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A Research Study on the Causes, Consequences and Remedies to Local Failures in Structural Elements in Buildings: A Case Study of Lagos State

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Abstract

The frequency at which buildings fail in Nigeria has become a serious concern, embarrassment and challenge to the construction industry. This occurrence has affected the entire human endeavor ranging from psychosomatic upset where lives, property are lost in their numbers. This paper is targeted at using structured questionnaires meticulously administered to over 300 professionals and clients in the construction industry. This exercise is intended to ascertain the leading types of building failures, causes, consequences of building failures and remedies to building collapse. The five Likert scale comprising strongly agree, agree, undecided, disagree and strongly disagree were employed. The responses were afterward analyzed using statistical variables like the weighted average, mean, ranking indexes. Based on the analysis obtained, the leading types of building failure ranges from Functional failure, Carbonation of concrete, Corrosion of reinforcement, spalling of members, Staining and soiling of the finishes. The causes of failure from the analysis were found to be Errors of computation in design, failure to account for loads the structure is expected to carry, erroneous theories in design, bad management decisions, frauds, not building according to drawing and specifications by the contractor. The consequences of local failures are reduction of flexural rigidity of the elements, collapse of building, adverse effect on appearance and Injuries/death Remedies obtain were to anticipate the most extreme way the material can contribute to a failure when selecting materials, building envelopes must resist thermal transfer and block movement of air and water from one side to another, make provisions for wet materials to dry out within the mold, ensure woods are not too dry or too wet. It is however of great importance for all stakeholders involved to rise to the situation thereby bringing about necessary changes in the built industry.

Keywords: Local Failure, Structural Element, Building, Professionals.

1.0 INTRODUCTION

Building can be defined as a structure with a roof and walls such as a house or a factory [1]. The wall here may include columns, beams to support floor slab, down to foundation which transfer the load from superstructure to sub-structure or bedrock. Collapse for a layman can be defined as a suddenly fall down or give way, or sudden failure [1].As soon as collapse occurs, there is little or no repair to restore to normality or completely. Structural elements such as slabs, beams, columns and foundations are elements designed and created to safely and economically transmit load from point of application to point of support [2]. They are composed of steel and concrete adequately bounded together since steel is strong in tension; it provides much of tensile strength required by the member while concrete which is strong in compression and weak in tension assists the steel in carrying the required tensile stress [2]. These structural elements will fail partially or totally when unduly overloaded or not built to specifications. These local or partial failures could be caused by exposure of reinforcement (in slabs, beams and columns), buckling of columns, slab and beam deflections, uneven settlement of foundations etc [3]. These local failures reduce the flexural rigidity of the elements, have adverse effect on appearance and consequently, if not properly remedied, lead to total collapse of building. It is therefore, necessary to study the causes of these local failures and suggest remedies to them, because of the serious consequences; it may have on safety of structures, lives and properties.

Deficiency in basic design and detailing of a member to provide sufficient resistance to normal loading is one of the causes of local problem in building [3]. The characteristic strength of concrete used in the design of structural elements is often higher than that achieved by local contractors. Also the characteristic strength of reinforcement recommended in British code used in design is often higher than that produced locally. [4]. Since the strength of concrete achieved by local contractors does not measure up to that used in design, the resistance of the concrete is drastically reduced when this already reduced tensile resistance of the concrete has been exceeded, failure in bond between concrete and steel occurs and finally exposes the reinforcement. Spall and exposure of reinforcement also occur due to poor detailing of structural elements, insufficient lap length especially in beams and columns to transfer stresses from one bar to the other [5-6].

Failure is an unacceptable difference between expected and observed performance. A failure can be considered occurring in an element when that element can no longer be relied upon to fulfil its principal functions. Excessive deflection resulting in serious damage to partitions, ceilings and floor finishes could be classed as a failure [6-7], ascribed faulty design, and faulty execution of work and use of faulty materials as major cause of structural failures. [7-8] attributed building failures in Nigeria to the following causes design faults (50%), faults on construction site (40%) and product failure (10%).

