Assessment of types and significant causes of building defects in University of Ilorin, Ilorin, Nigeria

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Abstract

Cases of building collapse in Nigeria has been on the increase since the turn of the millennium. Yet, it has been observed that most of these buildings do not just give way and fail; they first show symptoms of distresses in the form of defects. It can be said that defects in buildings constitute undesirable challenges and threats to users. Thus, investigation studies were carried out in University of Ilorin on some of its buildings, so as to determine the types and major causes of defects with a view to ultimately suggest appropriate reducing measures. The research was divided into qualitative strategy which served to reveal physical extent, and quantitative strategy which helped to gather factual data and study the relationship between how such facts accord with findings and research of past literatures. Case study survey and questionnaire survey were used. While the former helped to present the frequency of defects as actually obtainable, the latter method of assignment provided the perception levels of study respondents (clients, consultants, contractors and end users) on defects in University of Ilorin buildings. Findings thus reveal that active cracks (>1.5mm wide) on beams, columns, slabs and walls are the most frequent type, while improperly sloped roof gutters are the least frequent type. Also, workmanship error accounted for the most probable cause of 70% of the type of defects, while defective material accounted for the most probable cause of 30% of the types of defects.

Keywords:
Defects, failure, buildings, construction industry, Unilorin.

Introduction

The rapid population explosion and technological advancement in all facets of life has made man to adapt to the environmental changes and secure a better form of housing to provide shelter for himself and his family. Man presently is not only after the provision of just any housing facilities but is reliant for both aesthetics and function. The functionality of building and its envelopes are dependent on its ability to act as a weather barrier, air barrier and thermal barrier (Wilson, 2013). It also includes the safety from fire, security as well as appearance and structural stability (Wong, 1998). The construction industry plays an essential role in the economic development of any developing nation (Kheni, Gibb & Dainty, 2008). Okeola (2009) averred that at least 50% of the investment in various development plans is primarily in construction and the industry is the next employer of labour after agriculture in underdeveloped countries. The construction industry in Nigeria generates almost 70% of the nation's fixed capital formation, in spite of that, its performance within the economy is very poor (Federal Office of Statistics, Abuja as cited in Arazi & Mahmoud, 2010).

The last decade however exposed the declining level of clients' satisfaction from the built facilities as a result of poor quality performance in addition to the perennial problems of time and cost overruns in the Nigerian construction industry (Arazi & Mahmoud, 2010). The performance of reinforced concrete structures can be severely reduced by poor design and construction techniques. These may cause reinforcement corrosions or degradation of the concrete itself, which in turn may lead to reinforcement corrosion. The creation and development of the systematic flow for assessment procedure will assist the consultant, engineer, architects and surveyors in selecting the better methods in order to minimize the defect and deterioration of building structures (Barry, 2002).

A building defect is any characteristics exhibited which hinders the usability of the building for the purpose for which it was designed and constructed. Defect is defined as 'frailty or shortcoming that prevents an item from being complete, desirable, effective, safe, or of merit, or makes it to malfunction or fail in purpose (businessdictionary.com, accessed 2016)'. It is the non-conformity of an element or fittings with respect to a standard that may, but will not necessarily result in failure (Kasim, 2009). Building defect occurs to either the new building or the old ones. Defect within new buildings maybe of non-compliance with Building Code and published acceptable tolerances and standards. Although, the older buildings or buildings out of warranty period, may not comply with these standards but must be judged against the standard at the time of construction or refurbishment. (Hall, 1988).

Most building defects are avoidable; they occur in general, not through a lack of basic knowledge but by non-application or misapplication of it (Douglas & Ransom, 2007). Systematic monitoring and assessment of concrete structures is imperative in order to maintain safe structures and keep costs of repair or replacement at a minimum. Structural evaluations, both destructive and nondestructive, are used for quality control and quality assurance purposes to locate defects or precursors to damage that will constrain the functionality of a structure. Unfortunately, defects are not typically noticed until they cause visible damage such as cracking and spalling. These observable “after- effects” are an indication that the structure has possibly undergone significant loss of strength due to poor design, overload, or simply a result of other structural damage such as reinforcement corrosion (FHWA, 2005).

