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Effect of Faulty Design on Construction and Maintenance of Buildings in Asaba, Delta State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author JCI initiated the idea, designed, carried out data acquisition and compiled the first draft of the manuscript. Author KCO supervise every stage of the work and proof read the original manuscript. Author FOE managed the literature searches and analysis. All authors read and approved the final manuscript.

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Case Study

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ABSTRACT

Aim: The aim of this study is to evaluate how faulty design affects construction and maintenance of building projects in Asaba, Delta state with a view to establishing their level of occurrence and providing ways of mitigating them.
Study Design: It was a survey research, the study was effected via literature review and a well-structured questionnaire. Likewise, interviews were carried out to substantiate the findings of the questionnaire survey.
Place and Duration of the Study: The study was conducted in Asaba, Delta State, Nigeria for a period of 2 years.
Methodology: Being a survey research, 80 questionnaires were administered to the respondents and only 67 were returned which represents 84% response rate. The data collected was presented and analysed using tables, frequency, mean score and relative importance index. The analysis was

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aided by a computer-based software, named Statistical Package of Social Sciences (SPSS) version 22.

Results: The study found out that; inadequate structural design, lack of details, lack of inspection, inaccurate measurement, not complying with specification, use of expired materials, wrong use of equipment, inadequate performance of equipment, unclear specification were rated as the most severe defects in each of the groups. Also, the findings showed that defects found in the study are categorized as design deficiencies, material deficiencies, construction deficiencies and subsurface deficiencies.

Conclusion: The study concluded recommending that the designers must take into account maintenance issues during design and construction stages. Also, proper sensitization of building contractors with respect to durable materials which are suitable to the immediate environmental condition should be purse as well as the construction techniques and competence of workforce. Likewise, strict quality assurance and quality control (QA/QC) program should be encouraged during project design and construction.

Keywords: Design; construction; building; building defect; Asaba.

1. INTRODUCTION

The relationship between design, construction and maintenance is closely related but not easily distinguished. Accordingly Maisarah and Mastura [1] observed that a functional design can promote skill; economy, conveniences, and comforts while a non-functional design can impede activities of all types from quality of care, and raise cost to intolerable levels. Furthermore, [2] argued that most time, people pay attention to building project and little or no attention to maintenance. In a related development, [3] it was revealed that there are substantial numbers of people who do not know the meaning of maintenance. Consequently, many believes that building with best aesthetics design and materials requires little or no maintenance [4]. Also, [5] observed that the maintainability aspect at the design stage is often ignored and this has contributed to future problems when implementing maintenance work because aesthetics value was becoming more important in building projects than others variables. Furthermore, [6] observed that the effectiveness of the building is not dependent on its aesthetic value but on the ability to carry out maintenance works on the building in the future. If is not properly check would lead to the failure of the project in future [7].

Conversely, faulty building design and construction is becoming one of the major issues in building maintenances [8]. Its increase maintenance cost, either in the form of rework/rebuild or demolition, building failure [8]. Therefore, its sacrosanct for both the designer and the builder to consider the importance of maintenance at the onset of the design because decision made at the planning stage have a large effect on the maintenance of the building and the cost. However, [9] observed that most professionals ignore the aspect of maintenance during design, and when such design is accompanied by poor construction, it will result to poor buildings requiring constant maintenance during their life cycle. Also [10,11] observed that designers are usually unaware of the consequences of their design solutions until during post-occupancy survey. Therefore, it is imperative to consider maintenance at both design and construction stages by incorporating maintenance variables in order to trim subsequent maintenance effort during occupancy [9,12,13]. Accordingly [9,14] stated that for the design process to be enhanced, the building team members (architects, planners, engineers, contractors, facility managers and all major actors in the construction industry) need to come together and contribute towards the building maintainability at the project inception rather than leaving it for the maintenance personnel at the end of construction to battle with emergency maintenance.