Idrus, A.B [9] categorized the following as major causes of structural failures. Environmental changes, natural and man-made hazards, improper presentation and interpretation in the design. Ejeh, S.P [10] opined that deterioration of reinforced concrete could occur as a result of corrosion of the reinforcement caused by carbonation and chloride ingress, cracking caused by overloading, subsidence or basic design faults and construction defects.

1.1.1 AIM AND OBJECTIVES

The aim of this study is to identify the various possible causes, consequences and remedies to local failures in buildings. The specific objectives are:

- To administer structured questionnaires to professionals in the built industry
- To seek relevant professional data within the built industry
- To determine weighted average, mean and ranking indexes
- To use the ranking technique to ascertain the leading causes, consequences and remedies to local failure in buildings

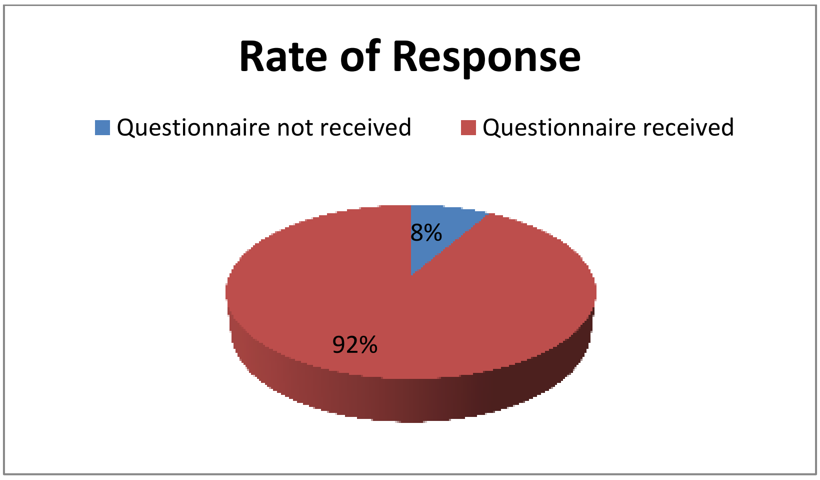

Figure 1.1: Rate of Response

1.2 ANALYSIS ON RESPONSE

Figure1.1 shows that 600 questionnaires were administered and 550 were recovered. This represents a response rate of 92% while those that were not received are 8%. It is an indication of good response from responders.

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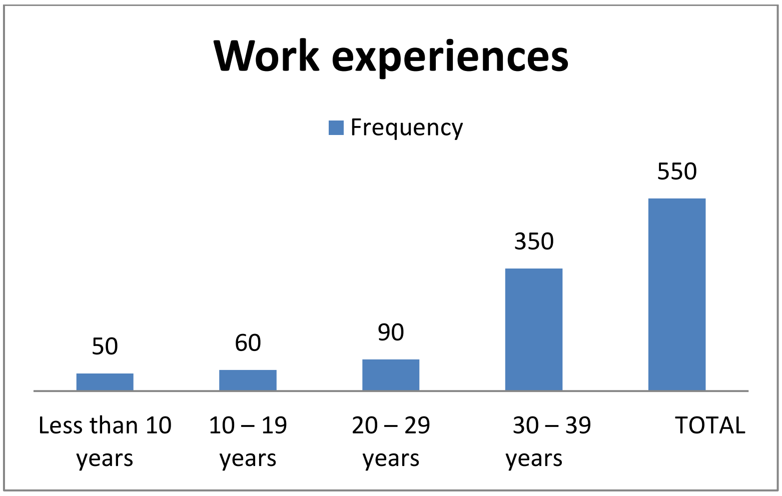

Figure 1.2: Work Experiences

1.3 ANALYSIS ON WORK EXPERIENCES

Figure 1.2 shows that 50 of the responders, most of who are professionals in the built environment have less than 10 years of work experience and 60 have 10 to 19 years of experience. Furthermore, 90 have 20- 29 years of work experience, while 350 have 30-39 years of experience. This shows that 64% of the responders who are mainly professionals in the built environment have 30 to 39 years of experience; meaning that they possess adequate years of cognate experience.