University of Ilorin was identified for the study due to the rapid dynamism in its built environment. It has been widely adjudged to be one of the fastest growing public tertiary institution in terms of Infrastructure in Nigeria. Also, it has been recognized that most buildings in the study area are Reinforced Concrete Structures. However, with this high surge in buildings, it comes with the imminent fear as to how well standard practices are followed in designing, construction and maintaining these structures. Presence of defects in buildings within University of Ilorin poses great threats to its occupants and users. This is due to its wide and increasing occurrence that cuts across different building projects in the area. These anomalies can be due to inadequate design, poor workmanships in the construction and lack of maintenance of the built facilities (Soudki, 2009). The defects do not only impair on the aesthetics of the buildings making end users unhappy but also if improperly managed can be an imminent and impending disaster in the making i.e. failure (Seth, 2014).

The aim of this research work is to analyze and suggest appropriate reducing measures to defects in buildings within University of Ilorin. The specific objectives are to identify the types and extents of defects present, to probe the causes of the identified defects and to ultimately suggest measures that can help to mitigate construction defects in future projects within University of Ilorin.

2. Review of previous works

Barker (2004) stated that, construction management is suffering from various issues related to the quality of its practices; perhaps most of these are task deviations or defects. Despite notable developments in project management tools, methods and strategies that are often able to efficiently meet quality requirements, the construction industry is still affected by construction defects and rework. This has recently become a global issue (Sommerville, 2007). Most previous studies attribute task deviations and defects to three cornerstones: task characteristics, task-related factors e.g. people, equipment, etc. and the surrounding conditions of the task e.g. weather, site conditions, etc. (Booner, 1994). A task's propensity toward deviation or defects is also based on the degree of complexity (Love et al., 2009).

Defects that is not taken care of could lead to termination of the functionality of the entire structure; failure. For example, a cast-in-place concrete building is determined as "Unsafe", when any of the following three conditions exists: Buckled or fractured columns; Exposure of vertical column reinforcement; or Large diagonal cracks extending though columns. It is to this end that the Federal Emergency Management Agency (FEMA, 2009) identified the various collapse and check points as shown in the Figure 1.

Identifying the precise causal factor(s) of building defects is frequently an onerous task for any investigator (Addleson,1992). Constraints of access, time and resources often make the investigator's job difficult and demanding. When problems occur in buildings it is crucial that their root cause is properly identified.

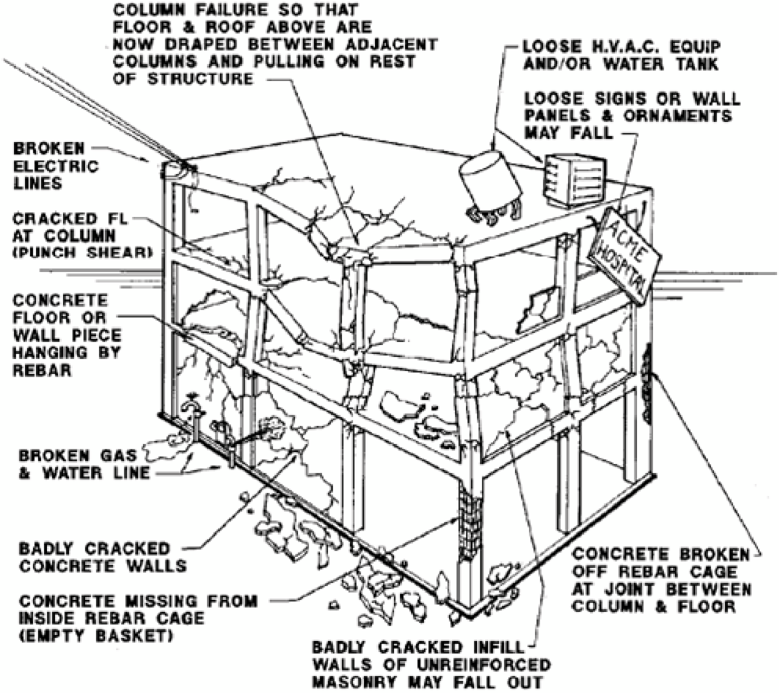

Figure 1: Collapse pattern and checkpoints (FEMA, 2009)

If the initial diagnosis is inadequate or mistaken, this may result in:

i. the significance of the defect being underestimated, leading to it being ignored, unattended to or marginalized.
ii. the significance of the defect being overestimated, leading to excessive or unnecessary remedial work.
iii. The wrong or inappropriate repair leading to the defect being ineffectively rectified, which could even aggravate the problem.

