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Design and Construction Defects Influencing Residential Building Maintenance in Nigeria

Baba Shehu Waziri

Lecturer, Department of Civil and Water Resources Engineering, University of Maiduguri, Nigeria.
E-Mail: shehuwaziri@gmail.com

ABSTRACT

Defects arising from design and construction are recognized to have substantial consequences on the level of maintenance during occupancy of buildings which often translate to high costs causing dissatisfaction of users. This study attempts to investigate through a field survey the significance of design and construction defects on maintenance of residential buildings in Maiduguri in northern Nigeria. 60 structured questionnaires were distributed to personnel in the offices of consultants, contractors and building owners who are responsible for design, construction and maintenance of residential buildings in order to obtain the desired data for analysis. 47 questionnaires representing a response rate of 73.33% were retrieved and analyzed using descriptive and inferential statistics with the aid of Statistical Package for Social Sciences (SPSS) 16 for WINDOWS. The results of the survey revealed that the use of defective construction materials, poor supervision, non-compliance with specifications and poor quality control on site are the most significant factors contributing to maintenance with Relative Importance Index (RII) values of 0.8617, 0.8351, 0.8245 and 0.8138, respectively. Therefore, it is imperative for design and construction professionals to ensure the use of good quality materials and comply with specifications through adequate supervision to trim the menace of maintenance during operation of residential buildings.

KEYWORDS: Residential buildings, Maintenance, Design defects, Construction defects, Nigeria.

INTRODUCTION

Despite the development in technology, residential buildings still suffer from defects resulting from inadequate design and construction making them vulnerable to unplanned maintenance during their life cycle. Greater part of these defects may be attributed to professionals ignoring maintainability during design and construction, leading to buildings requiring constant repair and maintenance which often translate to high cost causing dissatisfaction of users. This is further reiterated by Adejimi (2005) who observed that most professionals ignore the aspect of maintenance during design, and when such design is accompanied by poor construction, we obtain poor buildings requiring constant maintenance during their life cycle. Chohan et al. (2010, 2011) 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 (Olajide and Afolarin, 2010; Adejimi, 2005). Adejimi (2005) and Mohammed and Hassanain (2010) 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

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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. The involvement of facility manager at the design stage has the potential to reduce maintainability during operation of the facility (Mohammed and Hassanain, 2010).

CONCEPT OF BUILDING MAINTENANCE

Building maintenance is gaining recognition in recent times in most developing countries due to high demand on housing and its influence on the condition of existing facilities which is also referred to as one of the ways of sustaining existing stock of infrastructural facilities (Odediran et al., 2012; Olagunju, 2012). Maintenance is the combination of all technical and associated administrative actions intended to retain an item in or restore it to a state in which it can perform its required function (BS 3811, 1984). Maintenance requires the correct diagnosis of defects, correct remedial measures, sound technical knowledge of material usage, management of resources as well as the formulation and implementation of integrated plans and policies to sustain the utility. It is highly desirable, but hardly feasible, to produce buildings that are maintenance-free although much can be done at the design and construction stages to reduce the amount of subsequent maintenance work (Zulkarnain et al., 2011; Olajide and Afolarin, 2012). A prime aim of building maintenance according to Zulkarnain et al. (2011) is to preserve a building in its initial stage, as far as practicable so that it effectively serves its intended purpose. Maintenance is carried out to retain value of investment, making the building in a condition in which it continuously fulfils its function presenting a good appearance. Maintenance can therefore be referred to all necessary work done to preserve a building with its finishes and fittings so that it continues to provide the same or almost the same facilities and amenities and serve as it did when it was built.

As building components and all elements that make up the buildings unavoidably deteriorate with time due to inherent defects in design and construction and the effects of the environment, it is therefore difficult to produce maintenance-free buildings. Seeley (1997) asserted that no building can exist throughout its life span without one form of maintenance or the other. Every building has an expected life span and even the structures of the ancient world would erode into a mound of sand given enough time (Gatlin, 2013). The physical deterioration of the structures describes its wear and tear from usage, age, neglect, lack of maintenance, vandalism and weather. Usman et al. (2012) observed that the necessity of maintenance work on buildings is noted in the fact that all buildings and the materials and components therein deteriorate or suffer loss in aesthetics, strength and/or functional value with exposure to the elements of weather over time.

