IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

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To cite this article: O M Olofinnade *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **640** 012036

IOP Conf. Series: Materials Science and Engineering **640** (2019) 012036 doi:10.1088/1757-899X/640/1/012036

Perception of professionals on causes of structural cracks in concrete buildings

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Abstract. Of recent, the incessant collapse of buildings in some major cities in Nigeria has become a major concern to professionals in the construction industry and the general public because it has resulted in most cases loss of lives and valuables which could affect our attaining the sustainable development goals (SDGs). One of the key features that affect the quality of built structures and usage is crack. The occurrence of a crack in a structural member can weaken the member and eventually lead to building failure and outright collapse. This paper examines the perception of professionals in the Nigeria building industry on the causes and impact of crack on built structures. Primary data were obtained through questionnaires administered to practising professionals within Lagos state. Results obtained from the majority of the professionals indicate that occurrence of a crack in the building is majorly caused by foundation settlement, poor selection of construction materials and technique, design error and corrosion of the steel bar and thus have a significant impact on the structural integrity of the building. It was concluded by proposing certain preventive measures to mitigate crack in buildings so as to prevent possible building failure and attainment of the SDGs.

1. Introduction

Concrete is a combined construction material composing mainly of cement, aggregate and water. Moreover, it may be a sturdy construction material or an object which can be formed into different shapes and sizes. A study by Chen and Liew [1] reported that concrete has been the most commonly used construction material for several years and is expected to remain that way within the returning decades. Furthermore, concrete is mostly combined with steel reinforcement forming a composite material of reinforced concrete. Achieving good quality concrete mix is important in a structure, however, this is not only determined by the suitable selection of the constituent materials and their proportioning, but also by the proper technique in the production, placing, transportation, finishing and compaction and curing of the concrete, usually at a project site. However, it has been reported that the quality of concrete as established by its strength often reduces throughout the service life of the concrete structure [1, 2]. The properties of concrete changes with time, and that the quality of concrete throughout service life worsen with time as a result of chemical and physical attacks [1]. A study by Olofinnade *et al*. [3, 4] reported that at a temperature above 600^0C concrete element will have lost about 70 % of its strength. This is as a result of increasing exposure of the concrete element to an increase in temperature which resulted in changes in the chemical composition of the concrete and cracks that reduce the

concrete durability. The durability of concrete is duly a function of design, the grade of concrete, cement content of the mix, methods of construction, maintenance, conditions of exposure and environment [5]. As reinforced concrete becomes older, earlier developed cracks become sources of leakages and seepage of moisture, oxygen, chloride, carbon dioxide, and other aggressive chemicals and gases into the concrete leading to serious degradation of the structure and causing corrosion of steel and damages in the concrete resulting in concrete spalling; subsequently causing structural failure of the member [6]. However, the most common defect that occurs in concrete is cracking due to weak tensile strength and therefore represents an intrinsic property of concrete [7]. Crack in concrete affects the appearance, in some cases affects the structural adequacy and durability. Cracking can occur as plastic shrinkage cracks or it could be also caused by the movement of formworks. Moreover, it can also occur in the form of crazing which resembles a map pattern extending through the surface, caused by minor shrinkage as a result of drying condition. A study by Ryan [8] went further to explain that there are two main classifications of cracks in a structure which could be from structural and non-structural sources. Non-structural cracks appear due to internally induced stresses in the building materials due to environmental effects and often time the safety of the structure is not endangered. While structural crack appeared due to a major distresses of the component elements of the building due to design errors or over-loading. The crack could be termed as a building defect, however, it could also over time lead to a more serious problem for the building or a likelihood of building failure. It was opined by Richard [9] 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. Furthermore, Akinpelu [10] reported the following as major causes of structural failures includes; environmental changes; natural and man-made hazards; improper presentation and interpretation in the design. Various crack evaluation and restoration techniques have been extensive research and solutions proffer by various researchers [11 – 18]. This study is aimed at assessing cracks in a reinforced concrete building with a focus on the causes and possible solutions to common building failures in some parts of Nigeria.