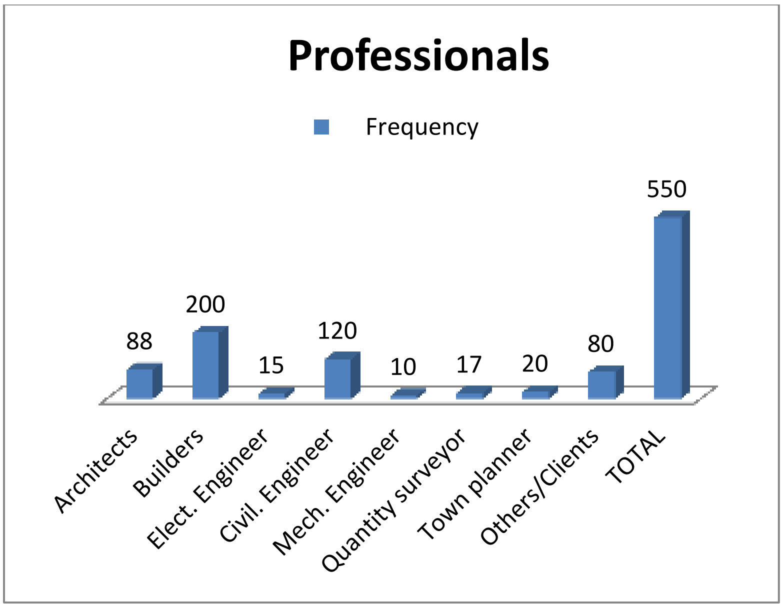

Figure 1.3: Professionals

1.4 ANALYSIS ON PROFESSIONALS

Figure 1.3 shows that 16% of the responders were Architects, 2.7% were Electrical engineers, 36.4% were builders, 1.8% was Mechanical engineers, 21.8% were Civil engineers, 3.1% were Quantity surveyors, 3.6% were town planners and 14.5% were other profession related and clients in the built environment. Thus, the responders are capable of providing information for this study based on professional point of view.

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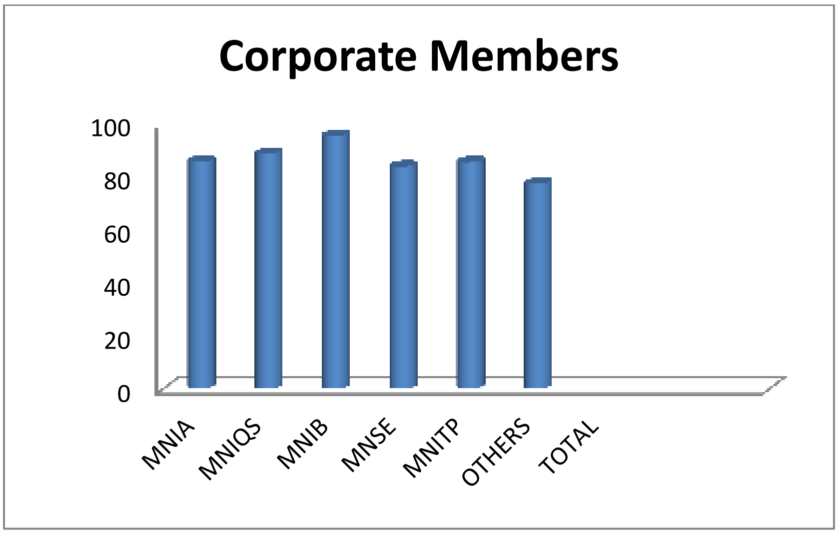

Figure 1.4: Corporate Members

1.5 ANALYSIS ON CORPORATE MEMBERS

Figure 1.4 shows that 75 out of 88, of the responders were registered architects, 15 out of 17 were registered quantity surveyors, 190 out of 200 were registered builders, 100 out of 120 were registered engineers and 100 out of 130 were other professionals related to the built environment. This showed that the responders were primarily registered professionals and is expected to be better informed on local failures in structural elements of buildings.

