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THE BUILDING INFORMATICS APPROACH TO MODELLING CONSTRUCTION QUALITY ASSURANCE PARAMETERS TO PREVENT STRUCTURAL COLLAPSE OF BUILDING

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ABSTRACT

Building collapses have become a global phenomenon and continue to occur unabated, with properties and lives being lost on a daily basis all over the world. This study addresses important issues that have been identified to be the major causes of the problem of building collapses. The study aims to develop parameters that could be used to assure quality processes in building construction using building informatics, with the intention to prevent building structure collapse on construction sites. In order to achieve this, a random survey technique was used based on the purposive method, in the form of a structured questionnaire distributed to 100 respondents. 100 structured questionnaires, designed using a Likert scale from 1 to 5, were employed in the data collection. The random sampling technique was used for the sample selection. The data collected were analysed using a relative agreement index and subjected to factor rotation, from which factors with high eigenvalues were extracted and used to create a model aimed at supplying information on building collapse prevention. The study reveals that the construction industry is filled with many unqualified personnel, poor supervision; non-compliance with designs (i.e. a structural issue) as a result of the addition of under designed or over designed components which can cause excessive loading; lack of regard for environmental issues; inappropriate planning of construction activities; poor maintenance; and, most importantly, the use of inferior materials in other to save costs, All these issues affect the construction industry and contribute to building failure.

Keywords: Business entity; Collapse; Government; Information; Intervention; Model

1. INTRODUCTION

Buildings are the most critical factor for the survival, shelter and wellbeing of people, and for the social, economic, cultural and environmental milieu in which most human activities are undertaken. However, there have been innumerable cases of building collapses, whose history could be traced back to the time of the building of the Tower of Babel, which collapsed on account of God. Various antecedents in the Babylonian Kingdom after this incident led to the promulgation of building regulations in 14BC by King Hammurabbi, an Emperor in the kingdom. According to Akinpelu (2002), buildings can be defined as permanent or temporary structures enclosed within exterior walls and a roof, and including all their attached equipment and fixtures that cannot be removed without cutting into the ceiling floors or walls (Agwu, 2014; Amusan et al., 2018).

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Building information is a system which provides information, as well as knowledge and data, that can be derived from data which represent values and are attributed to parameters, and knowledge which signifies understanding in the field of building construction, maintenance and use. It also contributes to residential construction training and consultation programs that use a building science-based systems approach to help clients build better buildings which are safe, durable, healthy, comfortable and efficient, and which are better for the environment and the economy. According to Douglas (2002) and Agwu (2014), the intervention approach involves using selected strategies to direct the process of intervention, based on the desired outcomes, data evaluation and evidence, which can serve to promote health, establish or restore skills and functions, maintain the existing status, introducing compensation strategies or methods.

Building collapse can simply be defined as a total or partial/progressive failure of one or more components of a building, leading to the inability to perform its principal functions of comfort, satisfaction, safety and stability. Building collapse occurs due to two major reasons: the cosmetic/additional reason, which is the addition of elements which were not formally planned for, thereby preventing the structure from being able to support these added components; and the structural or subtraction reason, which includes reductions in or omission of constituents in the structure, thereby making it unable to fulfil its appropriate functions or to be structurally instable (Oloyede et al., 2010; Hollis, 2006). This study is designed to analyze the various causes of building collapse, which have been proven to be the result of departures from the "as built"/expected state to an inferior one, leading to tragic situations and providing an explanatory approach with various preventive measures to prevent continuing occurrence of building collapse in Nigeria. For example, an alarming number of 130 building collapses with a death toll of 250 people took place between 1999 and 2009 in Lagos alone.

