includes memberships in the Institute of Fire Engineers (MIFE), UK, and the Society of Fire Protection Engineers (MSFPE), USA, among others. These affiliations highlight his global viewpoint and commitment to professional development.

In addition to his academic and administrative roles, Engr. Prof. Ufuah is an active, and seasoned research and development consultant with a proven track record in structural integrity assessments, design of onshore and offshore structures, environmental impact assessment, and general infrastructural development. He is a competent consulting engineer and academic with excellent communication, administrative and managerial skills, and ensuring that every engineering work is carried out in accordance with specifications, statutory regulations, and other contractual requirements. Engr. Prof. Ufuah is an astute leader possessing proven ability to manage personnel and material resources, and an academic with robust initiative, vision and resourcefulness in policy formulation. He is very proficient in Information and Communication Technology and able to manage project budgets and keep costs down. He is a fellow with a strong track record in delivering projects on time and within budget having adequate academic and administrative leadership with good human relations.

Engr. Prof. Ufuah's outstanding contributions have earned him numerous accolades, including the prestigious Petroleum Technology Development Fund (PTDF) Scholarship for his Ph.D. studies, the Venture-Out Centre for Excellence in Enquiry-Based Learning (CEEBL) Award from the University of Manchester, and recognition as the Best Graduating Student during his M.Eng and B.Eng programs. These honours reflect his excellence in both academia and professional practice. Furthermore, Engr. Prof. Ufuah's research largely covers structural stability under hazard conditions and environmental engineering matrices. His core academic competencies include, but not limited to performance-based structural fire design of engineering infrastructure, structural

behaviour under high temperatures or accidental loadings, assessment of the impacts of industrial wastes, tank farms, and environmental contaminants on regional hydrology and neighborhoods, numerical analysis and mathematical modeling, and competent use of advanced applications such as ABAQUS DS Simulia, COMSOL Multiphysics and ANSYS for complex civil and environmental engineering problem-solving. His peer-reviewed work is documented across global academic networks, including Google Scholar, Scopus and ResearchGate.

A dynamic scholar and leader, Engr. Prof. Ufuah is widely respected for his technical expertise, visionary leadership, and unwavering commitment to the advancement of engineering education and practice. He possesses exceptional interpersonal skills, a keen ability to resolve complex technical challenges, and a passion for mentoring the next generation of engineers. His work continues to inspire innovation, sustainability, and excellence in civil engineering, positioning him as a leading figure in the global engineering community.

Engr. Prof. Ufuah is the first Professor from the Department of Civil Engineering, Ambrose Alli University, Ekpoma to deliver an inaugural lecture, the first Professor to be elected Dean from the Department of Civil Engineering and the first recipient of the PTDF scholarship award in Ambrose Alli University, Ekpoma. He was the Ph.D scholar that represented Edo State in the PTDF scholarship scheme in 2008. Engr. Prof. Emmanuel Ehioriaze Ufuah is happily married to Dr. Mrs. Patience Ejemeare Ufuah and the union is blessed with lovely children.