Clearly, considerable care is required, if scarce resources in terms of labour-hours, money and materials are not to be wasted on inappropriate or unnecessary repair work triggered by the wrong diagnosis. The proper identification of the cause(s) is also essential where the liability for the cost of remedial work is to be reasonably ascertained. Every type of building contains defects to some degree. The consequences of such defects may be minor, but others are more important and may affect the building's appearance and usage of the property. However, the cost of rectifying or (worse still) not rectifying building defects could be extensive. In more serious instances, they may pose a hazard to health and safety for those in and around the property (Douglas & Ransom, 2007).

According to FindLaw (2012), defects usually include any deficiency in the performance or furnishing of the design, planning, supervision, inspection, construction or observation of construction to any new home or building, where there is a fault to construct the building in a reasonably workmanlike manner and/or the structure fails to perform in the manner that is reasonably intended by the buyer. In the building industry, there are different approaches to classify defects, like by its severity, by construction stage, by type, by cause, etc. (Macarulla et al., 2013). Generally, Western Countries categorize construction defects in one of four categories: design deficiencies, material deficiencies, construction deficiencies, or subsurface deficiencies (FindLaw, 2012). For the purpose of this research, defects would be classified systematically into: Patent and Latent defects, Structural and Non-structural defects, Substructure and Superstructure defects, Interior and Exterior defects.

3. Methodology

Both qualitative (Visual Inspection) and quantitative research strategies were adopted. The quantitative research helped to gather factual data and studied the relationships between facts and how such facts and relationships accord with theories and the findings of any research previously executed. On the other hand, the qualitative approach helped to present first-hand the extent and frequencies of the identified defects in the case study. A holistic representation of the investigated buildings which were selected on the basis of faculty/unit is shown in Table 1. However, due to time constraints, limited number of buildings were captured.

Visual Inspection (Case study survey)
This being the most basic form of Non-destructive testing was employed. It involved the physical examination of these defects with the aid of the eyes. Visual inspection is an essential precursor to any non-destructive test (NDT). It involved observation, classification and documentation of distresses on the

exposed surfaces of the structures as it relates to workmanship, structural serviceability, and material deterioration.

Table 1: List of some of the investigated buildings.

No.	Name of Building
1	Department of Statistics Office Block.
2	Department of Chemical Engineering and Department of Biomedical Engineering Block.
3	Faculty of Law Block of classrooms.
4	Faculty of CIS
5	Department of Material and Metallurgical Engineering Block.
6	Department of Microbiology Block.
7	Faculty of Pharmaceutical Sciences Block.
8	Office Block and Laboratory for the Department of Optometry and Vision Science.
9	New Senate Chamber.

Its particular importance is that the researcher was able to differentiate between the various signs of distress which were encountered. These include cracks, pop-outs, spalling, disintegration, colour change, weathering, staining, surface blemishes and lack of uniformity. Extensive information was gathered from visual inspection to give a preliminary indication of the condition of the structure and to allow formulation of a subsequent testing programme if need be.

Data collection

Primary and secondary data were included in this research. Primary data gathered through observation, checklist and questionnaire with study participants such as consultants, contractors, client and end-users. Secondary data was sourced from literatures, reference books, journals, previous studies etc. written on similar topic. Particular information was obtained from the Physical Planning Unit on the profiles of the buildings on Campus. Required information such as list of consultants and contractors were culled out from the profiles earlier obtained to give a good respondent base.