In Asaba the study area, [15] observed that most buildings have suffered as a result of lack of maintenance which is manifested in public housing in all major urban centres in Asaba, confirming declining investments in the maintenance of Buildings (Ofuani 2005). In a related study by Odama [16] on "Neighborhood management and maintenance in Nigeria'', confirmed that the country has had challenges of planning, development and management of its residential neighborhoods. This has resulted in deterioration of surrounding buildings and services due to lack of maintenance and unattended wear and tear caused by negligence by local authorities and Government agencies responsible for management of the built environment. Furthermore [16] attributed the high cost of housing maintenance to incorrect design decisions, poor workmanship, engineering shortcomings, lowering of standards and neglect due to lack of clear indication of responsibility. However, the prime objective of every design is to secure an attractive building; the one of high aesthetic value, it will also be appreciated that building serving different purpose tend to assume different forms, these forms have greater impact on construction maintenance culture which led to the emergence of this study. Therefore, this study aimed at assessing the faulty design and construction defects in building projects in Asaba, Delta state with a view to establishing their level of occurrence and providing ways of mitigating them.

2. LITERATURE REVIEW

2.1 Design Defect

Increase of maintenance cost or effort can be attributed to faulty designs. Many of these maintenance problems arise where the design is satisfactory in principle, but has low probability of achievement in practice [17]. This make the design unachievable during construction and if achieved, will required a lot in the part of workmanship. However, faults in building design place a heavy burden on the building for rest of its life and there is no compensation for it. In such situations, the responsibility falls on the shoulders of the designer to carefully consider issues that may affect the construction and maintenance of the building during design phase of the project [18]. Faulty design includes all defects that were caused during the early stage of design and particularly in the structural design such as: when designer ignores the spacing for contraction and expansion movement. Such movement causes cracking of the structure, which will result in fractures in pipes or joint failure [19].

According to Gibson [20], the implication of design fault on maintenance in buildings has resulted from the following:

i. The consequence of thermal movement: Thermal movement in materials can cause cracking in walls or plaster and fractures in structure elements if consideration has not been given to the thermal expansion. Thermal movement can also result in distortion of otherwise impervious joints with the result that penetration of water takes place or there is a loss of adhesion.
ii. The consequence of inefficient detailing: Inadequate detailing can cause deterioration of the building facade. In the absence of proper architectural detailing of rainwater discharge from the building face, water may penetrate into the building or stagnate within or on the construction
iii. The consequence of improper material selection: Incorrect material selection can add to the financial burden of maintenance, as well as be the cause of thermal movement, distortion, or early failure.
iv. The consequence of poor design for access for maintenance measures: Poor access for maintenance will cause delay in the repair process that escalates the cost and increases the probability of substandard remedial actions.

In the UK [21] stated that the use of a range of materials for the external envelope of a building can lead to differences in absorption pattern. The different levels of absorption of each material will affect the surface and cause concentration of water runoff with different pattern and staining on the facade. In Malaysia, [18] illustrated that thermal expansion, paint decay, cracks, dampness, and staining are the major defects that result from improper material selection and lack of knowledge regarding their physical properties that will affect future building maintenance. Additionally, dampness, fungi growth, surfaces decay and rot in wood are the major defects that result from poor ventilation design. In Singapore, an analysis of defects in wet areas of buildings by [22] illustrated that mastic failure, the staining of tiles, cracking, water leakage through cracks, water leakage where pipes passed through walls, paint defects, spalling of concrete, unevenness of tile surface and poor pointing are the most defects that result from mistakes made at the design stage, construction phase, maintenance practice and in materials selection.

2.2 Construction Defects

Defective construction works can be defined as works that fall short of complying with the express descriptions or requirements of the contract. Accordingly Olubodun [23] states the majority of modern buildings and civil structures are complex and involve the use of a great variety of engineering methods and processes.

Therefore, most projects face the possibility of defects and defective work, which generally result in structures that cannot perform their originally intended roles. Defective construction contributes to both the final cost of a project and the cost of maintenance, which can be substantial. Construction defects usually include any deficiency in the performing of the design, planning, supervision, inspection, construction, or observation of construction of any new home or building. The building is deficient if there is a failure during construction in other words, if the building does not perform in a manner that was intended by the buyer [24].