LIST OF PAST INAUGURAL LECTURERS IN AMBROSE ALLI UNIVERSITY, EKPOMA TO DATE

S/N	NAME	CHAIR	TITLE	DATE
1.	**Prof. Samuel Erivwo,** PhD. (Ibadan)	Religion	The Hound of Heaven and the Children of men (58pp)	11th Dec. 1987
2.	**Prof A. K. Yusuf**, PhD. (Wale), UK.	Electrical & Electronic Engineering	The Technologies and Application of Non Depletable Resources (34pp)	15th June 1988
3.	**Prof. Ade Akinbode,** B.A. (Hons), PhD. (Ibadan)	Geography	Spatial Diffusion of Agricultural Innovations in Dual Economics (52pp)	18th Jan. 1989.
4.	**Prof. J. E. A. Osemenkhian,** BSc. (Hons), PhD. (Cantab)	Physics	Looking into the Earth through its Magnetic Fields (24pp)	27th Feb. 1991
5.	**Prof. A. C. Unomah**, B.A. (Hons), PhD. (Ibadan)	History	Giving it Back: The Irony of National Resources in Africa (33pp)	Nov. 1995
6.	**Prof. B. I. C. Ijomah**, B.A. (Hons), UNN, M.A., PhD. (North Western)	Sociology	The Enigma of Nigeria Nationalism	21st Mar. 1996
7.	**Prof. Agnes E. Uduebor**, PhD. (Lagos)	Botany	The it may be Green (31pp)	4th Dec. 1996
8.	**Prof. Steve Okecha**, PhD. (Lagos)	Chemistry	Memoirs of a Test Tube Prophet (43pp)	25th June 1997
9.	**Prof. D. E. Agbonlahor**, MSc.; PhD. (Lagos)	Microbiology	Mankind Exploited, Microbes Revolted and their Maker Intervened (42pp)	22nd April 1998
10.	**Prof. Thomas A. Imobighe**, B.A. (Hons), Ibadan, MSc., PhD. (Wales)	Political Science	The Management of National Securities (57)	4th July 1998
11.	**Prof. S. U. Remison,** B.Sc. (Ibadan); PhD. (Readings)	Agronomy	The Elusive Green Revolution (48pp)	25th Feb., 1999
12.	**Prof. Olaitan Obanewa,** B. A. (Ed), Med.; PhD. (Syracuse)	Education	Administration, Non Formal Education and Development (55pp)	24th Feb. 2000
13.	**Prof. E. P. Oiakhenan,** M.Phil. (Leeds), PhD. (Wales).	Engineering	From Powder to Parts (71pp)	29th June 2000
14.	**Prof. D. O. Aigbomian,** BSc. (Ed), (Lagos), M. Ed. (Exerter) PhD. (UNN)	Science Education	Science for All: Implementations for the Teacher and National Development (57pp)	27th June, 2002
15.	**Rev. Prof. Anthony O. Echekube** B.D., B.A Phil; M.A. (Urbania), PhD. (Lateramensis)	Philosophy	A Metaphysical Analysis of the Concept of Re- incarnation toward Global Harmony and Peace (42pp)	26th Sept; 2002

16.	**Rev. Prof. Albert A. Segynola,** B.A. Hons (Lagos), M.Sc. (Ife), PhD. (Benin)	Geography	Environmental and Integrated Rural Sustainability: A Spatial Perspective (72pp)	7th Aug. 2003
17.	**Prof. O.1. Eguavoen;** B.Sc. (Hons), PhD. (Lagos)	Chemistry	Unravelling Chemistry Events and Products in Pyrex Vessels and Plastics (58pp)	27th Nov. 2004
18.	**Arc. Prof. Omagbe Osuide** B.Sc. M.Sc. (ABU),	Architecture	Strategies for Affordable Housing Delivery in Nigeria (37pp)	29th Jan. 2004
19.	**Prof. C.A. Dime** B.A.(Hons), PhD (Ibadan)	Religion	God, Male, Female or Asexual (37pp)	27th May. 2004
20.	**Prof. M.I. Isokun,** JP. B.A. (Hons), (Lagos); M.Sc. PhD. (Wales)	Sociology	Men and Their Laws, Why Men are Unable to Obey the Laws They Make (121pp)	27th Aug; 2004
21.	**Prof. M.O. Omo-Ojugo** JP. KSC. NCE (Abraka), B.Ed., M.Ed. (Philadelphia); PhD. (Ibadan)	Language Education	Esan Language Endangered? Implication for the Teaching and Learning of Indigenous Languages in Nigeria (40pp)	30th Nov. 2004
22.	**Prof. B.E. Agbokhan**, B.Sc. (Hons), (East London), M.Sc. (Sterling); PhD (Ibadan).	Economics	The Battle for Justice and Poverty of Nations (33pp)	24th Feb. 2005
23.	**Prof. C.P. Aloamaka,** B.Sc. (Hons), (Ibadan), MPA (Ekpoma), PhD. (Benin)	Physiology	A Physiologist View of Abnormal Blood Pressure: the Insanity of Blood Vessels (50pp)	26th May 2005
24.	**Prof. J.B. Longe** B.Sc (Ibadan), PGD. M.A. (Essex); PhD (Lagos)	Economics	That Nigeria Shall Not Die Poor: The Quest to Save the Poor (53pp)	1st Dec. 2005
25.	**Prof. George Akpede,** MBBS (Ibadan); FWACP., FMCPaed	Pediatrics	The Problem of Unsuspected Bacteraemia and Acute Bacterial Meningitis in Childhood Fever and Neurological Emergencies in the Tropics (87pp)	30th Mar. 2006
26.	**Prof. Sam. E. Ifidon** B.A. (London), MLS. (Western Ontario), PhD. (Ibadan)	Library and Information Science	Planning Without Information: The Bane Of National Development (52pp)	29th Jun. 2006
27.	**Prof. Sam. O. Uniamikogbo** B.Sc. (Hons), M.Sc. PhD. (Ife)	Economics	Nigeria Industrialization Pathway: The Dreams and Realities (42pp)	30th Nov. 2006
28.	**Prof. Fred. I. Emordi** B.A. (Hons), Dip. Ed. (Lubumbashi - Zaire), M.Ed. (Philadelphia - USA); M.Phil, PhD (Grenoble France)	French	Bonjour le Nigerial Commet Ca Va? French Language In Nigeria So Far, 1859-2007 (70pp)	29th Mar. 2007