Questionnaire administration

The methodology used utilize the questionnaire approach. Various checklist of factors, types, causes and effects of defects in buildings culled out from reviewed literatures were used. Then, thorough visual inspection of all the sample buildings were conducted where picture photographs as to reveal the extent of defects were taken. It was organized in the form of a priority scaling, i.e. Likert scale of agreements (1= strongly disagree, 2= disagree, 3= neutral, 4= agree and 5= strongly agree, and 1= not important, 2= less important, 3= moderately important, 4= important and 5= very significant). The analysis of the obtained results aimed at establishing the mean score (Average level of agreement) for the various parameters of building defects. This was done using the Statistical for Social Science (SPSS) program version 11. The score for each factor was then calculated by summing up scores assigned to its respondents. Therefore, the level of importance as indicated by the client & end users, contractors and consultants was used to measure the mean score of each factor.

4. Results and Discussion

4.1 Result of Visual Inspection

The survey was carried out on a total of nine (9) buildings using a checklist containing ten (10) different types of defects. The data obtained is as represented summarily in Table 2.

From Table 2, Non-structural/hairline cracks (<1.5mm wide) on notable concrete elements i.e. beams, columns, slabs and walls was observed to be the most prominent. All of the nine buildings used as case study had present in them this defect type. The next frequent defects observed was Paint peeling on façade face of walls, and Active cracks (>1.5mm wide) on slabs, beams and columns both of which ranked third (3^{rd}). Structural cracks (>1.5mm wide) on walls and Spalling of concrete from slabs, beams and/or columns both ranked fifth (5^{th}) in the order of frequency of occurrence. Three (3) out of the nine (9) buildings had problems of water damage or stains in ceilings, walls or floors. This defect type was ranked seventh (7^{th}). While two (2) of the buildings both had problems of seepage of water into the underside of roof and excessive deflection on beams and/or slabs, both coming as 8^{th} most frequent.

Table 2: Summary of observed building defects in descending order of frequency and rank (based on frequency of occurrence).

Defect Type	Frequency (No. of Buildings)	Rank
Hairline/non-structural cracks on walls.	9	1st
Hairline cracks (<1.5mm wide) on slabs, beams and/or columns.	9	1st
Paint peeling on façade faces of walls	5	3rd
Active cracks (>1.5mm wide) on slabs, beams and/or columns.	5	3rd
Structural cracks on walls.	4	5th
Spalling of concrete from slabs, beams and/or columns.	4	5th
Water damage or stains on ceilings and walls.	3	7th
Seepage of water into the underside of roof.	2	8th
Excessive deflection of beams and/or slabs.	2	8th
Improperly sloped roof gutters	1	10th

Only one of the buildings had an improperly sloped roof gutter and was ranked tenth (10th) in order of frequency.

4.2 Results and Analysis of Questionnaire Survey

Respondents' characteristics

This include information such as the respondent organization and job position and other general information on respondents. In this study, a total number of 40 questionnaires were distributed to the four (4) categories i.e. client, consultants, contractors and end-users. Out of the 40, only 32 was returned, which represents an eighty percent (80%) response rate. Figure 2 shows the categories of respondents. Out of the returned 32, 4 were from clients (12.5%), 7 from the end-users (21.9%), 16 from consultants (50%) and 5 from the contractors (15.6%). Specifically, 4 out of 6 clients responded to the questionnaires (66.7% response rate), 7 out of 8 end-users (87.5% response rate), 16 out of 18 consultants (88.9% response rate) and 5 out of 8 contractors (62.5% response rate). Figure 3 gives a pictorial appreciation of the varying response rates.