2. REVIEW OF THE RELATED LITERATURE

Studies relating to building collapse have been selected and reviewed, with reference to incidences in Africa, Europe and America. They include those of (Ayininuola & Olalusi, 2004; Ebehikhalu & Dawam, 2014; Ayeni & Adedeji, 2015; NBIMS, 2010) examined strategies for mitigating building collapse in Nigeria from the perspective of architects and other stakeholders in the building industry. Their paper examined the role of each player in the construction industry. The collapse of 26-year-old office building in Ashford, Middlesex was documented in an analysis, the collapse killed four men who were working in the building. Similarly, Alexander and Lewis (2018) conducted a study on the challenge of reducing the incidence of building collapse in Ghana. They reported that an airport building in Accra collapsed and injured six people in 2016, that 18 deaths were recorded in Accra in 2014, and that 70 people were injured in a collapse in 2012. In addition, Fernandez, cited in Alexander and Lewis (2018), documented findings on the collapse of buildings in African country with an emphasis on Kenyan cities. According to the study, 14 deaths were reported in Nairobi in 2006, 17 in Luanda in 2011, and 11 in Nairobi in 2013. Similarly, Leyendecker & Fattal (1973) documented details about the collapse of storey buildings in the USA. A 20-story building collapse at Skyline Plaza in California killed and wounded many people in 1973. Finally, Ayininuola and Olalusi (2004) conducted research on the causes of building collapse in Nigeria, attributing these to design, construction and structural faults and poor construction practice, among others. The design faults included poor structural design by non-professionals, lack of structural design, use of substandard materials, negligence in the use of appropriate personnel in building construction supervision, and poor workmanship and supervision.

The various explanatory approaches in this study include the formulation of various building information that is needed before, during and after construction; intervention based on previous causes and standards that should have been followed; and recent approaches/changes in technology to prevent the further collapse of buildings. According to Ede (2010) and Anumba et al (2004) the activities necessary for the realization of efficient structures take place in the following fundamental stages: the conceptual and design stage, the construction-supervision stage, and the post-construction service stage. All these stages are very important for the longevity and durability of a structure and all require planning rooted in the conception and design stage. Any mistake during any of these stages, especially at the root level, will over time affect the lifespan, construction process and continuing use. Various strategies must be put in place by the contractors, consultants and government agencies. This involves designing the building and forwarding the design to different professionals to verify the possibility of executing the structure at present, and the future effects of designing the building in such a way. Any corrections made at this stage should be followed, even if they might affect the aesthetics of the structure, so as to ensure that it can stand the test of time.

3. METHODOLOGY

The purposive sampling method with the random survey technique was used for the study by employing a structured questionnaire distributed to 100 respondents. 100 questionnaires were used for the analysis collection. The data collected were analyzed using a relative agreement index and subjected to factor rotation, from which the factors with high eigenvalues were extracted and used to create a model aimed at supplying information to prevent building collapse. The sample and population sample of 150 was adopted and a sample size of 100 was used. The data collected were analyzed using the Relative Agreement Index, simple percentages and regression analysis employing SPSS software, while factor analysis was used in the model development. The research locations were construction sites in Lagos State, Nigeria, while the respondents were professionals working on the sites. The equation used in the sample and population sizing is as follows: $n = (N/(1+Nb^2)$, or $n = N/(1+b^2N)$, where n is the size of the sample, N is the size of the population, and b is the margin error, which is 5% (0.05). Generally, the unit of analysis used in the study was based on the number of projects sampled and used for the analysis. The Statistical Software Package for Science and Social Science Students (SPSS) was used for the data analysis, with factor analysis and the mean tools of SPSS employed.

4. RESULTS AND DISCUSSION

The results of the analyzed questionnaires and associated discussion is presented in the tables in this section.

Table 1 Prerequisite qualifications for the competence of construction site professionals

In this table, a breakdown of the parameters that represent certain prerequisite qualifications for the competence of professionals to be engaged on construction sites was presented in Table 1.

S/N	Parameter	Relative Agreement Index
1	Engaging trained professionals for the construction process is important to prevent building collapse.	0.9564
2	Thorough supervision of workers on site.	0.9549
3	High technical competence is compulsory for qualification as a construction practitioner.	0.9430
4	Ethical practice procedures should be followed by construction professionals, which will lead to a reduction in building failures.	0.8658
5	For a professional to be effective in preventing building collapse, minimum professional requirements are needed.	0.7958
6	Knowledge-sharing partnerships (consultants working as a group) are an effective way to eliminate construction problems which may result in failure.	0.7573