2.0 METHODOLOGY

2.1 PRIMARY DATA

Primary data would have been gotten from the administration of structured questionnaires, visual inspections and in-situ testing of materials in the study areas. Questionnaires would be divided into 3 sections. Section A and B would be administered to all professionals in design construction team while section A and C would be administered to clients. The visual inspection would reveal the position, types and sizes of structural elements used, nature and size of reinforcement, the cover to reinforcement, the geology of the areas, design calculations and drawings. The in-situ testing would involve non-destructive test and destructive test. The non-destructive test would make use of the concrete test hammer and the ultrasonic pulse velocity machine. This would give approximate information on the strength of the structural elements. The non-destructive test would also involve the use of the cover metre to determine the location and cover to reinforcement embedded in the concrete. On the other hand, the destructive test would make use of X-ray coring machine and penetration resistance apparatus. This would provide compressive strength and possible tensile strength of materials.

2.2 SECONDARY DATA

The secondary data would be gotten from Nigerian Institute of Building (NIOB), Nigerian Institute of Structural Engineers (NISE), Council for the Regulation of Engineering (COREN), local authority (Town planners), Ministry of Environment and few media houses. The information to be gotten from the aforesaid bodies/establishments is expected to reveal some possible causes of structural failures and building collapses and also the effects on lives and properties.

2.3 METHOD OF DATA ANALYSIS

In this study, the respondents were requested to rate their level of agreement with the identified attributes on a 5-point Likert scale (1= strongly disagree, 2= disagree, 3= neutral, 4= agree and 5= strongly agree). The designated value of 1,2,3,4 and 5 were used to allot weight to the options in the course of analysis. The Weighted Value (WV) for each criterion was obtained by the product of the number of responses for each rating to a criterion and the respective weight of the value expressed as:

$$WV = F_i * V_i \quad (1)$$

Where WV is the weight value, F_i is the frequency of respondents rating attributes i and V_i is the weight attached to attribute i.

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The Summation of Weighted Value (SWV) for each factor was obtained by summing the product of the number of responses for each rating to a criterion and the respective weight of the value expressed as:

$$SWV = \sum_{i=0}^{5} F_i * V_i \qquad (2)$$

Where SWV was the total weight value, F_i is the frequency of respondents rating criterion i and V_i was the weight attached to attribute i. The average mean score was obtained by dividing the SWV of each and the total number of responders (N=550). This was expressed as:

$$Mean = \frac{SWV = \sum_{i=0}^{5} F_i * V_i}{N} \qquad (3)$$

RII is a structured technique to quantify the relative variation. The analysis is similar to that of mean ranking. However, RII was obtained in this study by dividing the SWV of each attribute by the product of the highest rating score (A=5) and the total number of respondents (N=550). This was expressed as:

$$RII = \frac{SWV = \sum_{i=0}^{5} F_i * V_i}{N * A} \qquad (4)$$

2.4 TYPES OF FAILURE

The ranking indexes for the attributes were later computed from the results of the ratings generated from the analysis.

Table 1.1: Types of failure on different storey buildings

Types of Failure	Type of Storey buildings					
	Above three Storey		Three Storey		Two Storey	
	RII	Rank	RII	Rank	RII	Rank
Aesthetic failure	0.966	3	0.938	5	0.966	3
Concrete shrinkage cracking	0.786	12	0.905	7	0.84	8
Flaking and peeling of paintwork	0.793	11	0.705	17	0.751	14
Staining and soiling of the finishes	0.959	4	0.962	2	0.982	1
Functional failure	0.986	1	0.951	4	0.972	2
Leaks in elements such as roofs, walls and floors	0.924	6	0.831	10	0.809	10
Failure of materials	0.834	9	0.836	9	0.831	9
Chemical attack of rendering or concrete, mortar or brick	0.979	2	0.964	1	0.982	1
Fungal attack of timber	0.966	3	0.959	3	0.972	2
System failure of components and elements	0.897	7	0.856	8	0.883	7
Carbonation of concrete	0.986	1	0.951	4	0.963	4
Corrosion of reinforcement and spalling of members	0.986	1	0.921	6	0.926	5