Construction defect are another source of the high cost of maintenance which happens during the construction stage and because of construction performance or material used. Faulty construction is one of the most common causes of early deterioration. Common construction faults include inadequate compaction and failure to position the reinforcement, so that it has adequate concrete cover. Under almost any exposure conditions these faults will eventually reduce the service life of the structure as a result of reinforcement rusting after the concrete has become carbonated [25]. As known, the environment of construction is constantly changing and the authorities' actions continuously give new conditions. At the same time, competition between companies may become stronger factor that leads the contractor accept the bid with low margin of profit. Studies show that the cost of defects in construction is in the range of 5-10% of the production cost. Therefore, knowledge of the causes of these defects is necessary for choosing adequate measures. Also, [26] Showed that 69% of all construction defect claims in U.S. are related to moisture penetration through the building envelope. It is injustice to beer this ratio to construction defects lonely, because these defects that relate to moisture penetration may result from using of bad insulation material or poor implementation of these materials. Defective construction includes activities such as compaction not done to specifications, which leads to ground movement and eventual failure of foundations. This may lead to the complete failure of a structure [27].

The Building Research Establishment (BRE) study showed that in London only a small portion of defects are attributable to faulty materials in terms of storing or placing in position [28]. Some manufactures of so-called high technology components have a little awareness of the rigors of a building site or the standard of accuracy achievable under such conditions. Thus, whilst the materials may be perfect on leaving the factory, they can quite easily be damaged during loading handling, unloading, storing or placing in position. Many such defects can be avoided by ensuring greater care at all stages in the process, proper training of operatives and closer supervision. To tackle this problem the construction industry is beginning to introduce the quality assurance techniques developed in other industries such as Quality Assurance (QA) groups and Quality Control (QC). Poor construction' is a broad term and it is associated with a number of faults, for example tile fixing, plastering, formwork, plumbing and flooring.

Therefore, it can be concluded that in order to avoid all such construction fault which can cause high future maintenance cost at a later stage, it is necessary to revise the traditional mode of procuring building construction by developing a correlation between designer and construction professionals [18].

3. METHODOLOGY

This study was a survey research and was carried out in Delta State, Nigeria. The population of this study consists of professionals in the Delta State Capital Territory Development Agency and Ministry of works particularly Architects, Builders and Civil Engineers. The questionnaires were distributed to the Professionals base on simple random sampling (see Table 1). 80 questionnaires were administered to the respondents and only 67 were returned which represents 84% response rate (see Table 2). Data were collected through the use of structured questionnaire. There were four (4) parameters that were used by the respondents to answer the questionnaires. The four (4) options given were Strongly affect, Moderately affect, Slightly affect and Does not affect. A four-scale point was used in solving the question provided. Being a descriptive research, tables, line –chart, mean and histogram were used for data presentation. However, Relative Important Index (RII) was used for ranking and computed using:

$$RII = \sum Fx / A*N$$

Where: $\sum Fx$ = Weight given to each statement by respondents and ranges 1 – 5;
A = Higher Response Integer; and
N = Total Number of Respondents

Table 1. Population distribution of the questionnaires and percentage response

Profession	No administer	No retrieved	Percent
Architects	25	20	30
Builders	40	38	57
Civil Engineers	15	9	13
Total	**80**	**67**	**100%**

Source: Field Survey (2019)

The analysis was carried out using SPSS version 20.

Table 1 shows that 25, 40 and 15 questionnaires were administered to Architect, Builders and Civil Engineers respectively in the study area, out which 20, 38 and 9 were retrieved respectively from the professionals. This corresponds to 30, 57 and 13% respectively.

Table 2 shows a total number of 80 questionnaires were distributed to the respondents in the study out of which 67 and 13 were returned and not returned respectively. This correspond to response rate of 84% and 16% respectively.

Table 2. Return rate of questionnaires

Questionnaires	Frequency	Percentage
Total of questionnaires administered	80	
No of questionnaires returned	67	84%
No of questionnaire not returned	13	16%
Total		**100%**