2. Methodology

The study areas of investigation for this research are located within Ota, Ogun state, in the western part of Nigeria. Many of the buildings within the study area are steel reinforced. They are mostly for residential, commercial and office purposes. Perspectives of specialized professionals in construction industries about cracks in buildings were harnessed through the administration of structured questionnaires. Furthermore, visual inspections as a method of non-destructive testing were used in assessing the nature of cracks of in the selected buildings. Among the personnel interviewed were Architect, Structural Engineer, Builder and contractor. The questionnaire was divided into eight key points. The breakdown of the key points are as follows:

Approach to construction of buildings in Nigeria, their understanding of crack in buildings and if crack can be a major reason for building collapse, the different types of crack in RC buildings in Nigeria, and what are the causes of these type cracks, how to prevent the occurrence of these types of crack and what is the level of impact of crack in structural of buildings.

On the other hand, a survey involving visual inspections of selected concrete buildings with visible cracks in the study area was carried out. Variety of crack types observed in the buildings were noted and their possible causes were catalogued. The on-site inspections entailed the use of digital camera and Schmidt Rebound Hammer testing tool for on-site determination of residual strength of the reinforced concrete member around the crack region and some distance away from the crack for strength

comparison. A total number of 100 questionnaires were administered targeting the above mentioned professionals and 86 were returned.

3. Results and Discussion

Figure 1 shows the percentage of respondents to the questionnaires administered for this research. From the 86 number questionnaires analysed, 21.93% are Architects by profession, 38.37 % are Structural Engineers, 17.44 % are builders and 20 % are contractors. The mode of their practice is 65.12 % are full- time practice, 12.79 % are in the academic and 22.09 % are part -time academic and practicing (Figure 2).

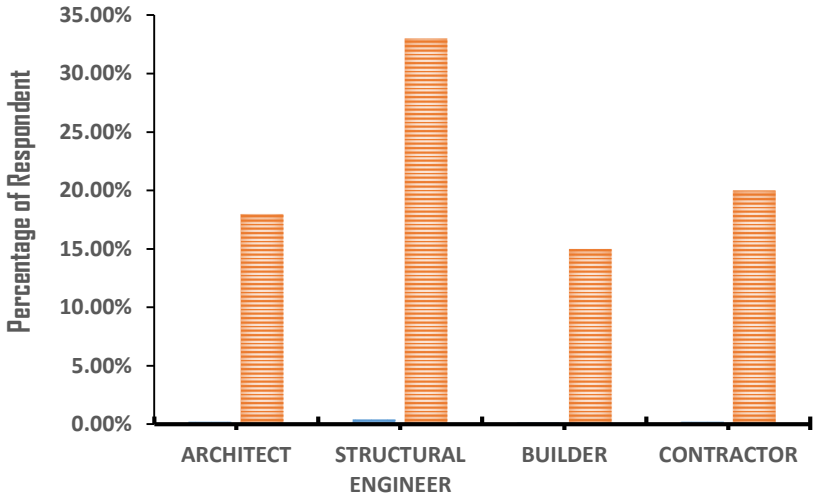

Figure 1: Results of Respondent

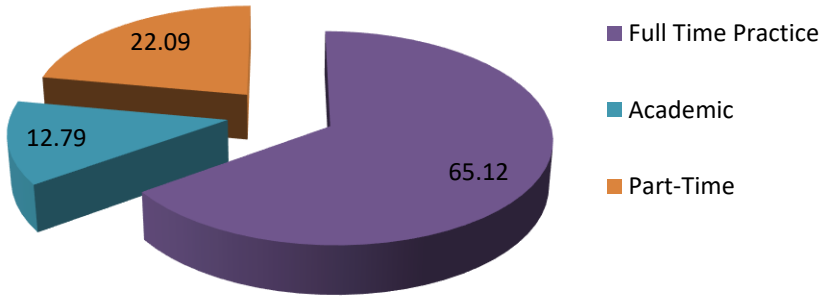

Figure 2: Results of Mode of the practice of the respondent

From the results obtained from the primary data, the majority of the respondents articulated that crack can collapse a building if the causes is a major structural defect in the reinforced concrete building. Cracks in the reinforced concrete building are some of the warning signs of building distress before failure. Moreover, about 91.86 % of the respondents agree that cracks can collapse a building while the remaining 8.14 % said that cracks cannot (Figure 3). This 91.86 % agree with the view of [4], that cracks will occur in a building due to

expansion and contraction of constituent materials, however, reinforced concrete buildings subjected to temperatures above 600°C are structurally unsafe as the concrete element will have lost about 70 % of its strength.