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Subsidence caused by downward movement of building	0.807	10	0.8	11	0.8	11
Deboning of plaster	0.772	14	0.754	13	0.742	15
Roof tiles and slate are delamination	0.779	13	0.728	15	0.769	13
Excessive distortion in beam, column or wall owing to structural movement	0.938	5	0.905	7	0.902	6
Quality and availability of regulator documentation	0.869	8	0.795	12	0.809	10
Site condition	0.71	16	0.751	14	0.775	12
Air quality impact	0.566	18	0.618	20	0.643	19
Noise level impact	0.628	17	0.621	19	0.671	18
Waste management around the site	0.71	16	0.672	18	0.708	17
Climate condition	0.745	15	0.708	16	0.729	16

2.5 ANALYSIS ON TYPES OF FAILURE

Table 1.1 shows various types of failure peculiar to the built industry. From the analysis obtained, the leading failures as shown from the table for different storey buildings are: Functional failure, Carbonation of concrete, Corrosion of reinforcement, spalling of members, Staining and soiling of the finishes.

Table 1.2: Causes of local failure in buildings

Causes of Failure	1	2	3	4	5	SWV	RII	Rank
Not building according to drawing and specifications by contractor	0	2	15	176	610	803	0.934	5th
Inadequate supervision and control of site operation and quality control	1	4	66	468	150	689	0.801	14th
Extra-ordinary load	1	2	135	464	45	647	0.752	16th
Earthquake/hurricane/heavy rain	1	12	177	292	165	647	0.752	16th
Defective site (sinking holes or swampy land)	0	2	39	196	545	782	0.909	8th
Errors of computation in design	0	2	9	72	750	833	0.969	1st
Failure to account for loads the structure is expected to carry	0	2	12	160	635	809	0.941	3rd
Erroneous theories in design	0	4	18	124	665	811	0.943	2nd
Reliance on inaccurate data	0	2	27	352	370	751	0.873	9th
Improper choice of materials/ misunderstanding their properties	0	2	150	268	270	690	0.802	13th
Lack of experience	0	6	174	368	95	643	0.748	16th
Poor labor productivity	1	0	54	448	205	708	0.823	10th
Bad management decisions	1	6	30	92	675	804	0.935	4th
Frauds	0	2	39	128	630	799	0.929	6th
Lack of control/supervision system	0	14	255	244	95	608	0.707	17th
Lack of communication system	0	20	243	248	95	606	0.705	19th
Lack of experience by building contractor	0	12	48	416	230	706	0.821	11th
Faulty execution of work	0	2	27	216	540	785	0.913	7th
Buckling of columns, slab and beam deflections	0	6	36	512	145	699	0.813	12th
Uneven settlement of foundations	0	14	129	420	85	648	0.753	15th
Use of faulty materials	7	52	267	176	30	532	0.619	20th

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2.6 ANALYSIS ON CAUSES OF FAILURE

Table 1.2 shows various causes of failure common to the built industry. From the analysis obtained, the leading causes of failures as shown are: Errors of computation in design, failure to account for loads the structure is expected to carry, erroneous theories in design, bad management decisions, frauds, not building according to drawing and specifications by contractor.

Table 1.3: Consequences of local failure in buildings

Consequences of Failure	1	2	3	4	5	SWV	RII	Rank
Injuries/death	0	2	15	176	610	803	0.934	4th
Structural damage	1	4	66	468	150	689	0.801	8th
Damage to contents	1	2	135	464	45	647	0.752	9th
Loss of functionality	1	12	177	292	165	647	0.752	9th
Environmental damage	0	2	39	196	545	782	0.909	5th
local failures reduce the flexural rigidity of the elements	0	2	9	72	750	833	0.969	1st
have adverse effect on appearance	0	2	12	160	635	809	0.941	3rd
collapse of building	0	4	18	124	665	811	0.943	2nd
poor detailing of structural elements, insufficient lap length especially in beams and columns	0	2	27	352	370	751	0.873	6th
Excessive deflection resulting in serious damage to partitions, ceilings and floor finishes	0	2	150	268	270	690	0.802	7th

