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STRUCTURAL FORM WORKS AND SAFETY CHALLENGES: ROLE OF BAMBOO SCAFFOLD ON COLLAPSE OF REINFORCED CONCRETE BUILDINGS IN NIGERIA

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ABSTRACT

Bamboo scaffold serves as provisional structure to support people, materials, structures under construction and for maintenance works in most developing nations of Africa and Asia. But the risk posed by the use for construction in nations like Nigeria where collapse of reinforced concrete buildings is frequent have not been researched upon in the past. This research looks at the hazard posed by adopting bamboo scaffolds in construction in Nigeria. A total of 102 collapsed reinforced concrete buildings were revisited. Structural health monitoring tools, expert judgment and statistical measures were used. Results showed that over 20% of the collapse cases considered are at the risk of being caused by failure of overloaded bamboo scaffolds.

Keywords: Bamboo scaffolds, Building Collapse, Rainstorm, Reinforced Concrete, Structural Health Monitoring

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1. INTRODUCTION

Scaffold is a provisional structure used to support people, materials, and structures under construction and for maintenance works [1]. It provides support for the structure to be worked upon and accesses and platforms to enable work to be done by a variety of trades on site and for supervision. In the construction industry, demand for scaffolding formwork for the construction of various type of structures and for the maintenance of existing ones is high

because it is indispensable for different processes in a building projects. The two most established systems are bamboo scaffolding and metal (steel) scaffolding. Metal scaffolds are structural designed, spaced and as to withstand the self-weight of structural elements to be supported, environmental and operation loads imposed on the falsework system. Combined stresses of bending and buckling define the type of cross sectional shape to be adopted. The multi-directional resistance of tubular sections to bending and buckling brought about tubes being the most preferred section for bamboo and steel scaffoldings. The similarity in shape and resistance has contributed to the continuous use of bamboo for scaffolding [2]. Both materials are recyclable. Though they are both made from tubes, the shape of steel is fixed while that of bamboo is variable due to its natural process of formation. More often than not, cross-bracing is added to improve resistance to buckling. Various pros and cons that are associated with the use of either bamboo or steel scaffolding for building construction was explored [3]. For the actualization of this research, structural health monitoring tools and approaches will be applied since some of those tools have been confirmed by researchers [4-6] as valid methods for assessing damages in structures or for forecasting causes of structural failure.

2. STEEL TUBULAR SCAFFOLD

The most common type steel scaffolds are of tubular shape joined by couplers. According to the Hong Kong Code of Practice for Metal Scaffolding Safety [7], specifies that steel tubular scaffolds be erected based on the design and drawings of certified engineer. The yield stress of a steel tube is in the range of 235N/mm^2 for an outside diameter of 48.3mm and thickness of 4mm. The quality of Steel scaffold can be trusted as it can be properly planned for safety and designed with less risk while necessitating far less skilled labor. The accessories are custom-built thereby enhancing more efficient product. The most common types in use are single-pole scaffold and the Independent tied scaffold [8].

3. BAMBOO SCAFFOLDING

Bamboo scaffolding is a type of scaffolding made from bamboo and widely used in building work for ages. Many famous monuments such as the Great Wall of China were built using bamboo scaffolding [9-10]. It was widely used in the building construction of low rise and multi-story buildings (up to four stories high) earlier to the development of metal scaffolding and in the more recent decades have been well advanced in Hong Kong.

Bamboo is the fastest maturing grass in the tropical regions of Asia and Africa and is cheap in regions where the plant is locally available. It provides the cheapest scaffolding system in regions with inexpensive semi-skilled labor and abundant bamboo material [10]. Quality bamboo has a good tensile and could be used multiple times thereby reducing the cost of construction. It is a fibrous material with verified tensile strength in the range of 156-185 N/mm^2, which implies a greater strength to weight ratio than steel. Bamboo is also cheaper, making it attractive in poor developing nations. Bamboo scaffold has a renewable resource and can be used effectively for up to 5 story building.