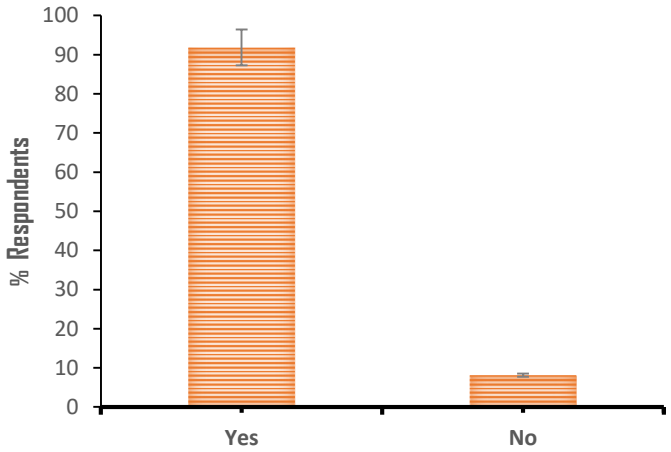

Figure 3: Results of Crack on building

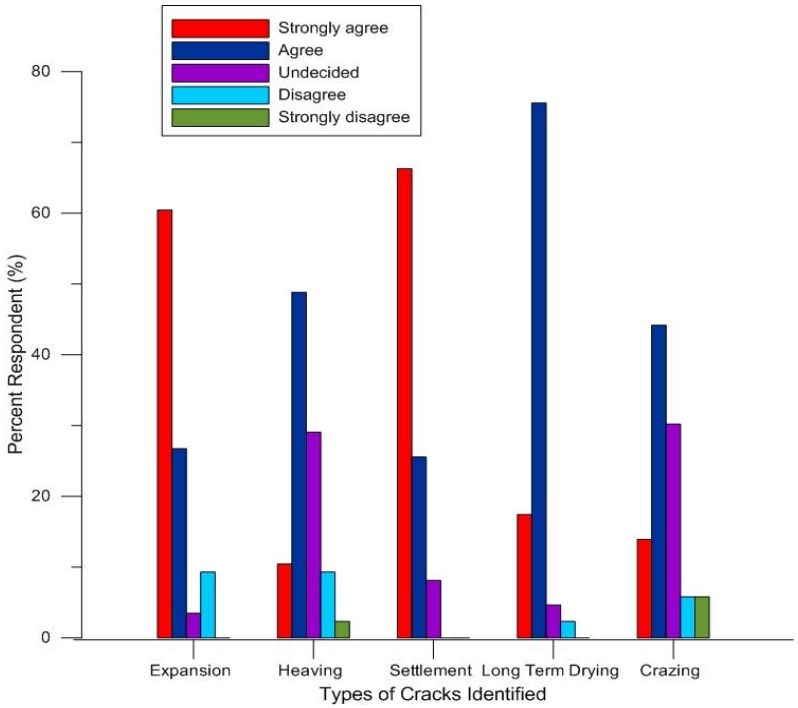

Figure 4: Results of the various type of Crack on reinforced concrete building

Figure 4 reveals that 66.28 % strongly agree that the most common type of cracks that occur in reinforced concrete buildings are settlement cracks, while 61.63 % and 60.47 % of respondent noted that plastic shrinkage cracks and expansion cracks respectively are also common. From this, it can be deduced that these three types of cracks are likely to occur in reinforced concrete buildings than the others mentioned. Settlement cracks

resulted from excessive settling of building under the working load during the service life of the building. Settlement cracks can appear during the construction stage of the building or much later, which in most time is due to foundation settlement resulting sometimes in major structural failure of the building. They are seen as cracks over reinforcement in deep section, they are also seen as arching cracks in columns and cracks at the change of depth in slabs.