4. RESULTS AND DISCUSSION

The results listed Table 3 reveals that inadequate structural design such as foundation is ranked first with mean score of 3.52 and severity index of 117.3. Ignoring load impact on structural stability which ranked second with the mean score of 3.34 and severity index 111.33. Inadequate on the reinforcement ranked 3rd with the mean score of 3.16 and severity index of 105.33. Ignoring aggressive environment and weather condition effects and ignoring variation soil condition were considered not to have much effect on the defects on civil engineering design by the respondents and ranked 4th in the list with the mean score of 3.09 and severity index of 102.90. Improperly locating conduits and pipe openings at critical structure ranked 5th with mean score 2.58 and severity index of 86. Exceeding allowable deflection were ranked 6th with mean score 2.42 and severity index of 80.66. Ignoring wind effect on the structure can be seen from the list that most of the respondents said that it does not cause the defect on civil design and were ranked 7th with mean score 2.28 and severity index of 80. Inadequate provision for movement were ranked 8th with mean score 1.78 and severity index of 59.33%. Ignoring biological effect is the least ranked 9th with the mean score of 1.39 and severity index of 46.33. It can be seen from the list that most respondents were of the opinion that defects in civil engineering design will cause deterioration of building which will lead to early maintenance of building.

The results listed in Table 4 that the significant defects in Architectural design in the study area are: not relating exterior material to climate condition ranked first with a mean score and severity index of 3.49 and 116.33% respectively. Closely followed by narrows stair passages and door (3.46 and 115.33) and Not considering the local climate condition when designing the exterior shape (2.94 and 98.00). However, the least significant architectural defect in Table 4 are inadequate joints between finished faces (2.57 and 85.66) and specifying finishing which need to be repaired as whole such as wall paper (1.93 and 64.33). This implies that not considering the climatic condition during selection of building material (especially materials to be use in the exterior part of the building) will significantly cause deterioration of the building.

Table 5 shows respondents opinion on design defects in maintenance practicality and adequacy. Table 5 also shows the ranking of four (4) defects, from the ranking, not considering space or exit for maintenance worker, equipment has the highest cause of design defects in maintenance practicality and adequacy. Followed by designing for permanent fixing which should be removable for maintenance ranked second with mean score 3.09 and severity index of 103.

Not considering the available maintenance equipment when performing the design ranked 3rd with mean score 2.94 and severity index of 98. Not considering maintenance during design was ranked 4th with the mean score of 2.94 and severity index of 90.67. This implies that not considering maintenance issues during building design will aid in fast deterioration of building.

Table 6 Shows that lack of Quality Assurance (QA) / Quality Control (QC) program during design has the highest ranking with the mean score 3.34 and severity index of 111.33 followed by Hiring unqualified designers (3.18 and 106.00), Poor technical updating or staff training (3.09 and 103.00), Designers field experience (3.01 and severity 100.33) ranked 2nd, 3rd and 4th respectively. Whereas, Misjudgment of users intended use (2.34 and 78.00) and Misjudgment of climate condition (2.46 and 82.80) ranked least respectively.

Table 7 shows that the lack of details in construction drawing ranked first among the defects due to construction drawing in the study area with a mean score of 3.61 and severity index of 120.33. Followed by lack of references with a mean score of 3.31 and severity index of 110.33 and conflicting details with a mean score of 3.04 and seventy index of 101.33. This implies that the lack of detailing in construction drawing leads to defects in construction.

In Table 8, lack of inspection was ranked 1st with mean score of 3.60 and severity index of 120.00 as defects due to construction inspection. Others according to their ranking are Unqualified inspectors (3.47 and 115.67). Proponent (owners), Negligence of importance of inspection (2.49 and 83.00), Weakness of inspection rule in implementing corrective actions during job execution (2.48 and 82.67). Consequently, these four defects in the construction inspection affect greatly the construction which will lead to costly maintenance.

From the opinion of the respondents listed in Table 9, the major defect in Civil/Building

Table 3. Defects in civil engineering design

	4	3	2	1	MS	R	Severity Index (SI)
Inadequate provision for movement	10	5	12	40	1.78	8	59.33
Ignoring aggressive environment and weather condition effects	35	15	5	12	3.09	4	102.90
Ignoring biological effect	2	5	10	50	1.39	9	46.33
Ignoring variation soil condition	30	20	10	7	3.09	4	102.90
Inadequate structural design such as foundation	47	10	8	2	3.52	1	117.33
Ignoring load impact on structural stability	40	15	7	5	3.34	2	111.33
Exceeding allowable deflection	15	10	30	12	2.42	6	80.66
Ignoring wind effect on the structure	10	8	40	9	2.28	7	80.00
Improperly locating conducts and pipe openings at critical structures	15	28	5	19	2.58	5	86.00
Inadequate concrete cover on the reinforcement	30	25	5	7	3.16	3	105.33