DESIGN AND CONSTRUCTION DEFECTS AFFECTING MAINTENANCE

The performance of buildings depends to a great extent on the quality of its design and construction decisions. Okuntade (2014a, 2014b) stated that inadequacies in the performance of buildings emanate from deficiencies in design and construction which reflect on the level of maintenance during operation (Adejimi, 2005; Usman et al., 2012). Zubairu (2001) noted that the extent to which the various factors contribute to maintenance problems in governmental office buildings in Nigeria are; inadequate architectural design 6%, inadequate structural design 7%, inadequate electrical design 9%, inadequate mechanical design 11%, poor construction 12%, use of poor quality components and materials 14%, natural deterioration due to age and environment 18%, misuse by occupants 18% and other factors 5%. Assaf (1996) categorized design and construction faults contributing to maintenance into (11) groups *viz*; defects in civil design, defects in architectural design, defects due to consulting firm's administration, defects due to

construction drawings, defects due to construction inspection and supervision, defects due to civil construction, defects due to contractual administration, defects due to construction materials, defects due to construction equipment, defects due to specifications and design defects in maintenance practicability and adequacy.

Design Defects

The failure of the design professionals to produce complete, accurate and well-coordinated design results in defects which may be grouped under design error, omission or a combination of both (Gatlin, 2013). Kiong and Akasah (2012) are of the view that design and maintenance are actually two crucial criteria in the building process on which the life cycle of buildings depends. The effectiveness of building design is measured by its aesthetic values in order to show how it would serve the required functions for better performance and accessibility for good maintenance. Seeley (1987) observed that 58% of defects were caused by design errors, 35% by wrong installation techniques, 12% by inferior materials and 11% by unexpected user requirements. This is an indication that improper design decisions will yield lower construction quality and in turn cause defects during the life span of the building. Large amount of maintenance expenditures can be reduced provided design and construction defects are known and reduced. In the United Kingdom, 20% of the average expenditure of building repairs is used to remedy defects caused by design and construction (Gatlin, 2013). This suggests that the performance of any building depends largely on the decisions taken at the design and construction stages. Seeley (1987) stated that maintenance of buildings can be positively or negatively influenced during the design stage. Therefore, there is a need to consider maintenance at the design phase of projects in order to prevent unplanned maintenance during occupancy, as design faults are expensive mistakes in terms of occupants' life and restoration cost.

Construction Defects

Construction defects according to Gatlin (2013) are deficiencies in design, construction and /or in the materials or systems used in a project that may not be readily observable and result in a building, structure or components that are not suitable for the purpose intended. Construction defects arise as a result of many factors which could be visible to the naked eye or concealed deep within the structure. Construction defects which directly affect the performance of a structure can be a result of defective design or construction. In general, construction defects comprise of defects such as a design that fails to meet the professional standard, a decision that is not in accordance with codes, among others. Construction defects and failures may also result from clients' poor and misguided decisions or design professional's failure to produce complete, accurate and well coordinated design and construction documents that provide sufficient information for the contractor to construct the building. Sometimes, they can be caused by the misinterpretation of design, poor workmanship and use of non-conforming materials.

The search for key factors that influence the level of maintenance of residential buildings with appropriate measures to assist in proposing solutions to the problems thereof has been an issue of concern. Sustainability of buildings as outlined by Olagunju (2012) includes ways of constructing, maintaining and cleaning a facility such that its health, efficiency, cost-effectiveness and durability are maximized. It is therefore imperative to consider maintainability of residential buildings to ensure sustainability and housing provision in the country.

RESEARCH METHODS

The data for the study were obtained through a questionnaire survey which was found to be effective due to the relative ease of obtaining appropriate data for realizing the study objectives. Structured questionnaires were administered to personnel in the

offices of consultants, contractors and clients in Maiduguri, Nigeria who are responsible for design, construction and maintenance of buildings for both public and private institutions. 60 structured questionnaires were designed and distributed out of which 47 indicating a response rate of 73.33% were retrieved and analyzed. The questionnaire consists of two sections. The first section captured the profile of the respondents, while the second part was comprised of design and construction factors affecting maintenance to be scored on a four-point Likert scale based on their significance. The ratings of the factors on the scale are: 4– very important, 3– averagely important, 2– somewhat important and 1– slightly important. Descriptive statistics have been used to analyze the demographic profile of the respondents, while relative importance indices (RII) have been used for analyzing the responses with the aid of Statistical Software for Social Sciences (SPSS 16) for WINDOWS. The rating of factors for degree of significance was based on the value of their respective relative importance index (RII), where RII> 0.76 is most significant, 0.67-0.75 is significant, 0.45-0.67 is less significant and <0.45 is not significant (Vanduhe, 2012). The agreement of the three categories of respondents was compared using Spearman's rank correlation.

