Climate Change and Non-structural Cracks Nexus in Residential Buildings; The case of Talba Estate in Minna, Nigeria

By

Dukiya O. T[1]., Adejumo T[2]., Dukiya J. S[3]., Dukiya J. J.[4*]

1. Federal Road Maintenance Agency, Jos, Nigeria
2. Federal University of Technology, Minna, Nigeria, Department of Civil Engineering
3. Federal University of Technology, Minna, Nigeria, Department of Mechanical Engineering
4. Federal University of Technology, Minna, Nigeria, Department of Urban and Regional Planning

❖ Correspondence author

Abstract

That climate change is a reality is no longer a news and that developing countries need much climate finance to be more resilient to the impact of the changes. Non-structural cracks are now a common phenomenon in residential buildings that is now endangering the integrity and liveability of such structure. This study carried out Identification of non-structural cracks, their severity over a period of two weeks, and their causes in Talba Housing Estate, Minna, Nigeria toward sustainable housing development of the SDG. Crack Comparator Cards (crack width gauge) was employed with visual inspection to identify, measure and assess the causes of non-structural cracks in the estate through systematic random sampling of 197 housing units out of the 500 total units. The result revealed that even though the Estate is on an elevated gentle slope land, 20% of the sampled units have active cracks, more than 90% of the structure have the challenge of efflorescence and foundation surface plaster pilling. There is continuous unsustainable maintenance cost since the house lack damp proof membrane (DPM) and damp proof course (DPC). It is therefore recommended that climate change potential impacts should be incorporated into housing designs while routing maintenance be adopted for the old ones.

Keywords: Climate change, Efflorescence, Housing estate, Housing livability, non-structural crack.

1. Introduction

Climate change terminologies seem to have pervade all human profession and has become a household word and the scientific definitions becoming more milder, even though its global impacts are frightening, disastrous, alarming and already threatening the continuous existing of human race. Direct atmospheric measurements made over the past 50 years have shown a steady increase in the atmospheric carbon dioxide (CO2) IPCC (2013). In fact, should the projected climate change scientific evidence surges beyond a country's designed bearing capacity, then there will be environmental catastrophes that may be more difficult to manage and adapted to, (Robert et al., (2010). The destressing aspect of the issue is the greater certainty that human activity warms the climate and that the rate of change is likely to be greater than any time in modern history (IPCC 2007, 2013). More so, greenhouse gases such as: Water vapour (H2O), Carbon dioxide (CO2), Methane (CH4), Ozone (O3), Nitrous oxide (N2O), and Halocarbons seem to be still in use as substitutes for chlorofluorocarbons (CFCs) in refrigerant fluids, and CFCs from pre-Montreal Protocol usage as refrigerants and as aerosol-package propellants remain in the atmosphere (Forster et al., 2007). More so. the agricultural sector happens to be one of the highly vulnerable anthropogenic activities that also aggravate the GHG while the impacts of climate change on irrigation agriculture infrastructure are also enormous in the face of unsustainable food security across the globe especially among the developing countries and Sub-Saharan countries.

The housing structure in many African countries like Nigeria is a reminiscent of the poverty level where the gross self-own housing stuck hardly follow any standard. More so, corruption virus that has invaded political office holders as revealed in the housing estates that are constructed through government contract awards across the county leads to substandard housing delivery that are not climate change resilient. Extreme rainfall, humidity and temperature have direct impacts on building structures most especially where standards are compromised. Water table variability is a major factor as it affects the building sub-structure and walling up to window levels. More so, the indiscriminate extraction of building materials tends to exacerbate the general ecological degradation in the continent (World Bank. 2022; UNECA, 2023).

Building structure is the centre of human activities and is next to food as a necessity of life. The liveability of a building structure is function of societal wellbeing and the epitome of their technological advancement across generations. Building defect in the form of cracks in all its forms is of great relevance to the health and safety of the occupants. Non-structural cracks in buildings are common phenomena across regions of the world, that are caused by both anthropogenic and natural factors. Although, climate variabilities may have played a major role in the form and severity of the crack that refute 'do-nothing-approach' as an option for the occupants or community.

The increasing number of building collapses in Nigeria has raised concerns about structural stability (Abubakar, 2024). While not all collapses can be attributed to non-structural cracks, their presence may indicate underlying factors that contribute to overall building instability (Cordesman et al.,2016). Changes in precipitation pattern globally has exacerbated soil water capillary in buildings, erosion and gully activities that is a threat in most urban centres. Changes in soil water aquifer has direct impact on load bearing capacities of hitherto assumed stable soils for building structures. Lightning that is highly dynamic and climate related affects developing countries of tropical and subtropical regions mostly, where population density deforestation is on the increase, the fatalities caused by lightning have increased significantly in building cracks and roof wreckages especially in Bangladesh (Jayaratne and Gomes 2012; Islam 2018; Holle et al. 2018). While Doshi et al. (2018) in their study, discussed the need for proper materials and construction techniques to prevent cracks, and adopted preventive measures, such as testing concrete strength and repair techniques for cracks in buildings.