Figure 5 shows the perspectives of the respondent on the causes of a crack in RC buildings. From the results, 95.35 % of respondents strongly agree that the major causes of cracks in reinforced concrete buildings are as a result of poor construction technique (PCT) and unprofessional supervision during construction and that these poor construction techniques can range from poor mix ratio, poor quality control of construction materials to other problems of inadequate rebar placement or wrong placement of reinforcement bar. Meanwhile, 60.47 % strongly agree that the major causes of cracks on Nigerian buildings are as a result of structural design errors (SDE) which comes from the part of the design engineer or structural engineer. Also, 36.05 % strongly agree that the major causes of cracks on Nigerian buildings is as a result of corrosion of reinforcement (COR), which results from inadequate cover to reinforcement exposing the rebar to weather conditions. Furthermore, 79.07 % agree that cracks are caused in building as a result foundation movement (FM) and settlement of soils.

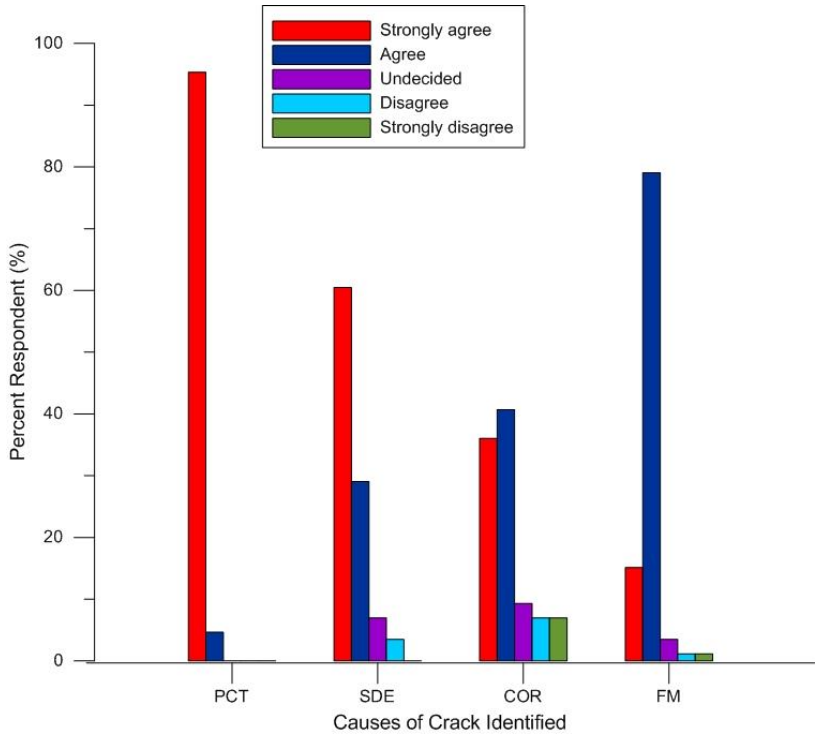

Figure 5: Results of the Causes of Crack on reinforced concrete building

Building failures may be as a result of defects occurring at varying stages in building construction and often times, these defects are visible or noticed as cracks on reinforced concrete buildings. From the results, 54.65 % of the respondents strongly agree that crack has a high impact in structural failure of reinforced concrete building practising especially if the cause is structural. Also, 36.05 % agree that crack impact in reinforced concrete is of medium impact while 9.3 % agree it is the low impact (Figure 5). However, any reinforced concrete buildings, in most cases, that is full of structural defects might lead to building collapse with time.

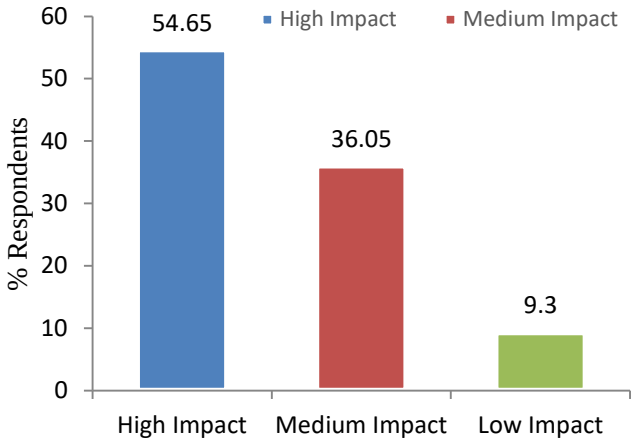

Figure 6: Results of the Impact of crack on reinforced concrete building

The average rebound hammer values obtained at test points were utilized to evaluate the quality and residual strength of the concrete. Figures 6 - 8 shows the probable average residual strength of the investigated buildings for site A, B and C respectively. It was deduced that the structural element surface with cracks lost 2 – 10% of its strength for site A, 5 - 10% for site B, 1 - 11% for site C. Although from visual inspection, cracks could be seen on the surface parts of the buildings but were not extensive hence it being insignificant.