2.7 ANALYSIS ON CONSEQUENCES OF LOCAL FAILURE

Table 1.3 shows various consequences of failure common to the built industry. From the analysis obtained, the leading consequences of failures as shown are: local failures reduce the flexural rigidity of the elements, collapse of building, adverse effect on appearance and Injuries/death

Table 1.4: Remedies to local failure in buildings

Remedies to Failure	1	2	3	4	5	SWV	RII	Rank
Anticipate the most extreme way the material can contribute to a failure when selecting materials	0	2	15	176	610	803	0.934	1st
Make provisions for wet materials to dry out within the mold	1	4	66	468	150	689	0.801	3rd
Ensure woods are not too dry or too wet	1	2	135	464	45	647	0.752	4th

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Prioritize the continuity of building envelopes	1	12	177	292	165	647	0.752	4th
Building envelopes must resist thermal transfer and block movement of air and water from one side to another	0	2	39	196	545	782	0.909	2nd
Building assemblies must be designed to accommodate seismic forces	0	2	9	72	750	833	0.969	1st
Good & Adequate Supervision	0	2	12	160	635	809	0.941	3rd
Use Of Standard Materials	0	4	18	124	665	811	0.943	2nd
Involvement Of Professional Builders In The Construction Process	0	2	27	352	370	751	0.873	10th
Soil Investigation	0	2	150	268	270	690	0.802	14th
Discipline Of Professionals, If Proven They Are Involved In Failures	0	6	174	368	95	643	0.748	17th
Promulgation Of Appropriate Legislation Against Building Failure	1	0	54	448	205	708	0.823	11th
Compliance To Approved Drawings	1	6	30	92	675	804	0.935	4th
Proper Check Of Detailing By Builder And Design	0	2	39	128	630	799	0.929	6th
Correct Use And Installation Of Fittings	0	14	255	244	95	608	0.707	19th
Involvement Of Professional Builders In The Composition Of Building Regulation	0	20	243	248	95	606	0.705	20th
Strict Compliance To Data Available And Geotechnical Properties Of The Soil	0	12	48	416	230	706	0.821	12th
Prompt And Necessary Measure Towards Deterioration & Defect	0	2	27	216	540	785	0.913	7th
Publicity Of The Consequences Of Illegal Buildings	0	6	36	512	145	699	0.813	13th
Enforcement Of Insurance Of	0	14	129	420	85	648	0.753	16th

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Buildings Against Failures								
Adequate Site Investigation	7	52	267	176	30	532	0.619	23th
Education Of The Occupiers Of The Building	3	22	333	168	25	551	0.641	22th
Adequate Maintenance	1	8	255	316	15	595	0.692	21rd

2.8 ANALYSIS ON REMEDIES OF LOCAL FAILURE

Table 1.4 shows various remedies to local failure common to the built industry. From the analysis obtained, the leading remedies to failures as shown are: Anticipate the most extreme way the material can contribute to a failure when selecting materials, Building envelopes must resist thermal transfer and block movement of air and water from one side to another, Make provisions for wet materials to dry out within the mold, ensuring woods are not too dry or too wet

3.0 CONCLUSION

The entire study adopted the **r**anking technique to ascertain the leading causes, consequences and remedies to local failure in buildings in Nigeria. The five Likert scale comprising strongly agree, agree, undecided, disagree and strongly disagree were employed for all participants. The responses were afterward analyzed using statistical variables like the weighted average, mean, ranking indexes. Based on the analysis obtained, the leading types of building failure ranges from Functional failure, Carbonation of concrete, Corrosion of reinforcement, spalling of members, Staining and soiling of the finishes. The causes of failure from the analysis were found to be Errors of computation in design, failure to account for loads the structure is expected to carry, erroneous theories in design, bad management decisions, frauds, not building according to drawing and specifications by contractor. The consequences of local failures are reduction of flexural rigidity of the elements, collapse of building, adverse effect on appearance and Injuries/death Remedies obtain were to anticipate the most extreme way the material can contribute to a failure when selecting materials, building envelopes must resist thermal transfer and block movement of air and water from one side to another, make provisions for wet materials to dry out within the mold, ensure woods are not too dry or too wet.

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