Original Article

An assessment of failure of building components in Nigeria

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ABSTRACT Building collapse is usually an outcome of progressive deterioration of the various components forming the building unit. This paper identified and assessed the nature and sources of both the generic and specific causes of failure of building components in Nigeria. Osun State was purposively sampled for the study. Data were obtained through use of a structured questionnaire, and results were analysed using a relative importance index. Analysis showed that building components tend to fail at different rates depending on the materials, designs, method of construction, environmental conditions and the use to which the building is put. Substandard materials and design errors were identified as major causes of component failure. The specific causes of failure of building components, apart from substandard materials and design errors, relate primarily to construction method and the use of the various components.

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INTRODUCTION

A building delivered to the satisfaction of the client and his consultants is one that is accepted as being of high quality and built using good levels of workmanship. This is, however, bound within the premises of estimated cost. In 2005 the Nigerian construction industry witnessed a number of high-profile building collapses. During this year, the property and environment column of the Vanguard Newspaper was painted black with incidences of collapsed structures across the length and breadth of the country, including the region of Osun. Building collapse is rarely a phenomenon that is beyond scientific explanation. There can be no failure of a building without a prior failure of some building components. The technology of construction can never guarantee complete elimination of some degree of failure because of the fact that structures settle down, however slightly, on completion, as a result of consolidation of subsoil imposed by the weight of the structure.

Thus, depending on the magnitude of this movement, failure can develop. In Nigeria, when a building collapses as a result of component failure, professional bodies tend not to accept responsibility for the incidence. Rather, each of the bodies that represent town planners, quantity surveyors, engineers, architects, builders and building organisation will often seek to attribute blame outside the profession. The loss of materials and money, cost of remedial measure, infliction of permanent injury, loss of life and so on, which result from building component failure, are both monetarily and psychologically significant. The rate of failure of building components in Nigeria is a cause for concern and as such demands urgent attention. Adequate measure will start once designers take a holistic consideration of their designs and become aware of the financial and psychological implication of any failure of the building components both during and after completion.

RELATED WORK

Some relevant earlier studies in this field include the works of Alan (1990), Ilesanmi (1988), Freddy (1999), Ayininuola and Olalusi (2004), Adejimi (2005), Olajumoke *et al* (2006) and Amobi (2006). Alan (1990) and Amobi (2006) identified building components as capable of failing in structure, function and aesthetics. Amobi (2006) classified factors that contribute to substructural components failures to include differential settlement of foundation, shear and plastic failures and design failures; and the superstructural components failures to include overloading, bulking, natural disaster, poor structural design, inferior materials, poor workmanship and overloading. Ayininuola and Olalusi (2004) identified factors contributing to building failure as including the use of substandard materials and engagement of quacks rather than professionals by clients in an attempt to cut down construction cost. Olajumoke *et al* (2006) identified causes of structural failure in slabs to inadequate thickness and inadequate reinforcement. The work of Freddy (1999) was on maintenance measure of buildings. These studies did not, however, assess the failure of the individual components and the specific causes of failure of the components. Adejimi (2005) opined that more effort during the design stage could help to prevent or reduce unnecessary maintenance problems that can come up later in the life of a building. According to Ilesanmi (1988), individual consideration of each component could help to prevent failure at low cost. Thus, we consider this study to provide useful information in assessing the cost implication of components failure in building.

METHODOLOGY

This research concentrated on the failure of building components and how this leads to building collapse. The selection of Osun State in southwestern Nigeria as the case study was triggered by a number of factors. Firstly, there is a regional culture of not using professional design and construction personnel, instead to tend to rely upon the use of non-professionally trained craftsmen. This is particularly prevalent with the building of residential dwellings, as most residential developers employ the services of craftsmen for the whole of building processes. Other practices that are reputedly typical of construction and building use in this region are the use of unprocessed locally sourced materials; volatility of change of building use; inadequate fixing of objects on building component (for example, nailing to walls, use of ceilings not designed as being load bearing for storage, hanging fresh animals carcasses from upper floor and so on), among many others, that characterise the construction and use of buildings in this area. Data for the study were collected through the use of survey questionnaires. Buildings considered were both residential and commercial, but not civic.