4: Strongly affect, 3: Moderately affect, 2: Slightly affect, 1: Does not affect, MS: Mean score, R: Ranking

Table 4. Defects in architectural design

Items	4	3	2	1	MS	R	Severity Index (SI)
Narrow stair passage and doors	30	25	15	7	3.46	2	115.33
Not relating exterior material selection to climate condition	45	15	2	5	3.49	1	116.33
Specifying finishing which need to be registered as whole (such as wall papers)	3	4	45	15	1.93	5	64.33
Not considering the local climate condition when designing the exterior shape	25	20	15	7	2.94	3	98.00
Inadequate joints between finished faces.	20	15	15	17	2.57	4	85.66

4: Strongly affect, 3: Moderately affect, 2: Slightly affect, 1: Does not affect, MS: Mean score, R: Ranking

Table 5. Design defects in maintenance practicality and adequacy

Items	4	3	2	1	MS	R	Severity Index (SI)
Not considering space or exit for maintenance worker, equipment	35	25	5	2	3.39	1	113.00
Designing for permanent fixing which should be removable for maintenance.	30	20	10	7	3.09	2	103.00
Not considering the available maintenance equipment when performing the design	25	20	15	7	2.94	3	98.00
Not considering the maintenance during design	20	15	15	7	2.92	4	90.69

4: Strongly affect, 3: Moderately affect, 2: Slightly affect, 1: Does not affect, MS: Mean score, R: Ranking

construction are: inaccurate measurement (3.61 and 120.34), damaged formwork (3.46 and 115.34%) and excavation tool close to the building (3.31 and 110.34). Others are painting in unsuitable conditions or unsuitable surface (3.24 and 108.08), insufficient reinforcement concrete cover (3.01 and 100.34) and cold joints (2.75 and 91.67). However, lack of communication with a mean score of 2.19 and severity index of 73 and early form work removal with a mean score of 2.13 and severity index of 71 ranked 11th and 12th position respectively. These results indicate that inaccurate measurement and damaged formwork will cause serious defect during construction.

Defects due to contractors administration were examined and the results listed in Table 10, indicate that not complying with the specification ranked 1st with mean score of 3.49 and severity index of 166.33. Inability to read the drawing ranked 2nd with mean score of 3.39 and severity score index of 133.00%. Insufficient site supervisory ranked 3rd with mean score of 3.36 and severity index of 112. Poor communication with the design form and the owner ranked 4th with mean score of 3.01 and severity index of 100.33. Unqualified supervision ranked 5th with mean score of 2.94 and severity index of 98.00. Speedy completion or cheap quality work ranked 6th with mean score of 2.64 and severity index of 88.00. Multinational construction experience ranked 8th with mean score of 2.06 and severity index of 68.66. This shows that not complying with the specification and inability to read the construction drawings will cause faulty construction which will lead to building deterioration.

Table 11 shows that the use of exposed material ranked 1st with mean score of 3.61 and severity index of 120.33 followed by selection of materials which is unsuitable for existing climate conditions ranked 2nd with mean score 3055 and severity index of 118.33%. Poor materials handling and storage ranked 3rd with mean score of 2.79 and severity index of 93.00%. Different thermal movement in dissimilar materials ranked 4th with mean score of 2.29 and severity index of 75.66%. this shows that use of expired materials will cause deterioration of building.

Table 12 shows that Wrong use of equipment and inadequate performance of equipment both ranked 1st with mean score of 3.58 and severity index of 119.33. Then, Lack of required amount of equipment ranked 3rd with mean score of 2.87 and severity index of 95.66. This shows that wrong use of equipment and inadequate performance of these equipment will lead to poor output of construction work.