RESULTS AND DISCUSSION

Profile of Respondents

The general response rate for all the three categories of respondents was 73.33% (47 out of 60 respondents). 31.91% of the respondents were from contracting organizations, 29.79% were from consulting organizations and 38.30% were clients. The response rate of contractors was 75% (15 out of 20 respondents), that of consultants 70% (14 out of 20 respondents) and that of clients 90% (18 out of 20 respondents). The profile further revealed that 12.77% of the respondents have 1-5 years of working experience, 21.28% of them have between 6 and 10 years of working experience, 25.53% have between 11 and 15 years of experience and 40.42% have over 15 years of experience. Academic qualification of the respondents indicated that the majority of them (53.19%) possess a high level of academic qualification; i.e., Master Degree, First Degree or H.N.D. holders. 57.44% cover a wide spectrum of high ranking personnel in which 23.40% belong to the top management level, such as directors, deputy directors and principals. Therefore, the information provided by the respondents can be considered as reliable.

Relative Importance of Design and Construction Defects

Design Defects

Defects resulting from design and construction influencing building maintenance were surveyed from relevant literature. The significance of these factors to building maintenance was investigated from the perceptions of the three categories of respondents (clients, consultants and contractors). The results of design defects, construction defects, agreement upon their rankings and overall factors are presented in Tables 1, 2, 3 and 4, respectively.

The results indicate that contractors considered architectural design defects as the most significant defect with an RII of 0.8667, followed by defects due to specifications and defects in construction drawings with RII values of 0.8333 and 0.7833, respectively. Consultants considered defects due to specifications as factor number one with an RII of 0.8036. The second most significant factors by their ranking are: ignoring maintainability during design, lack of design standards, design changes by owner and poor structural design all with an RII of 0.7679. Architectural design defects and inadequate assessment of exposure are rated third with an RII of 0.7500. Clients considered architectural design defects as the most significant defect with an RII of 0.8611, while poor structural design was ranked second with an RII of 0.8472. Clients also considered lack of design standards and design changes by owner

as the third most significant defects influencing maintenance. The results are further presented in Figure 1.