29.	**Prof. I.B. Igbinosa** B.Sc. PhD (UNN),	Zoology	Insects and Our Environment: The Conflict Between Man and Insects (63pp)	25th Oct. 2007.
30.	**Prof. Vincent Osa, Aghayere** B.Sc (Sam House Huntsville, Texas); MPA (East Texas Commerce, TX); PhD. (Benin).	Public Administration	The Dynamics of Centre Periphery Dominance in the Nigeria Political System: The Local Government Experience (58pp)	28th Feb. 2008
31.	**Prof. F.E. Iyoha** B.A. MPA. (New York), PhD. (Southampton)	Public Administration	Local Government and the Elusive Rural Development in Nigeria: Constraints on Local Authorities Capacity and the Promise of Decentralized Participatory Development (75pp)	26th June 2008
32.	**Prof. Sinatra Ohiokhia John Ojo** B.Sc. M.Sc., PhD. (Benin)	Political Science	Promise and Performance of Democracy in Nigeria: Irony and Fictiveness (71pp)	27th Nov. 2008
33.	**Prof. A.U. Umoru**, B.Sc. (Ibadan), M.Sc. (Ife); PhD. (Leeds)	Zoology	Insects, Crops and Insecticides (96pp)	28th Mar. 2009
34.	**Prof. B.E. Okoegwale,** B.Sc. (Calabar), M.Sc. (Ibadan), PhD. (Benin).	Botany	Plants in the Service for Man (52pp)	25th Mar. 2010
35.	**Prof. F.E. Egharevba,** B.Sc., M.Sc. PhD. (Ibadan)	Chemistry	Chemistry and Quest for Discovery and Innovations (52pp)	27th May 2010
36.	**Prof. A.O. Onigbinde,** B.Sc. (Ife), M.Sc. PhD. (Ibadan)	Biochemistry	Out of the Garden of Eden: Biochemical Pathway (42pp)	29th July 2010
37.	**Prof. P. O. Onolenmhenhen,** B.Se (Maiduguri), M.Sc. (ABU), PhD. (BENSU).	Crop Science	Etymology: A Missing Link in Our Search for Food Security (60pp)	28th Oct. 2010
38.	**Prof. R.O.A. Aluede** B.Ed. M.Ed. (Benin); PhD. (Port-Harcourt)	Education	Balancing educational Imbalance: The Nigeria Experience (53pp)	27th Jan. 2011
39.	**Prof. A.D. Badaki** B.A. Hons (Jos), LLB. (Hons) (BENSU); B.L. (Lagos); LLM. (Lagos) LLM (EDSU), PhD. (AAU)	Law	Interpretation of Stature: The Letter or Spirit of the Law (100pp)	31st Mar. 2011
40.	**Prof. Jude AigbeAgho** B.A. Hons (Bensu). M.A. PhD. (Ibadan)	English	From Protest to Assent: Unraveling Africa Novel as a Protean (44pp)	26th May 2011
41.	**Prof. A.U. Omoregie** B.Sc. M.Sc., PhD. (Ibadan)	Crop Science	A Father, His Son and Their Agriculture: A Bio Agricultural Odyssey (72pp).	30th July 2011