But bamboo scaffold is bedeviled with many challenges. Inconsistent bamboo quality can create problems as the actual strength varies with great uncertainty. Bamboo scaffold design are highly estimated and based more on the capability of the fabricator thereby portending great safety risks. It can be cost effective and quite safe if properly built, but for it to be safe, it must be over designed with more materials therefore tending to be expensive while the urge to cut cost and negligent oversight can lead to severe fatalities. Accessories foe bamboo

scaffolding are not customized, does not have a solid footing and anchorage base on the ground, thereby exposing it to a great risk for instability.

4. SAFETY CHALLENGES OF SCAFFOLDING

Safety of scaffolding will depends on the quality of materials adopted and the assembling process. The factory-built steel scaffold system comprising of the tubular sections and the accessories has a definite advantage due to regular shape, engineered design better construction procedure. Bamboo material, on the other hand, has intrinsic size inconsistency with anisotropic comportment. It is less ductile than steel and stands a high risk of being brought down by high wind and overload. The safety risks of bamboo scaffolds is heightened by size variability and strength uncertainty of bamboo material, fittings, design method and construction procedures.

5. THE HONG KONG EXPERIENCE ON BAMBOO SCAFFODING

Hong Kong with its largely modern architecture, still accommodates bamboo scaffolds for new building and for the renewal of high-rise buildings [11]. Bamboo scaffolding in Hong Kong existed prior to the British colonization of the 1800s [10]. The Hong Kong's success story on bamboo scaffolds was greatly helped by the Government's regularization policy of the bamboo scaffolding trade which led to the abundance of skilled bamboo scaffolders. The Hong Kong Institute of Construction Managers [12] provided the most trusted specification for bamboo scaffolding. Essentially, easy access to bamboo material, reduced cost and availability of bamboo scaffolder specialists propelled the trade to a great height. Bamboo is easily available from mainland China. In 2013,over 1,751 registered bamboo scaffolders and about 200 scaffolding companies were present in Hong Kong [13].

But in the recent years, the use of bamboo scaffolds in Hong Kong is beginning to diminish due to safety risks, shortages in labor and material. Construction workers in Hong Kong have one of the highest fatality rates in the developed world. The labor shortage is unconnected to the unwillingness of the youths to take up this trade due to the great accident risks and unsafe work environment.

6. BAMBOO SCAFFODING IN DEVELOPING NATIONS

Outside Hong Kong, bamboo scaffolding is mostly seen in developing nations of Asian and Africa such as India, Bangladesh, Sri Lanka, Indonesia, Nigeria etc. Tropical rain forest of African and Asian countries are the home of bamboo, which matures to the required sizes and thickness just in three years. The supply of bamboo is highly sustainable in these tropical regions. In many African countries, notably Nigeria, bamboo scaffolding is commonly used in large scale construction in rural and urban areas [14]. In fact, bamboo is an essential building and construction commodity in Nigeria due to the abundance from the tropical rain forest. But unlike in Hong Kong, in most these developing tropical nations, the absence of Government regularization and skilled manpower for bamboo scaffolding is evident. In Nigeria, the absence of Government regularization of bamboo scaffolding trade has opened doors to all form of quackery and in many cases leading to frequent fatal accidents and rampant failure of structures under construction.

7. BAMBOO PROP-UP AND RISKS OF BUILDING COLLAPSE IN NIGERIA

Common causes often blamed for collapse of buildings in Nigeria are use of low-quality building materials, employment of incompetent artisans, incompetent contractors, poor

supervision, non-compliance with specifications/standards, non-enforcement of existing laws and endemic poor work ethics of Nigerians and of the cause failure of the Nigeria system which is corruption [15-18]. The effects of this trend of collapse is devastating in economic terms and human casualties, therefor running against the UN Sustainable Development Goals driving at making the world a better and safer place to dwell in [19].