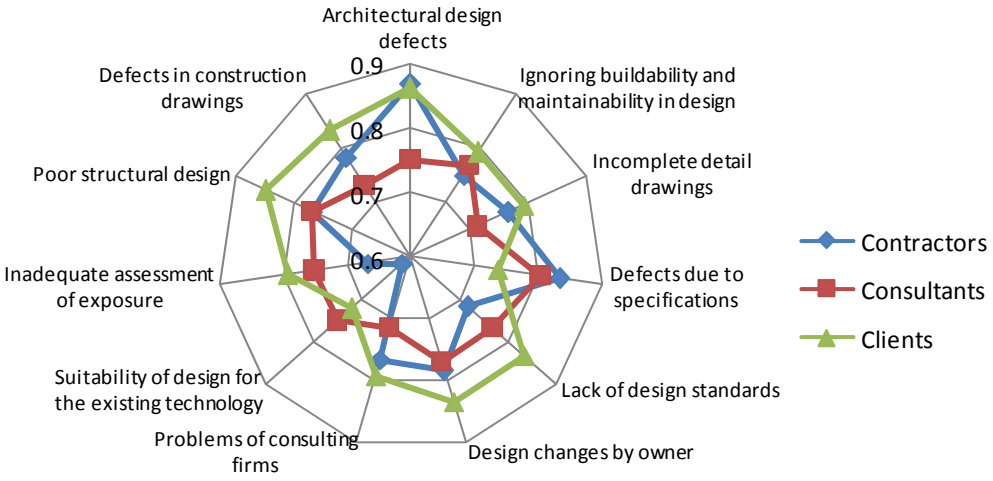

Figure (1): Relative importance of design defects

Table 1. Design defects affecting maintenance

No.	Design Factors	Contractors		Consultants		Clients	
		RII	Rank	RII	Rank	RII	Rank
1.	Architectural design defects	0.8667	1	0.7500	4	0.8611	1
2.	Ignoring buildability and maintainability in design	0.7500	5	0.7676	3	0.7917	4
3.	Incomplete detail drawings	0.7667	4	0.7143	6	0.7917	4
4.	Defects due to specifications	0.8333	2	0.8036	1	0.7361	5
5.	Lack of design standards	0.7167	6	0.7679	2	0.8333	3
6.	Design changes by owner	0.7833	3	0.7679	2	0.8333	3
7.	Problems of consulting firms	0.7667	4	0.7143	6	0.7917	4
8.	Suitability of design for the existing technology	0.6167	7	0.7500	4	0.7222	7
9.	Inadequate assessment of exposure	0.6667	8	0.7500	4	0.7917	4
10.	Poor structural design	0.7667	4	0.7679	2	0.8472	2
11.	Defects in construction drawings	0.7833	3	0.7321	4	0.8333	3

Construction Defects

Defects arising from the construction process were also recognized to have significant consequences on the level of maintenance. The results of the relative importance of construction defects from the perceptions of the three categories of respondents are presented in Table 2 and Fig. 2.

Table 2. Construction defects influencing building maintenance

No.	Construction Factors	Contractors		Consultants		Clients	
		RII	Rank	RII	Rank	RII	Rank
1.	Poor supervision	0.9000	1	0.8571	2	0.8611	2
2.	Communication gap between contractors and design professionals	0.7833	5	0.7143	9	0.7500	7
3.	Defective construction materials	0.8500	2	0.8750	1	0.8750	1
4.	Poor quality control on site	0.8333	3	0.7321	8	0.7917	4
5.	Improper construction methods used	0.6667	9	0.8036	4	0.7917	4
6.	Site defects such as poor soil conditions	0.7333	6	0.8393	3	0.7778	5
7.	Lack of proper reinforcement in concrete	0.7167	7	0.6608	8	0.7917	4
8.	Use of new and untested materials	0.8000	4	0.7679	6	0.7917	4
9.	Lack of coordination of work	0.7333	6	0.6964		0.8333	3
10.	Defects due to civil construction	0.7333	6	0.7857	5	0.7778	5
11.	Faults due to contractual administration	0.6833	8	0.7679	6	0.7778	5
12.	Improperness or lack of required equipment for construction	0.6500	10	0.6429	10	0.7500	7
13.	Damaged or improper formwork	0.7167	7	0.7333	7	0.7167	8
14.	Incompetent workforce	0.8000	4	0.7857	5	0.7917	4
15.	Non-conformance with specifications	0.8333	3	0.8036	4	0.7626	6
16.	Poor construction procedures	0.8333	3	0.7857	5	0.7167	8

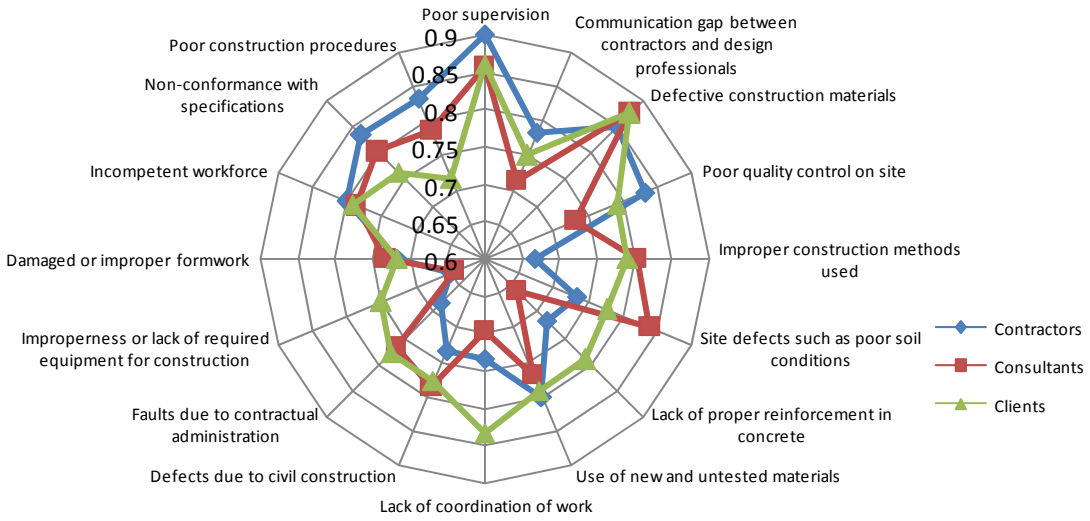

Figure (2): Relative importance of construction defects

The results indicate that contractors considered poor supervision and inspection of construction projects, use of defective construction materials and poor quality control on site as the three most important factors with RII values of 0.900, 0.850 and 0.8333, respectively. Consultants considered defective construction materials, poor supervision and site defects such as poor soil conditions as the first, second and third defects with RII values of 0.8750, 0.8570 and 0.8393, respectively. Clients considered defective materials, poor supervision and lack of coordination of construction work as the topmost defects affecting maintenance with RII values of 0.8751, 0.8611 and 0.8330, respectively.