7	Neglecting professional responsibilities or careless handling of site responsibilities.	0.7492
8	Multi-skilled engagement of construction professionals is desirable for effective performance.	0.6759
9	Professional qualifications can lead to better performance in projects.	0.4898
10	The government should enforce the inclusion of multi-skill worker components in the composition of site professionals.	0.8675

Information on the requisite qualifications for professionals working on sites is presented in Table 1; the quality of personnel goes a long way to determining their output on site. Engaging trained professionals for the construction process is important to prevent building collapse, while high technical competence is compulsory for qualification as a construction practitioner. These two factors were ranked first and second. It was advocated that ethical procedures should be compulsory on project sites in order to produce a disciplined workforce; this was ranked third, with a relative agreement index of 0.865. In addition, according to the analysis, it was discovered that professional qualifications can result in better performance on projects sites and make professionals more effective in preventing building collapse, and that minimum professional requirements are needed; these factors were ranked fifth and sixth. However, nowadays professionals have to be multi-skilled for effective performance, therefore engagement of multi-skilled construction professionals is desirable for effective performance (Douglas, 2002; Ozaki, 2003; Lekan et al., 2017).

Table 2 Application of quality management system information in determining the quality of materials

S/N	Parameter	Relative Index
1	Quality management system implementation on site could prevent building collapse.	0.9581
2	Prevent the use of substandard materials on site.	0.9456
3	Purchase approved grade and quality materials on site.	0.9368
4	Quality management systems must be established on site.	0.8893
5	Use of wrong composition mix of concrete and materials on site for construction.	0.8802
6	Training of construction workers in quality management is needed on site to prevent building failure.	0.8705
7	Non-destructive testing of construction components can be used to ensure the required quality is maintained.	0.8281
8	The introduction of a quality manual is needed to ensure quality management on site.	0.7899

The parameters of quality management system information that could be used to determine the quality of material used on site is presented in Table 2.

Information on the application of quality management system information to determine the quality of materials for use on site is presented in Table 2. Such systems should be established on site for best practice; this was advocated as part of the quality parameters needed on site to prevent building collapse. Quality management system implementation, with an RAI value of 0.9581, is suggested as an approach that should be enforced on site as it has a tendency to prevent building collapse (Douglas, 2002). Moreover, preventing the use of substandard materials on site, with an RAI of 0.9456, and preventing the incorrect composition of concrete and materials on site (0.8281), were advocated. In addition, non-destructive testing of construction components can be used to ensure the required quality, and materials could be subjected to such tests to discover the level of their quality in order to make improvements (Nduka et al., 2018; Hollis, 2006). In addition to the above, the following actions should be taken: on-site quality management training; training construction workers on quality management; and introduction of a quality manual and establishment of a quality management system on site (Douglas, 2002; Ezeagu et al., 2014; Baby & Jebadurai, 2018).

Table 3 Parameters for curing system adequacy in building construction

In this section, the parameters for determining the adequacy of curing systems of concrete structures in building construction are presented.

S/N	Parameter	Relative Index
1	Adequate curing of concrete work is needed to mitigate cracks, thereby preventing collapse.	0.889
2	An appropriate curing period is needed for all concrete works to prevent deflections and collapse.	0.887
3	Thorough supervision is needed during the curing process to ensure it is performed adequately.	0.8723
4	The curing period should be placed in the programme of work to ensure time is allowed.	0.8424
5	The curing process should be continuous throughout the period, irrespective of any occurrence during construction process	0.8357
6	Management should ensure that the curing process is undertaken by contractors.	0.7780
7	Rapid hardening cement can be used to reduce the curing time during a short time frame.	0.7012
8	Only water provides the best curing function during the curing process	0.6471
9	Construction activities (i.e. casting and laying of blocks) should be discontinued on a building component that is undergoing curing.	0.6376
10	The use of contaminated water, such as sea or lagoon water, affects the curing process.	0.5690