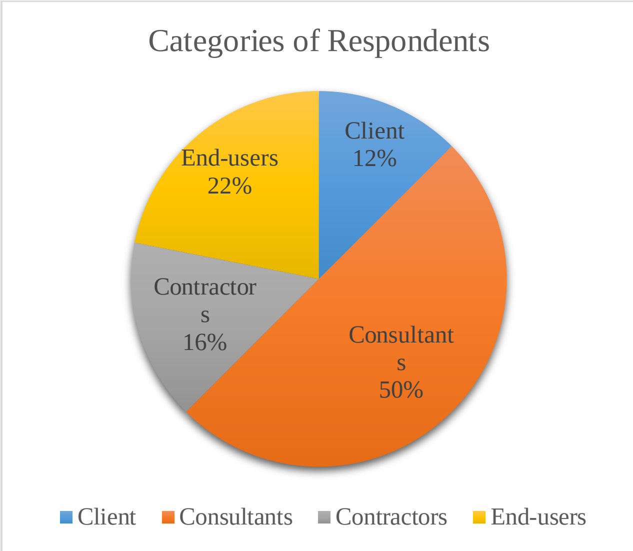

Figure 2: Categories of respondents

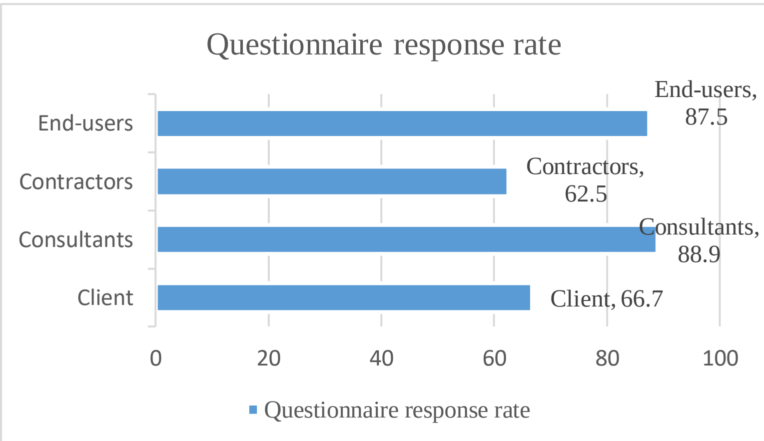

Figure 3: Questionnaire response rate

Table 3: Respondents' job positions.

Respondent's job position	Client	Consultants	Contractors	End-users
Graduate Engineer	--	2	--	--
Project Engineers	2	4	--	--
Assistant Engineer	--	2	--	--
Site Engineer	--	--	2	--
Senior Engineer	1	--	1	--
Architect	1	--	--	--

Table 3 shows that 4 (25%) of the consultants were Project Engineers, 2 (12.5%) were Graduate Engineers while another (2) 12.5% were Assistant Engineers. The remaining 8 (50%) did not disclose their job positions. Also, 40% of the contractors were Site Engineers while there was just 1 (25%) Senior Engineer within ranks. 2 (40%) others from the contractors' end did not disclose their job positions. For the Client (Works and Physical Planning Unit), there were 2 (28.6%) Project Engineers, 1 (14.3%) Site Engineer and 1 (14.3%) Architect. While none of the end-user was a professional from the civil engineering profession.

Table 4: Frequency of the levels of agreement.

S/No	Levels of Agreement	Frequency (X_i)	Percent (%)	Π chart Angle (◦)
1	Strongly agree	4	12.5	45.0
2	Agree	21	65.6	236.2
3	Neutral	5	15.6	56.2
4	Disagree	1	3.1	11.3
5	Strongly disagree	1	3.1	11.3
	Total	32	100	360

From Table 4, 12.5% of the respondents strongly agree that there is the presence of water stains or damage in ceilings and walls, 65.6% agree, 15.6% are neutral, 3.1% disagree and also 3.1% strongly disagree. The percentage of respondents that agree is significant enough to consider this as a defect type within the case study. The variation in level of agreements is shown pictorially in Figure 4 .

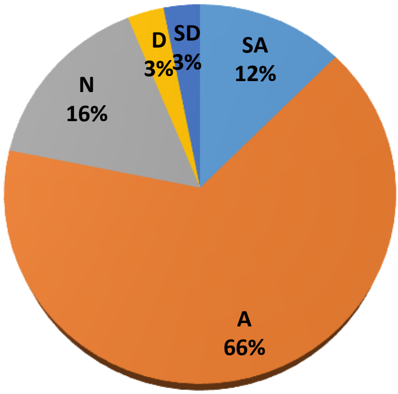

Figure 4: Varying levels of agreement on the presence of water stain on ceilings and walls. (SA- Strongly Agree, A- Agree, N- Neutral, D- Disagree, SD- Strongly Disagree).