Table 6. Defects due to consultant firm administration and staff

Items	4	3	2	1	MS	R	Severity Index (SI)
Hiring unqualified designers	27	30	5	5	3.18	2	106.00%
Designer ignorance of materials properties	19	20	25	3	2.82	5	94.00%
Poor technical updating or staff training	30	20	10	7	3.09	3	103.00%
Designers field experience	25	20	20	2	3.07	4	100.33%
Designers technical background	20	18	15	14	2.66	6	88.67%
Misjudgment of climate condition	15	14	25	13	2.46	7	82.80%
Lack of QA/QC program during design	35	25	2	5	3.34	1	111.33%
Misjudgment of users intended use	10	15	30	12	2.34	8	78.00%

Table 7. Defects due to construction drawing

Item	4	3	2	1	MS	R	Severity Index (SI)
Lack of details	45	20	1	1	3.61	1	120.33
Conflicting details	30	20	7	10	3.04	3	101.33
Lack of references	35	20	10	2	3.31	2	110.33

Table 8. Defects due to construction inspection

Item	4	3	2	1	MS	R	SI
Lack of inspection	45	18	3	1	3.60	1	120.00%
Unqualified Inspectors	38	20	10	2	3.47	2	115.69%
Proponent (Owner) negligence of inspection	10	25	20	12	2.49	3	83.00%
Weakness of inspection rules in implementing corrective actions during job execution	8	30	15	14	2.48	4	82.69%

Table 9. Defects due to building/civil construction

Item	4	3	2	1	MS	R	SI
Inaccurate water proofing and drainage	25	20	15	7	2.72	7	90.67
Insufficient reinforcement	20	30	15	2	3.01	5	100.34
Poor soil compaction	10	9	40	8	2.31	9	77.00
Inadequate wiring	10	5	45	7	2.27	10	75.69
Inaccurate measurement	50	10	5	2	3.61	1	120.34
Painting in unsuitable conditions or unsuitable surface	30	25	10	2	3.24	4	108.00
Excavation tool close to the building	35	20	10	2	3.31	3	110.34
Loss in adhesion between material	15	14	30	8	2.54	8	84.69
Lack of communication	8	4	48	7	2.19	11	73.00
Damaged formwork	45	15	7	-	3.46	2	115.34
Early formwork removal	13	12	35	7	20.13	12	71.00`
Cold Joints	18	19	25	5	2.86	6	91.69

Table 10. Defects due to contractors administration

Item	4	3	2	1	MS	R	SI
Not complying with specifications	45	15	2	5	3.49	1	116.33
Unqualified workforce	10	20	30	7	2.49	7	83.00
Inability to read the drawing	40	20	-	7	3.39	2	113.00
Insufficient site supervision	35	25	3	4	3.36	3	112.00
Speedy completion or deep quality work	15	15	35	2	2.64	6	88.00
Unqualified supervision	25	20	15	7	2.94	5	98.00
Poor communication with the design form and the owner	30	15	15	7	3.01	4	100.33
Multinational construction experience	5	8	40	14	2.06	8	68.66

Table 11. Defects due to construction materials

Items	4	3	2	1	MS	R	SI
Selection of material which is unsuitable for existing climate condition	50	10	3	2	3.55	2	118.33%
Use of expired materials.	55	5	2	3	3.61	1	120.33%
Different thermal monument in dissimilar material	10	15	25	15	2.27	4	75.66%
Poor materials handling and storage	20	25	10	12	2.79	3	93.00%

Table 12. Defects due to construction equipment

Items	4	3	2	1	MS	R	SI
Wrong use of equipment	50	10	3	4	3.58	1	119.33
Inadequate performance of equipment	50	10	3	4	3.58	1	119.33
Lack of required amount of equipment	25	20	10	12	2.87	3	95.66

Table 13. Defects due to specification

Item	4	3	2	1	MS	R	SI
Specifying inadequate mix design	20	25	20	2	2.94	4	98.00
Not defining adequate materials	45	20	1	1	3.63	2	121.00
Unclear specification	50	15	1	1	3.71	1	123.67
Not specifying the allowable load limit	20	25	20	2	2.94	4	98.00
Not specifying the QA/QC for construction procedure	40	20	2	5	3.42	3	114.00

Table 13 shows that unclear specifications ranked 1st with mean score of 3.11 and severity index of 123.67%. Not defining adequate materials ranked 2nd with mean score of 3.63 and severity index of 121.00%. Not specifying the QA/QC construction procedure ranked 3rd with mean score of 3.42 and severity index of 114.00%. Specifying inadequate mix design and not specifying the allowable load limit both ranked 4th with a mean score of 2.94 and severity index of 98.00%. This implies that bad specification will lead to faulty construction

From the foregoing, particularly as regards the categorization of these defects. The mean score and severity index value indicate that defects are caused by faulty design and construction with affect the building maintenance. From the perception of the respondents, the following were rated as most severe defects from the group of defects:

i. Inadequate structural design such as foundation;
ii. Not relating exterior material selection to climate condition;
iii. Not considering space or exit for maintenance worker, equipment;
iv. Lack of QA/QC program during design;
v. Lack of details;
vi. Lack of inspection;
vii. Inaccurate measurement;
viii. Not complying with specification;
ix. Use of expired materials;
x. Wrong use of equipment;
xi. Inadequate performance of equipment; and
xii. Unclear specification.