42.	**Prof. E.F. Alofohai**, MBBS. (Lagos); FMCS. (Nigeria)	Medicine	Surgery in Primary Healthcare: A Boost in the Millennium Development Goals (MDS) in Developing Countries (59pp)	13th Sept. 2011
43.	**Engr. Prof. Ajuwa, Christopher,** M.Sc., (Moscow); PhD. (Austria), MNSE; R. Engr. (COREN)	Mechanical Engineering	Engineering Materials and Mechanical Design: The Foundation of Industrial Development (55pp)	24th Oct. 2011
44.	**Prof. C. A. Agbebaku**, LLB. (Bensu), B.L. (Lagos), LLM. (Bensu)	Law	Women's Right and Gender Equality: A Case of Universalism or Cultural Relativism (73pp)	30th Oct. 2012
45.	**Prof. Ambrose 0. 0. Ekpu**, LLB. (Bensu), B.L. (Lagos), LLM. (Bensu).	Law	The Pernicious War for Land: What Hope for Armistice (55pp)	28th Feb. 2013
46.	**Prof. O. P. G. Nmorsi**, B.Sc. (Hons), M.Sc. (Benin), MD. Dip. in Trop Med. PhD. (Ekpoma)	Zoology	The Impact of Parasitic Infection on Longevity of Man (70pp)	25th Apr. 2013
47.	**Prof. (Mrs). A.O. Ekundayo**, B.Sc. (Lagos); M.Sc., PhD. (Ibadan).	Microbiology	Microbial Impact: Gains and Losses (91pp)	27th Jun. 2013
48.	**Prof. (Mrs). C.O. Isiramen,** B.Ed. (Benin), M. A. (Ibadan), PhD. (Ekpoma).	Religion	Single Womanhood and Nowadays Churches in Nigeria: A haven or a Hoax (104pp)	27th Nov. 2014
49.	**Prof. J. E. Onunminya,** MBBS (Jos); FMCS	Medicine	Problems of Unorthodox bone Setting	26th Mar. 2015
50.	**Prof. E. C. Onwuka,** PGDE, M.Sc., PhD., PGDE.	Economics	Contending Without Being Contentious in the World Market: The Tragedy in Africa and its Globalizes in Poverty (62pp)	27th May, 2015
51.	**Prof. Maria Ihenata Ekozien**, B.Sc. PhD. (Benin).	Microbiology	The Benign, the Bad and the Beautiful (72pp)	30th July, 2015
52.	**Prof. Victor Amen Uhumwangho**, B.A. (Hons), M.A. PhD. (Ekpoma), LLB; BL; PGDE,	English	The Politics of Language (60pp)	25th Feb. 2016
53.	**Prof. A.I. Onimawo** FRHP; FNSH,; PhD	Biochemistry	Nutrition in first 1000 Days of Life: The Genesis and Summit of Human Development (66pp)	28th July, 2016
54.	**Prof. Sylvernus O. Oboh**;	Animal Science	Nutritionist View of Wastes to Wealth and the Endless Search Animal Feed Raw Materials O	25th Aug, 2016

55.	**Rev. Fr. Pro f. John A. Onimawo**, B.D., Dip. M.A. PhD.	Religion	The Nature May Take Its Cause.	6th Oct. 2016
56.	**Prof. Samson Imasogie Omonfumwa** B.Sc. (Hons.) (Ife); PGDE; M.Sc., PhD. (Benin)	Geography	Spatio Social Indicators Model: A panacea for a Realistic Measurement of Socio-Economic Development (63pp)	27th Oct. 2016
57.	**Prof. Luckey A. Elakhame**, PhD. FES. FILA. KSI.	Zoology	Unravelling the Hidden Treasure of Water (88pp)	24th Nov. 2016
58.	**Prof. (Mrs). A.N.T. Eguavoen**, B.Sc. M.Sc. PhD. (Ibadan).	Sociology	Tensions and Contentions in Gender Debate: Natured or Nurtured (110pp)	26th Jan. 2017
59.	**Prof. OyaziwoAluede,** B.Ed., M.Ed. PhD. (Benin)	Guidance and Counselling	The Quest for Safer School in Nigeria: My Epistle ( )	23rd Feb. 2017
60.	**Prof. Fredrick Ikechukwu Esumeh**,	Microbiology	Man-Microbe Interaction: An Intense Struggle *Sensustricto* (81pp)	30th Mar. 2017
61.	**Prof. (Mrs) Helen Ojomon Efoghe,** NCE (Ibadan); B.A. Ed (Benin); PhD (Abraka).	Educational Management	Human Factors in Educational Management: Thorns or Roses (63pp)	27th April 2017
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67.	**Prof. Julius U. Azalama**, B.Sc., M.Sc., PhD.	Public Administration	Toward a Paradigm Shift in Anti -	30th Nov. 2017