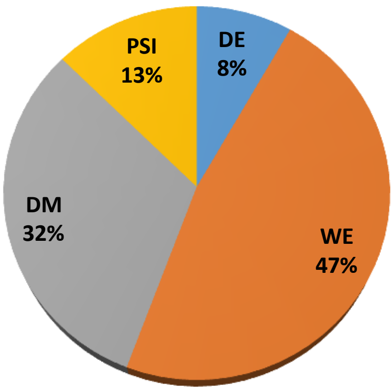

Figure 5: Variation in most probable causes of water damage and stains in ceilings and walls according to respondents. (DE- Design Error, WE- Workmanship Error, DM- Defective Material, PSI- Poor Subsurface Investigation).

Table 5: Frequency of the levels of agreement.

S/No	Levels of Agreement	Frequency (X_i)	Percent (%)	Π chart Angle (∘)
1	Strongly agree	5	15.6	56.2
2	Agree	19	59.4	213.8
3	Neutral	5	15.6	56.3
4	Disagree	2	6.3	22.5
5	Strongly disagree	1	3.1	11.2
	Total	32	100	360

From Table 5, 15.6% of the respondents strongly agree that there is the occurrence of seepage or leakage in the underside of roofs, 59.4% agree, 15.6% are neutral about it, 6.3% disagree and 3.1% strongly disagree. The percentage of respondents that agree is significant enough to consider this as a defect type within the case study. The variation in level of agreements is shown pictorially in Figure 6.

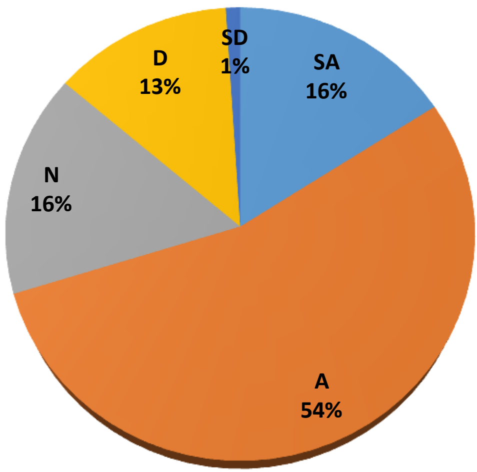

Figure 6: Varying levels of agreement on the occurrence of seepage or leakage of the underside of roofs. (SA- Strongly Agree, A- Agree, N- Neutral, D- Disagree, SD- Strongly Disagree).

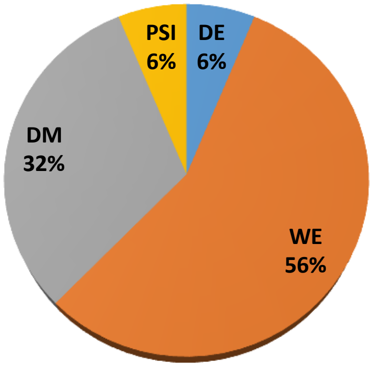

Figure 7: Variation in most probable causes of seepage or leakage of the underside of roof according to respondents. (DE- Design Error, WE-Workmanship Error, DM- Defective Material, PSI- Poor Subsurface Investigation).

5. Conclusion

There exists different types of defects in concrete elements in University of Ilorin, the extent of which varies in buildings. Such defect types include but not limited to active and hairline cracks (>1.5mm and <1.5mm wide respectively), spalling of concrete and excessive deflection, as they affect beams, slabs and columns; water damage or stains, paint peeling on façade faces of walls, structural cracks and hairline/non-structural cracks as they affect Ceilings and walls; and seepage/leakage of water into the underside of roof and improperly sloped gutters as they both affect roof.

From the analysis of the questionnaire data, Workmanship error accounted for the most probable cause of 70% of the types of defects, Majority of the respondents opined that proper and periodic maintenance, implementation of a comprehensive quality assurance and quality control plan, proper synergy between consultants' specifications and contractors' implementation and strict adherence to details from structural engineers are all very important measures in reducing defects in University of Ilorin buildings.

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