Table 1: Type of respondents

<i>Respondents</i>	<i>Number administered</i>	<i>Number collected</i>	<i>Percentage</i>
Architects	20	18	20
Quantity surveyor	20	18	20
Builders	20	14	15.56
Engineers	20	14	15.56
Estate valuers	20	16	17.77
Town planners	20	10	11.11
Total	120	90	100

Table 2: Academic qualification of the respondents

<i>Qualification</i>	<i>Number of respondents</i>	<i>Percentage</i>
Ph.D.	1	1.11
M.Sc./M.Tech.	7	7.78
B.Sc./B.Tech.	20	22.22
Postgraduate Diploma	14	15.56
HND (Higher National Diploma)	45	50.00
OND (Ordinary National Diploma)	3	3.33
Total	90	100

A total of 120 questionnaires were administered to professionals, including architects, quantity surveyors, town planners, engineers, estate surveyors and builders. A total of 90 questionnaires representing 75 per cent of total administered were completed and returned for the analysis. The response rate is as shown in Table 1. The questionnaires were of two parts: the first part identified the demographic features of the respondents, and the second part identified both the general and specific causes of building components failures. Each of these was presented in tables. The data were analysed using a relative index ranking. Both the general and specific causes of component failure for various building elements were assessed, and they were ranked on the extent to which they affect the specific failure of the particular component to be studied.

DATA ANALYSIS

The statistical tools used for data analysis are:

1. Table and percentage with respect to explanation.
2. Descriptive analysis: Relative importance index. The formula for the analysis is given below:

$$\frac{\sum_{i=2}^{n=5} n_i k_i}{\sum NXRh}, \text{ that is } \frac{5n_5 + 4n_4 + 3n_3 + 1n_1}{\sum NXRh} \quad (1)$$

where $\sum N$ is the total of questionnaire collected and Rh is the highest value in ranking order.

RESULTS AND DISCUSSIONS

Tables 1–4 represent the type, academic qualification, working experience and the professional qualification of the respondents, respectively. Table 2 shows the minimum

academic qualification of the respondents to be National Diploma, and this represents only 3.33 per cent of the respondents. The average year of experience of the respondents is estimated at 8 years; and 48 respondents representing 53 per cent of the total respondents are either associate or corporate members of their various professional bodies. We are convinced that our respondents possess adequate qualification and experience to supply reliable data for this study and through their professional standing will afford accurate data.

Table 5 shows that the use of substandard materials ranks first among the general causes of failure of building component with relative importance ranking of 0.84. This may be attributed to economic considerations in an attempt to maximise construction profit, aided by there being little or no checking by the Standard Organization of Nigeria on the use of quality materials. Following this closely is the category of failure attributed to 'Design Error'. *Force majeure* is identified as the least general cause with relative importance of 0.34. Although this actually rarely occurs in Nigeria, it cannot, however, be overlooked.

Table 6 indicates that building foundation failure is attributed mostly to the nature of soil, overloading and persistent leaking of drains in that order. This may be because many residential building developers are either unaware of the need for soil investigation before construction work or see it as a needless activity. Overloading can occur if calculation of

Table 3: Working experience of respondents

<i>Years</i>	<i>Mid point</i>	<i>Frequency</i>	<i>Fx</i>
0–5	2.5	47	11.75
6–10	8	13	104
11–15	13	11	143
16–20	18	7	126
21–26	23	5	115
26 and above	26	5	130
Total		90	735.5

Mean = 8.