Mere evaluation and identifying the causes of non-structural cracks will not be too relevant without providing effective remediation strategies (Kim 2021, Wiggenhauser et al., 2018). This study therefore carried out Identification of non-structural cracks, their severity over a period of two weeks, and the causes to proffer appropriate cost-effective remediation approaches for sustainable housing development of the SDG.

1.2 Related Literature

Generally, cracks are classified into structural and non-structural groupings. The structural ones are attributed to faulty design, and construction or overloading which often compromises building safety. While the non-structural cracks are more of internally and externally induced stresses exposures. Building cracks can be classified based on widths into thin (< 1mm), medium (1mm to 2mm) and wide (> 2mm wide). Cracks occurs where both Internally and externally induced stresses in building components lead to dimensional and chemical reaction changes and whenever there is a restraint to movement generally.

Non-structural cracks in residential buildings are of significant concern in civil engineering, as they have the potential to cause both functional and aesthetic issues over time. These cracks are typically the result of internal stresses in reinforced concrete elements. Ahmed et al. (2024) in their study covered in detail the vulnerability of non-structural elements, their life cycle assessment, and how they relate to exterior and interior damages that often start as non-structural cracks. Non-structural cracks are prevalent problem in concrete structures such as beams and columns, often occurring due to factors such as concrete deterioration, reinforcement corrosion, faulty design, poor construction, temperature changes, and shrinkage properties of certain materials used during construction (Golewski 2023).

Shittu et al (2013) in his study revealed how poor-quality construction materials and workmanship have contributed significantly to structural defects in Nigeria and failure to address these defects in the past has continually aggravated building collapse disaster in major cities of the country. In fact, the issue of non-structural cracks in residential buildings has been a focus among researchers in the built environment due to its aftermath impact on the safety and aesthetics of the built environment. For instance, a study by Chik et al (2023) on visual assessment of cracks on residential buildings, focusing on their width and direction, highlighted the importance of periodic building integrity evaluation. While More and Hirlekar (2017) focused on the various causes of crack, that include moisture variation, thermal movement, changes due to chemical reaction, and cracks caused by vegetation. While Ajagbe and Ojedele (2018) in their study of the causes of cracks in buildings, find out that drying shrinkage, compressive force from beams exceeding the ultimate strength of the affected blocks, and foundation settlement due to underground erosion were among the main causes of cracks.

As concrete ages, non-structural cracks can lead to leakages and seepages, allowing moisture, oxygen, chloride, and other aggressive chemicals and gases to degrade the structure. These cracks can be of various types and understanding them is crucial for diagnosing the underlying issues and implementing appropriate remediation strategies. The width of the crack also plays a significant role in determining its impact, with thin, medium, and wide cracks having different implications for the structure (Askar et al., 2023; Eli, 2023).

Non-structural cracks can be caused by various factors, usually induced by internal stresses within building materials (Eli, 2023). These cracks are often superficial, with a depth of only a few millimetres, and are primarily present on the surface, but with cumulative disastrous effects. The major causes of non-structural cracks include the following: 1) Climate change elements, 2) Inappropriate Joint Detailing: 3) Higher Shrinkage of Concrete: 4) Poor Workmanship; 5) Poor Building materials, such as burnt clay bricks, mortar, and some stones, have pores. 6) Corrosion of Reinforcement: and 8) Tectonic movement and Foundation Settlement.

Studies on remediation of structural and non-structural cracks have been carried out by researchers like More et al. (2017), Doshi et al. (2018), and Askar et al. (2023). According to Zarak et al. (2018), crack defects can be divided into three categories: (technical, aesthetic, and functional defects). Although their study mainly focused on technical and functional defects, it highlighted the fact that certain cracks with certain dimensions were aligned with defects indicating peculiar causes. Whilst it is impossible to ascertain the cause of a crack by mere looking, it is very possible to streamline plausible causes simply by identifying crack patterns, and directions, and taking measurements. It is also possible to ascertain if a crack is structural or non-structural by experienced observers. Odeyemi et al., (2023) specifically observed that the use of substandard materials in construction is one of the major causes of building cracks and collapse in Nigeria.