But reference is really never made of the contribution prop-ups and scaffolding systems as immediate cause of collapse. In Europe, design of scaffolding system is a legal requisite for any construction projects as prescribe by the prevailing codes of standards. In Honk Kong, design of bamboo scaffolding has a manual [12]. But in Nigeria there is hardly any design requirement for bamboo prop-ups used in most construction sites and in most of the cases the fabrication is undertaken by people with unverified experience and no certification. The principle of fabrication of most bamboo scaffoldings lack proper engineering principals as the quality of bamboo adopted can only be verified by visual inspection and the accessories needed for installation commonly invented based on fabricator's intuition, as there is no legal framework for the trade. For small load cases, these approximately designed prop-ups can withstand the stresses coming from the load, but when by any means the load increases, the chances of collapse is very high. In Honk Kong where the use of bamboo scaffolding is highly standardized and regulated, the high risks and fatalities in building cites is dissuading the youths from taking to building profession even in the presence of enticing work pay.

Building structures are built on the basis of static equilibrium, such that only small movement of any part of the structure is permissible. Excessive deflection due to gravity load and lateral movement will precipitate in collapse [20]. If any part loses equilibrium and goes into motion, a sort of chain reaction starts, pooling all the unstable part of the structure down. Once a prop-up looses balance or can no longer perform the duty for which it is envisaged, catastrophic failure ensures and such collapse are classified as fragile since there is hardly any pre-warning of impending collapse. The scenarios that are possible for bamboo scaffold collapse are two: the first is due to direct overload caused by normal design dead and imposed load for which collapse can occur at any time of the year while next is for improvise overloading due to a combination of normal design dead and imposed load together with unplanned imposed load such as rain storm. In fact, past research [21] have proved that most building collapse in Nigeria occur during the raining season. Based on these forgoing facts, this research tries to investigate the role of bamboo prop-ups in building collapse in Nigeria. Failure of poorly erected bamboo scaffolder in Nigeria, though rarely researched on or properly investigated in the past, is believed to be one of the significant causes of structural collapse in Nigeria.

8. METHODOLOGY

Having introduced the risks surrounding the use of bamboo scaffolds in construction, this research investigates the part played by bamboo prop-ups in causing building collapse in Nigeria. The material considered for the research is the bamboo scaffold fold system adopted for new constructions in Nigeria. Historical data on building collapse in Nigeria is collected and analyzed. 100 cases of building collapse in Nigeria [22, 23] were used for the research. Until a sickness is diagnosed, the search for appropriate cure cannot begin; in the same vein, until the extent to which bamboo scaffold failures contribute to building collapse in Nigeria is established, the search for solutions to the problems of bamboo scaffold failures cannot begin in earnest. Common features of scaffolding related collapse is that it affects only buildings under construction. So this research will focus on collapse of buildings under construction.

Structural health monitoring approach of visual inspection and expert judgment will be adopted in conjunction with statistical measures.

9. RESULTS AND DISCUSSIONS

This research scrutinized 102 cases of collapsed buildings in Nigeria for the period from 1974 to 2016 and identified the distribution of the building according to the season of collapse (Figure 1 and the use of the buildings at the point of collapse (Figure2).