Table 4: Professional qualification of respondents

<i>Professional</i>	<i>Number of respondents</i>	<i>Percentage</i>
Nigerian Institute of Quantity Surveyors (NIQS)	10	20.83
Nigerian Institute of Building (NIOB)	6	12.50
Nigerian Institute of Architects (NIA)	7	14.58
Nigerian Institute of Estate Valuers and Surveyors (NIEVS)	7	14.58
Nigerian Institute of Town Planners (TPL)	8	16.67
Nigerian Society of Engineers (NSE)	10	20.83
Total	48	100

Table 5: General causes of failure of building components

<i>General causes</i>	<i>5</i>	<i>4</i>	<i>3</i>	<i>2</i>	<i>1</i>	<i>Frequency</i>	<i>R/I</i>	<i>Rank</i>
Natural effects	2	1	17	38	32	90	0.38	7
Design errors	22	38	23	6	1	90	0.76	2
Use of substandard materials	38	35	12	5	0	90	0.84	1
Poor workmanship	12	39	27	10	2	90	0.70	5
Poor construction techniques	13	36	30	11	0	90	0.71	4
Lack of maintenance culture	11	33	29	17	0	90	0.68	6
Incompetent subcontractors	17	32	29	12	0	90	0.72	3
<i>Force majeure</i>	0	4	17	17	52	90	0.34	8

Table 6: Specific causes of failure of building foundation

<i>Specific causes</i>	5	4	3	2	1	<i>Frequency</i>	<i>RII</i>	<i>Rank</i>
Nature of soils	17	25	24	18	6	90	0.66	1
Seasonal weather changes	1	7	26	35	21	90	0.45	7
Natural phenomena	6	11	18	28	27	90	0.47	6
Overloading	24	18	13	26	9	90	0.65	2
Inadequate compacted fill	7	18	34	15	16	90	0.56	4
Foundation washed away by storm	7	16	28	21	18	90	0.54	5
Persistent leaking drains	5	24	27	21	13	90	0.57	3

Figure 1: Foundation failure.**Table 7:** Specific cause of failure of building floors

<i>Specific causes</i>	5	4	3	2	1	<i>Frequency</i>	<i>RII</i>	<i>Rank</i>
Abuse and damage by occupants	20	27	19	13	11	90	3.36	2
Normal wear and tear	9	11	31	24	15	90	2.72	5
Lack of DPC and tanking	26	23	26	13	2	90	3.64	1
Attack by fungi and termite (suspended ground floor)	10	28	33	16	3	90	3.29	3
Hollow block not filled solid in foundation	6	25	25	18	16	90	2.86	4

forces and loads upon building components is not professionally done before construction commences. Seasonal weather changes and natural phenomena are likewise factors to consider; however, these hardly affect foundation failure in this area (Figure 1).

The analysis presented in Table 7 shows that most building floors fail as a result of absence of damp roof course/membrane, and abuse and damage of floor by occupants. This is a true reflection of situation in this area where people make firewood cooking, pounding, grinding and so on, on the floor. Where damp proof course/damp proof membrane (DPC/DPM) is restricted mostly to public and corporate development, residential developers hardly introduce DPC/DPM into their constructions. The result also indicates attack by fungi and termite as a specific cause, but this is restricted to suspended ground floor. Normal wear and tear and hollow block not filled solid in foundation, though are also factors to consider, they are of little effect on floor failure.

Table 8 shows that building wall failure is owing to use of unsuitable mortar, poor bonding and absence of projecting features, resulting in rain water carrying deposit to faces of wall in that order. This can be attributed to inadequate levels of workmanship

Table 8: Specific causes of failure of building walls

<i>Specific causes</i>	<i>5</i>	<i>4</i>	<i>3</i>	<i>2</i>	<i>1</i>	<i>Frequency</i>	<i>RII</i>	<i>Rank</i>
Wall not allowed to dry out before painting	7	19	24	30	10	90	2.81	5
Using unsuitable mortar	6	41	31	11	1	90	3.44	1
Poor bonding	19	27	19	14	11	90	3.21	2
Absence of projecting features resulting in rain water carrying deposit to faces of wall	6	26	40	13	5	90	3.17	3
Abuse and damage by occupants	11	27	26	16	10	90	3.14	4

Figure 2: Wall failure because of defective bonding and defective workmanship.