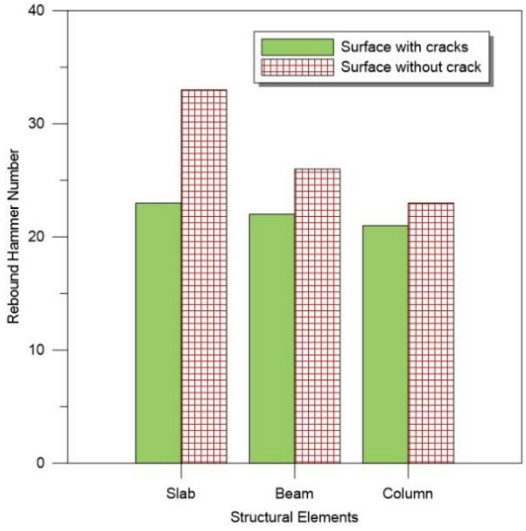

Figure 7: Rebound Hammer Test Results for Site A

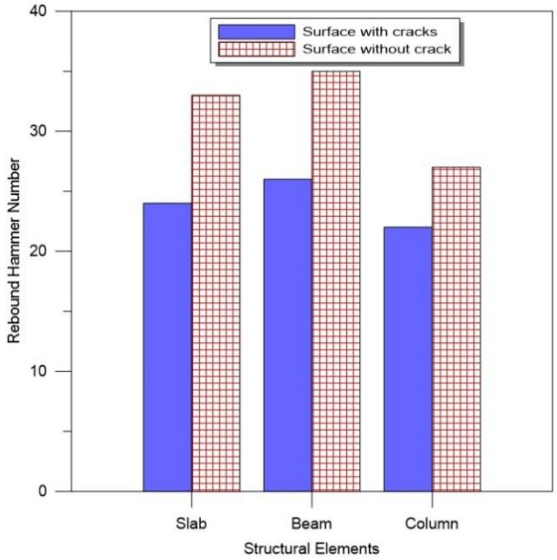

Figure 8: Rebound Hammer Test Results for Site B

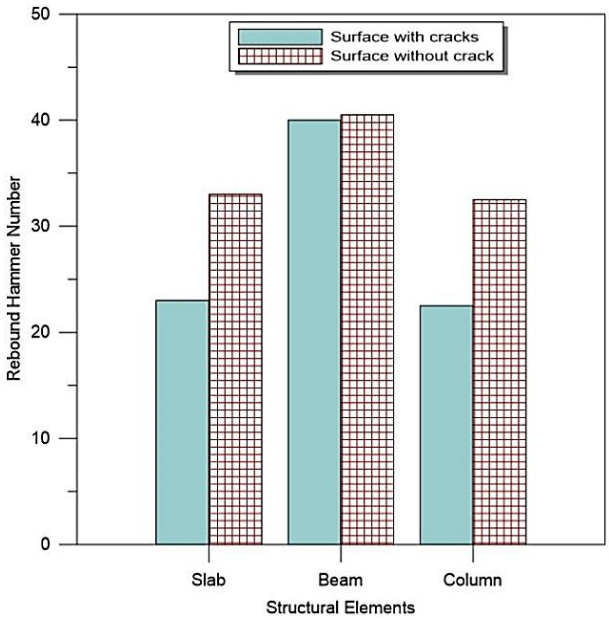

Figure 9: Rebound Hammer Test Results for Site C

4. Conclusion

From this study, three major types of crack were identified to be predominant in some of the selected concrete buildings. They are; settlement cracks; plastic shrinkage cracks; and expansion cracks. These are also common types of crack on concrete buildings in Nigeria. It was deduced that these identified crack types are caused by; poor construction techniques, structural design errors and foundation movement. It was also buttressed that cracks have a significant effect on structural failure. Cracks can be controlled if certain measures are taken into consideration, such as avoiding the usage of poor construction materials, minimizing design errors and strict adherence to the standard code of practice.

Acknowledgment
The authors appreciate the management of Covenant University for their supports.

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