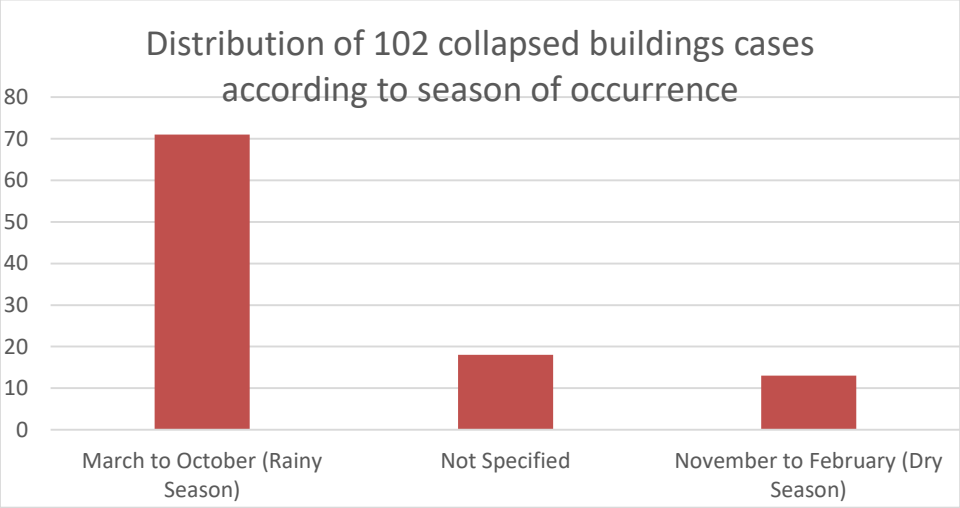

Figure 1 Distribution of 102 collapsed buildings cases according to season of occurrence.

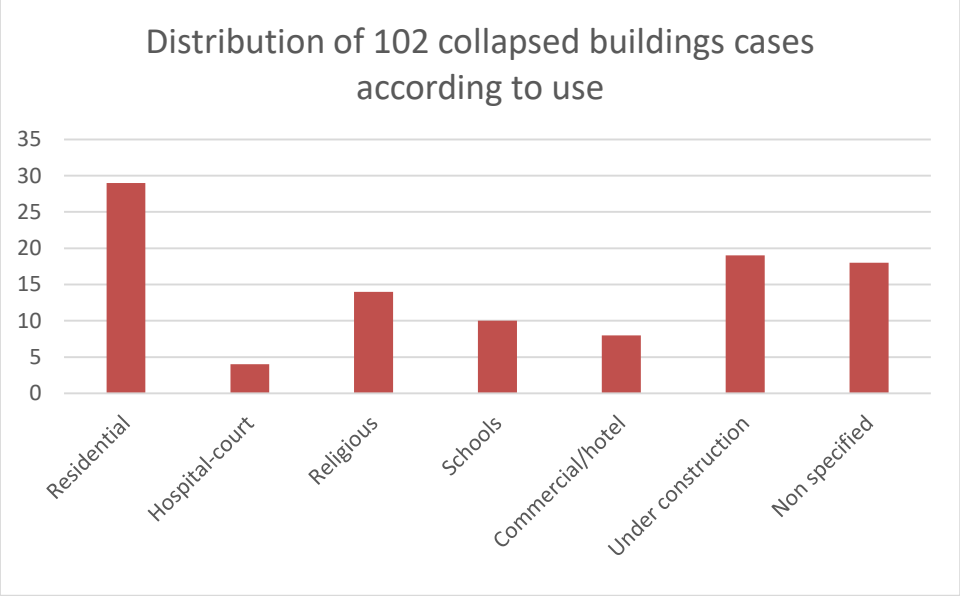

Figure 2 Distribution of 102 collapsed buildings cases according to use

The predominance of collapse during rainy season is very evident as shown in figure 1. Of the over 71 of the total collapse cases of 102 considered, and 19 buildings were under construction. These 19 and a fraction of 18 collapse cases with incomplete data as regards the period of collapse fall into the categories of building collapse suspected to be caused by failure of scaffolding systems. These collapse are perceived to be at more risk of being caused by bamboo scaffolds related failure since their occurrence was during the rainy season which is the season more prone to rain storm overloading bamboo scaffolds. In fact, 13 of the

cases had either excessive loading or rain storm as the possible cause of collapse. Figure. 3 shows a case of a building failure due to weak bamboo prop-up collapse.

Figure 1 Rubble of a church building that collapsed in Ibadan, Nigeria [24].

10. CONCLUSION

From the research, the risk of building collapse due to bamboo scaffolding collapse appears more evident. Failure of poorly erected bamboo scaffolder in Nigeria, though rarely researched on or properly investigated, remains one of the significant causes of structural collapse, thereby contributing to make the Nigerian's construction industry to be ranked among the most dangerous in the world. The research brought to fore the need to beam search light into the contribution of scaffolding systems to the frequent building collapse cases in Nigeria and also to create awareness on the necessity of more rigorous control and monitoring of the quality of bamboo scaffolding adopted for construction in Nigeria.

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