It can be seen that the most of the severe defects are related to faulty design and construction. This indicates that faulty design and construction will cause deterioration of building which will lead to maintenance. This supports the claim by [11] that effect of design and construction faults in maintenance is a global problem.

Generally, the most significant faults contributing to building defects based relative significant index are:

i. Lack of inspection: The inspection of construction work is the responsibility of the supervisory staff comprising of the site engineer, site agent, general foreman and other foremen. Hiring highly qualified and experienced supervisors on projects has a far fetching effect on the outcome of the project. When supervisors lack expertise and training necessary for adequate supervision, the consequence is having a building requiring constant maintenance. Earlier studies by [17], [29] have indicated that adequate supervision will certainly reduce most construction defects, thereby leading to low maintenance during operation which the findings in Table 8 supports;

ii. Defects due to Specifications*:* Defects arising as a result of wrong specifications of materials, workmanship and method of construction and contractors working outside specifications results in poor-quality buildings and structures requiring frequent maintenance during their life cycle. Such practice undermines the effort spent during the design stage and increases the maintenance effort required to retain the building for usage. The studies of Building Research Establishment Digests [29], [30] have strongly emphasized the effects of specifications on the maintenance requirements of buildings and findings in Table 13 supported this assertion.

iii. **Architectural defects:** Defects resulting from architectural design faults, such as wrong material selection for doors and windows, wrong exterior material selection, wrong selection of ventilation ducts, etc. have significant consequences on the maintenance effort during the life cycle of buildings [11]. This supports the findings in Table 4 that architectural design defects have been ranked by all respondents as an important factor contributing to maintenance;

iv. **Unclear specification:** Unclear specification is considered as a significant defect by all the categories of respondents. To ensure the implementation of specifications and other decisions taken during the design and construction phases, quality control must be exercised. [29] stated that even with adequate and proper supervision, total quality management must be implemented to reduce construction defects. [9] indicated that specification is a significant factor which affects maintenance and therefore should be considered during the design stage which the findings in Table 13 supports; and

v. **Lack of detail*:*** The delivery of buildings in accordance with specifications and to the quality desired by the owner is achieved through adequate supervision and implementing adequate detailed design. This can further be adequately realized by engaging quality, experienced and competent designer. If the design is not detailed correctly, the outcome of the buildings will be requiring constant maintenance. The designer must be experienced and technically sound in order to realize the project objectives [29]. The findings listed in Table 8 supports this assertion.

5. CONCLUSION AND RECOMMENDATION

The findings of this study indicate that most of the severe defects in building originate from faulty design and construction which result in quick deterioration of building that require maintenance at early stage of building occupation/habitation in the study area. Thus, the study concluded by making the following recommendation:

1. Design errors/defects:

i. Provide technical update to designer;
ii. Improve communication between different members of the design, owner, maintenance staff and contractors;
iii. Aligning material performance against adverse weather conditions;
iv. Preventing impacts from occupants and loads;
v. Preventing water leakage that causes other defects;
vi. Improve specifications;
vii. Improve design clarity, design details, and layout; and
viii. The designer must take into account maintenance considerations during the design and supervision stages by choosing of durable materials.

2. Construction errors/defects:

i. Strict monitoring during construction;
ii. Quality controls and quality assurance (QC/QA) program must be improved on the site to achieve acceptable performance standard and practical specifications;
iii. Construction contractors should be aware about materials selection, construction techniques used and skilled labor hiring;
iv. Maintenance contractor should make sure that all used construction material will serve the buildings intended use and tolerate the environmental conditions;
v. Improved training of craftsmen, supervisors, and all members of the team engaged in the construction of buildings to avoid any constructional defects; and
vi. Use suitable materials appropriate to climatic conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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