68.	**Prof. S.E. Iyayi**, B.Sc. (Hons), (UNN), M.Ed. (Philadelphia); M.Sc., PhD (Ibadan)	Physics	Physics in the Service of Man: Solid State Physics and Its Applications. (111).	22nd Feb. 2018
69.	**Prof. FO. Ikpotokin** B.Sc. (Hons) (Bensu); M.Sc., PhD. (Benin)	Computer Science	The Pathway to Computer Programming Efficiency for Optimal Utilization	29th Mar. 2018
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111.	**Prof. Victor Usinomen Okojie,** PhD (Uniben); M.Sc. (EDSU); PGD (Uniben); B.Sc. (Zaria).	Analytical Environmental Chemistry	The Dynamics of Metals and Other Chemicals of Concern in Environmental Media: Implications for Human Health	16th May, 2024
112.	**Prof. Theophilus O. Agweda,** B.Sc. (Hons) (Ekpoma); M.Sc. (Ibadan); PhD. (Ekpoma)	Sociology	To be Infected is not to be stigmatized: An Invitation for Socio- Medical Balancing	30th May, 2024

113.	**Prof. Momoh, Lawal. Rilwani**, B.Sc. (Hons) (Jos); M.Sc. (Lagos); PhD. (Uniben)	Geoinformatics	Sensing and Synthesis for Advancement: Exploit with Geoinformatics	13th June, 2024
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115.	**Engr. Prof. Adavbiele, Airewe Stephen** Ph.D. (AAUE); M. Eng., (EDSU); Grad. Eng. (NSE); HND (Auchi); Cert. Gas Turbine Engine Technology (IGTI, USA); AMASME; MNSE, R. Engr. (COREN);	Mechanical Engineering (thermo-fluids)	Handling Puzzles In Aerospace Travels: The CFD Approach	11 July, 2024.
116.	**Prof. Cletus E. Abhulimen**, Ph.D (Benin), M.SC (EDSU) B.Sc (Ed) (Lagos), N.C.E (Abraka)	Mathematics (Numerical Analysis/ Computational Mathematics)	"Everything is Mathematics: Numerical Tools, my Language"	8th Aug. 2024
117.	**Prof. Patrick Osatohanmwen Oviasuyi**, BPA (Hons) (Benin), PGDE,(Sokoto), M. Sc.(Benin), Ph.D.(AAUE), FCAI, FNIM, FPAM, FCEnt, FCDA	Public Administration	Community–based Associations: A Potent Instrument For Local Government Administration In Nigeria	29th Aug. 2024
118.	**Prof. Samuel Olushola Ajagun,** NCE (Uniben) B.A. Ed. (Hons.) (Illorin); MPA (Illorin), M.Sc. (Benin) PGD. (Ekpoma), Ph.D. (Ekpoma)	Public Administration	Sink or Float? Interrogating Corruption and Poverty in Nigeria	26th Sept. 2024
119.	**Prof. Mabel Ejoghoye Aziegbe**, B.A. Ed(Abraka); M.A (Ibadan), Ph.D (Ekpoma)	French Applied Linguistics	The Non-use of Sub-dot Diacritics in Esan Orthography: A Disservice: A Disservice in Esan (76pp.).	10th Oct. 2024
120.	**Prof. Henry Odhianosen Imhonde,** B.Sc. (Hons), M.Sc., Ph.D. (Ibadan).	Psychology (Clinical)	How are you? Wholistic Approach to Psychological Well-being. (77pp.).	31st Oct. 2024
121.	**Prof. Mariam A. IYEH**, B.A Hons. (Illorin), M. A. (EDSU), Ph.D. (Ibadan)	Dance Studies and Performance Aesthetics	Dance Beyond Entertainment: The many faces of Dance in Service of Humanity-Curriculum and Pedagogical Concerns	28th Nov., 2024

122.	**Prof. Henry H. Isitekhale** ND. (Anwai), HND (Umudike); PGD (Nsukka); MSc. (Ekpoma); PhD. (Ekpoma).	Soil Science	Sustaining Soil Health for the assurance of food security in Nigeria.	16th Jan. 2025
123.	**Prof. Mrs. Odia Edith A.** B.Sc.(Hons), (Ekpoma), MSc. (Ekpoma), PhD. (Ekpoma).	Chemistry	"Chemical constituents in Botanicals: Exploring the gifts of nature for our Well- being"	13th Feb., 2025
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128.	**Prof. Matthew Aziegbemhin Izibili** B.A. (Hons), (Ekpoma); M. A. (Ibadan); PhD., (Ekpoma); PGDE (Sokoto); FCAI	Philosophy	Philosophy In The Service of Society: The Esan Model of Aihẹbholo-Ọria.	15th May, 2025
129.	**Professor Alex Payim Igbe** MBBS (Nsukka), FWACP (Nsukka), Cert. Mgt. Devpt. (Nsukka)	Pathology	Pathology: "...That They Might Have Life And ...Have It More Abundantly"	29th May, 2025
130.	**Prof. Gladys Otasowie Igene** B.Agric (Ekpoma), M.Sc (Ibadan), Ph.D (Ekpoma)	Agricultural Economics	Food And Nutrition Security Quagmire: What Alternative Do We Have?	26th June, 2025