Failure of structural components in buildings has been attributed to inappropriate curing of materials used for building, especially concrete. Adequate curing of concrete works is needed to mitigate cracks and could help prevent building collapse; and this is scored with an RAI value of 0.8894. In addition, an appropriate curing period is needed for all concrete works to prevent deflections and collapse, and this curing process should be continuous throughout the period, irrespective of any occurrence of mistakes during construction process; these issues were scored with RAI values of 0.8871 and 0.8357, respectively. The right type of cement and good quality water can improve the quality of concrete, while adequate precaution should be taken to ensure good quality building work (Folagbade, 1997; Ogunsemi, 2002; Akinpelu, 2002; Anyanwu, 2013; Nduka et al., 2018). Certain activities could be combined to ensure good site practice and which could lead to good quality structures and eliminate building collapse. These activities include discontinuing casting and the laying of blocks in structures that are undergoing curing since they are yet to develop full strength (RAI 0.6376); and that the curing period should be included in the programme of work (RAI 0.8424). However, above all, thorough supervision is needed during the curing process to ensure it is done adequately and to the best standard (Ozaki, 2003; Anumba et al., 2006; Oloyede et al., 2010; Amusan et al., 2018).

5. BUILDING INFORMATICS INTERVENTION DECISION MODEL

Table 4 presents the informatics factors that could help in decision making at various stages of building construction. They were collated and rotated using the factor reduction method of regression analysis; in this way they were reduced to 13. A summary of the rotated parameters and emergent factors are presented in the table.

Table 4 Rotated factors for the model

S/N	Factor	Eigenvalues		
1	Informing workers on the steps to ensure quality management could act as a measure to guarantee quality construction.	F4(1.0000)		
2	Thorough supervision of workers is needed by professionals for the execution of construction work following the design.	F1(0.9993)		
3	Excessive loading can be caused by improper alignment of structural members during construction.	F16(0.9980)		
4	High technical competence is needed before someone can be ascertained as a professional in the industry.	F1(0.9973)		
5	Construction works without an adequate number of professionals should be stopped by the governmental supervisory agencies.	F5(0.9969)		
6	Excessive dead loads on a building could cause increased loading, leading to failure.	F10(0.9967		
7	The use of a quality manager on site can help to prevent use of inferior materials.	F2(0.9965)		
8	An appropriate approach to design in construction could assist in mitigating building failure.	F8(0.9993)	F1(0.9977)	
9	Inadequate approaches to site and environmental conditions could result in building collapse.	F9(0.9988)	F1(0.9969)	
10	Appropriate approaches to the planning of site activities could help to avert building failure.	F5(0.9978)	F4(0.9970)	F13(0.9973)
11	An appropriate approach to building maintenance could help to mitigate building collapse.	F10(0.9983)	F5(0.9967)	F4(0.9969)

A summary of the intervention model is given below; the parameters presented are the action points that could be implemented to help prevent building collapse. These are as follows: prevent excessive dead loading of buildings, which can cause failure [F10 (0.9967]; the use of a quality manager on site can help to prevent the use of inferior materials [F2 (0.9965)]; an appropriate approach to design in construction could assist in mitigating building failure [F8 (0.9993) F1 (0.9969)]; an Inadequate approach to site and environmental conditions could result in building collapse [F9 (0.9988); +F1 (0.9969)]; an appropriate approach to the planning of site activities could help to avert building failure [F5 (0.9978); F4 (0.9970); F13 (0.9973)]; and finally, an appropriate approach to building maintenance could help to mitigate building collapse [F10 (0.9983); F5 (0.9967), F4 (0.9969)] (Akinpelu, 2002; Lekan et al., 2017; Alianto et al., 2017; Mohammadi & Mukhtar, 2018; Ogunsemi, 2002; Baby & Jebadurai, 2018).

6. CONCLUSION

From the analysis presented in the study, it has been established that professional qualification can lead to better performance on project sites, and that for professionals to be effective in preventing building collapse, minimum professional requirements are necessary; for example, a diploma in a construction-related discipline. Moreover, to ascertain material quality, non-destructive testing of construction components can be used to ensure the required quality and for improvements to be made. Similarly, excessive changes in the use of buildings could result in a reduction in the strength and stability of a structure, and therefore adding more structural components to cater for changes in use could help to prevent structural failures. The model presented could assist in safeguarding against building collapse if used during construction work with regard to issues that relate to the determination of the quality of materials, construction design and operation processes.

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