Agreement of Rankings of Respondents

The rankings of the defects by the three categories of respondents were compared using Spearman's rank correlation. The result is presented in Table 3 which revealed that there is no significant difference between the rankings of the different categories at 95% confidence level. The result further indicated that there is agreement between the rankings of clients and consultants at 99 % confidence level.

Relative Importance of All Factors

The relative importance index values of both design and construction defects were combined and are presented in Table 4. The results indicate that defective construction materials, poor supervision, defects due to specifications, poor quality control on site, architectural design defects, use of new and untested materials, incompetent workforce and ignoring buildability and maintainability at the design stage are the topmost defects affecting maintenance with RII values of 0.8617, 0.8351, 0.8351, 0.8245, 0.8138, 0.8032, 0.7979 and 0.7766, respectively.

Table 3. Spearman's rank correlation coefficient results

Group	Spearman's rho	P-value
Clients and consultants	0.374	0.036
Clients and contractors	0.481	0.009*
Consultants and contractors	0.343	0.050

* Correlation is significant at 0.01 level.

Table 4. Ranking of all factors affecting maintenance

No.	Defects	RII	Rank
1	Defective construction materials	0.8617	1
2	Poor supervision	0.8351	2
3	Defects due to specifications	0.8351	2
4	Poor quality control on site	0.8245	3
5	Architectural design defects	0.8138	4
6	Use of new and untested materials	0.8032	5
7	Incompetent workforce	0.7979	6
8	Ignoring buildability and maintainability in design	0.7766	7
9	Incomplete detail drawings	0.7659	8
10	Inadequate assessment of exposure	0.7659	8
11	Non-compliance with specifications	0.7632	9
12	Poor structural design	0.7606	10
13	Defects in construction drawings	0.7394	11
14	Site defects such as poor soil conditions	0.7394	11

No.	Defects	RII	Rank
15	Suitability of design for the existing technology	0.7234	12
16	Faults due to contractual administration	0.7234	12
17	Poor construction procedures	0.7123	13
18	Problems of consulting firms	0.7074	14
19	Lack of design standard	0.7021	15
20	Improper construction methods used	0.7021	15
21	Improperness or lack of required equipment for construction	0.6915	16
22	Defects due to civil construction	0.6841	17
23	Design changes by owner	0.6702	18
24	Lack of proper reinforcement in concrete	0.6543	19
25	Communication gap between contractors and design professionals	0.6532	20
26	Damaged or improper formwork	0.6512	21
27	Lack of coordination of work	0.6277	22

The least important factors as indicated by the survey are: communication gap between contractors and design professionals, damaged formwork and lack of coordination of work with RII values of 0.6532, 0.6512 and 0.6277, respectively. The results are further presented in Figure 3.