131.	**Prof. Hanson Osadiayo Taiwo Iyawe, FNSN** B.Sc. (Benin), M.Sc. (UniBen), Ph.D (AAUE)	Bio-Chemistry	Excavating Latent Realities in the Campaign Against Oxidative Stress (75pp)	17th July, 2025
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134.	**Prof. Emmanuel Eghe Egbon** NCE, B.Sc. (Ed), M.Sc. (UniBen), Ph.D (AAU, Ekpoma)	Analytical and Environmental Chemistry	Drinking and Eating with Clay Vessels, Renewed Hope: Dynamics of Multi Functional Earth Material (57pp)	28th Aug., 2025
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136.	**Prof. Lawrence Nosa Edosomwan** B.Sc. (Hons), M.Sc., Ph.D (University of Ibadan),	Soil Survey	Alleviating Environmental Issues for Sustainable Agriculture: The Soil Survivor's Contribution.	25th Sept., 2025
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140.	**Prof. Eunice E. Omonzejie** BA. Ed. (Ife), DEF (Grenoble-France) MA (Benin), Ph.D. (Benin), MNAL	Metropolitan French And Francophone Literatures And Cultures	African Migrant Masculinities, Modernities And Cultural Identities: Decoding Contemporary Realities In Francophone Fiction	19th Feb., 2026
141.	**ENGR. PROF. VINCENT OPE-OLUWA AFENYE AKPAIDA** B. ENGR, M.ENG, (Benin), Ph.D. (Ekpoma)	Electronic and Telecommunication Engineering	Exploring Path Loss In Telecommunication Engineering And It's Signifinance in Scripture	26th Feb., 2026
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146.	**Prof. Nnebe, Samuel Ekene** BSc. (nsukka), Msc. (Akwa) MBA(Ekpoma) Ph.D (Abkaliki) FNCS, FAAN	Computer Science	Leveraging the Garbage in garbage out paradigm; quest for smarter data System	7th May 2026
147.	**Prof. Abdul- Raqaq Mcsionel Momoh** BSc. (Hon), Msc. (Medical microbiology MBBS, Ph.D)	Medical Microbiology	Making him a Man again. Circuventing the pitfall associated with bacterial infection in male factor infertility pp92	21th May 2026
148.	**Prof. Okechukwu Felix Emeflike** (AMLSCN, FMLSCN,MLS,PhD, FWAPCMLS)	Haematology and blood Transfusion Science	The Silent Witness in Our Veins	4th June 2026
149.	**Prof. Anthony, Aizebioje Coker** Dip(Badagry), BA(Hons)(EDSU), MA(UI)PhD(AAUE)	Modern Languages	Dictatorship and tyranny as conjoined twins: Discourse in francophone Africa Literature	18th June 2026

150.	**Prof. PR. Felix Ilori Olousi** NCE(TECH), (AKOKO-LAGOS), B.SC. (ED) (TECH) BENIN M.ED., PHD (EKPOMA)	INSTITUTE OF EDUCATION	Industrial- Technicalization Of School Curriculum in the Era of Artificial Intelligence: A Paradigm Must Change	2nd July 2026
151.	**Prof. Deans, Osawaru-ogbegie, Rosemary, Iyalekhuosa** B.Sc (Dallas Texas), M.Ed (Benin) M.Ed (Benin) Ph.D,(EKPOMA)	EDUCATIONAL MANAGEMENT	Intrinsic Satisfiers: Veritable Keys For Reflective Measurement of Staff And Timely Actualization Of Organization Goals	16th July 2026
152.	**Prof. Mrs Bridget Esele Uwameiye (FHEPAN)** NCE (Warri) B.Sc (Ed) Ekpoma, M.Ed (Benin), Ph.D (Benin)	HOME ECONOMICS	From Generation To Generation: Reclaming Indigenous Wisdom For Contemporary Homes And Schools	20th August 2026