Table 9: Specific causes of failure of roof

<i>Specific causes</i>	<i>5</i>	<i>4</i>	<i>3</i>	<i>2</i>	<i>1</i>	<i>Frequency</i>	<i>RII</i>	<i>Rank</i>
Inadequate lapping of roof covering	12	33	28	16	1	90	0.69	4
Inadequate eave projection	6	15	33	24	12	90	0.55	7
Using of immature wood/timber	38	31	17	4	0	90	0.83	1
Defective flashing and cement fillers	7	21	25	27	10	90	0.57	6
Poor bitumen roofing felt	5	30	30	15	10	90	0.61	5
Poor/inadequate seasoning of timber	36	30	18	6	0	90	0.81	2
Attack by termite and fungi	31	30	25	3	1	90	0.79	3

Figure 3: Roof failure because of (a) inadequate eave projection and termite attack and (b) termite attack alone.

Table 10: Specific causes of failure of structural elements

<i>Specific causes</i>	<i>5</i>	<i>4</i>	<i>3</i>	<i>2</i>	<i>1</i>	<i>Frequency</i>	<i>RII</i>	<i>Rank</i>
Type, proportion, grading and quality of aggregates	32	31	21	5	1	90	0.80	1
Water/cement ratio	19	33	23	11	4	90	0.71	6
Overloading	23	40	19	7	1	90	0.77	2
Corrosion of reinforcement bars	17	25	43	4	1	90	0.71	6
Type and quality of reinforcement	18	34	24	13	1	90	0.72	5
Deviation from standard specification	31	28	17	13	1	90	0.77	2
Inadequate compaction and curing	20	37	30	3	0	90	0.76	4

Figure 4: (a) and (b) Structural element failures.

in an industry dominated by tradesmen operating outside professional control. Following closely to these in the ranking is abuse and damage by occupants. These abuses include nailing on the wall and others. Wall not allowed to dry out before painting with relative importance of 2.81 comes last in the ranking. This may not be a serious specific cause, as this is only done where immediate commissioning is required (Figure 2).

Table 9 indicates the use of immature timber as the major cause of roof failure. This may be because of the fact that this type of timber is seriously prone to termite attack, which is also ranked third in the specific cause of roof failure. The result also identified inadequate eave projection as having the least impact on roof failure (Figure 3a and b).

Table 10 shows the type, proportion, grading and quality of aggregate with relative importance ranking of 0.80 as the most specific causes of structural element failure. This again could be attributed to attempts to maximise profits by reducing building material costs. This is followed by deviation from standard specifications and overloading, both receiving relative importance index of 0.77. Corrosion of reinforcement bars and water/cement ratio were also both ranked 0.71, and they are identified as the least specific causes of structural elements failure in building (see Figure 4a and b).

CONCLUSION

Building components tend to fail at a greater or lesser rate depending on some general and specific causes. Two major general causes held responsible for building components failures during this survey were the use of substandard materials and design error. Although the nature of soils and overloading are generally identified as being among the major specific causes of failure of building foundation, the survey established the lack of an efficient damp-proof membrane and failure to install appropriate tanking in the basement as being the highest factor responsible for failures to the ground floors of buildings. Another significant factor was identified as being abuse and damage by occupants. Failure of building walls was identified as often occurring as a consequence of the use of unsuitable cement/mortar ratio and poor bonding of the bricks. Inappropriate material choice was again identified as being a significant factor in roofing failure, with the use of immature wood/timber and poor/incomplete seasoning of timber being cited as a primary failure. Failure of structural elements in building is caused primarily by type, proportion, grading and quality of aggregate; and overloading and deviation from standard specification in use. Having identified all these factors/causes, it appears apparent that giving adequate consideration to them at both design and construction stages could help to reduce the deterioration rate of the building components and thus prolong the useful life of the components and the building as a whole. This would also go a long way to minimise future maintenance cost. To achieve this, however, building clients should learn to depend on qualified construction professionals rather than craftsmen. As inappropriate usage and overloading of building components was cited as being a significant factor, these professionals, in addition to rendering adequate services to clients, should endeavour to enlighten the clients on the appropriate use of the building as designed. This is particularly relevant for residential buildings.

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