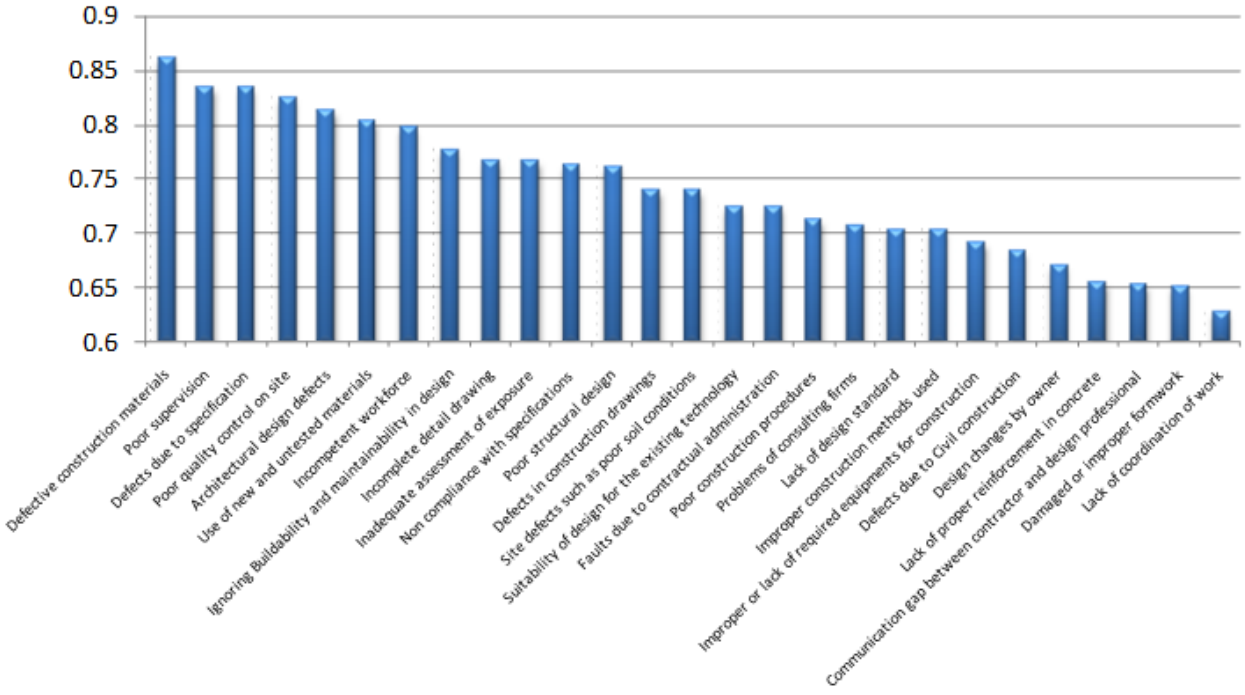

Figure (3): Relative Importance of all Factors

The implication and the effect of design and construction faults in maintenance is a global problem (Chohan et al., 2011). From the study, the most significant faults contributing to residential building maintenance are; use of defective construction materials, poor supervision of construction work, defects due to specifications, poor quality control on site, architectural design defects, use of new and

untested materials and incompetent workforce for construction.

***Defective construction materials*:** the use of inferior or sub-standard materials is a key defect that leads to early deterioration of building components or of the whole building during its operation. This usually occurs when specifications are not complied with or when the specifications themselves are erroneously prepared. The quality of materials usually reflects its strength, durability, aesthetics and economy. The studies of Okuntade (2014a, 2014b) have also indicated the significance of the quality of materials for the maintenance requirements of residential buildings.

***Poor supervision*:** the supervision 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 Assaf et al. (1995) and Okuntade (2014) have indicated that adequate supervision will certainly reduce most construction defects, thereby leading to low maintenance during operation.

Defects due to specifications: defects arising as a result of wrong specifications of materials, workmanship and method of construction and contractors working outside specifications result 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 Okuntade (2014) and Chochan et al. (2014) have strongly emphasized the effects of specifications on the maintenance requirements of buildings.

***Poor quality control on site*:** poor quality control 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. Okuntade (2014 a, 2014b) stated that even with adequate and proper supervision, total quality management (TQM) must be implemented to reduce construction defects. Adejimi (2005) indicated that quality and workmanship control is a significant factor which affects maintenance and therefore should be considered during the design stage.

Incompetent workforce: the delivery of buildings in accordance with specifications and to the quality desired by the owner is achieved through adequate supervision and implementing Total Quality Management (TQM). This can further be adequately realized by engaging quality, experienced and competent workforce. If the workforce that is directly executing the work lacks competence, the outcome will be buildings requiring constant maintenance. The workforce must be experienced and technically sound in order to realize the project objectives (Okuntade, 2014a).

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 (Chohan et al., 2010, 2011). Architectural design defects have been ranked by all respondents as an important factor contributing to maintenance.

CONCLUSIONS

The search for key factors that influence the level of maintenance of residential buildings is fundamental in ensuring sustainability and maintainability. It was observed that numerous building defects could be explained partly or entirely as the result of readily identifiable faults in design or construction which could have been foreseen and hence prevented. From the study, the significance of various defects resulting from design and construction processes has been identified and established as critical to residential

building maintenance. The topmost defects have been found to be: use of defective construction materials, poor supervision of construction work, defects due to specifications, poor quality control on site, architectural design defects, use of new and untested materials and incompetent workforce for construction. Therefore, clients, contractors and consultants alike should ensure the implementation of designs during construction to curtail the menace of maintenance.

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