The study conducted by Onsachi et al. (2018) on buildings in the School of Engineering at Kogi State Polytechnic, revealed that incompetence of subsoil materials leading to differential foundation settlement and observables cracks in the structures. The study considered the particle size distribution, natural moisture content, Atterberg limit, specific gravity, maximum dry density, and electrical resistivity, further revealed that the causes of cracks were because of low specific gravity of the foundation soil.

According to other research, the most common types of non-structural cracks include plastic shrinkage cracks, plastic settlement cracks, crazing, cracks due to movement of formwork, cracks due to thermal movement, hairline cracks, vertical cracks, stucco cracks, and joint separation (Jain, 2024). Once the type of crack is identified, the next step is to determine the cause of the tensile stresses that resulted in the crack. These stresses could stem from various factors such as plastic settlement, early thermal contraction, or restrained drying shrinkage (Kim, 2021). It is believed that once a comprehensive investigation is carried out on structural condition, it will reveal if a crack indicate serious trouble that may compromised the load-carrying capacity of the structure and calling for urgent remediation that may involve filling the crack, reinforcing the area around the crack, or other methods based on the type and severity of the crack (Onsachi et al., 2018; Doshi, 2018; Eli, 2023).

1.3 Remediation of Non-structural Cracks

The remediation of non-structural cracks in buildings is a critical aspect of maintaining the integrity and aesthetics of building structures. Repair materials and process depend on the types of cracks according and their positions in the structure (Ladvikar et al., 2022). Although cracks in concrete cannot be avoided, they can be managed by utilizing the right materials, employing proper building methods, complying with the applicable codes and standards, and following intact design criteria (Mathai, 2020; Askar et al., 2023). It is very well known that concrete expands when it is hot, and contracts when it is cold. If these metrics (expansion and contraction) are not accounted for during pre-construction and post-construction processes, it can result in the formation of non-structural cracks (Fasisal et al., 2020)

Crack categorization according to their width include Hairline cracks: Less than 0.1mm, no repair required. Fine cracks: Up to 1mm, treatable with normal decoration. Cracks easily filled: Up to 5mm, can be masked by suitable linings. Cracks requiring opening: 5-15mm, may need repointing or replacement of external brickwork. Extensive damage: 15-25mm, requires breaking-out and replacement of the wall section. Structural damage greater than 25mm, the structure becomes unstable and requires major repair work. These cracks can be further categorized into thin (2 mm). The standard for non-hazardous cracks (non-structural cracks) is a surface width not exceeding 0.3 mm for general structural members and 0.2 mm for members at risk of exposure to moisture or contact with soil. (Haavik, 1990; Basham, 2021; and Mand 2023).

The repair of non-structural cracks in concrete is a critical aspect of building maintenance that ensures the longevity and aesthetic integrity of structures. Various remedial measures and procedures can be employed to address these cracks; each tailored to the specific type and severity of cracking. These methods range from epoxy injection, which is suitable for hairline cracks, to more extensive repairs such as grouting, stitching, rebaring, shotcrete application, and surface sealing as illustrated in Fig. 1. The choice of repair strategy is determined by factors such as the width and depth of the crack, the type of crack, the cause of cracking, the crack pattern and environmental exposure (Watts, 2022).

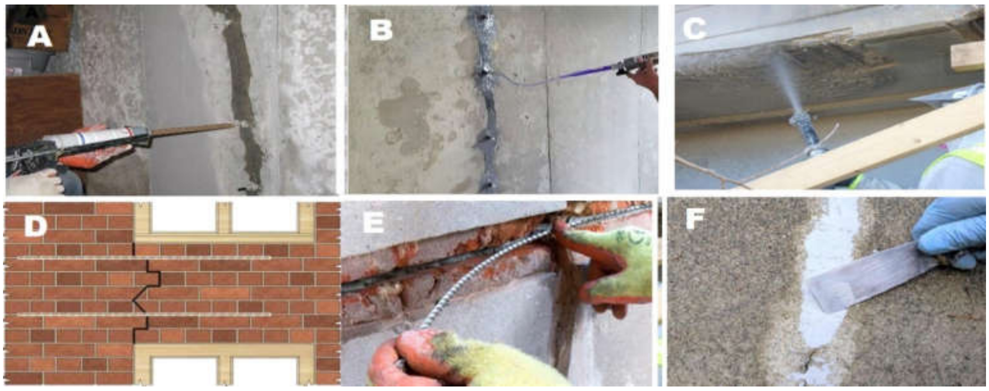

Figure 1 a) Grouting using polymer injections, b) Epoxy Injection using epoxy paste c) Shotcrete method of crack repair d) Crack Stitching using metal plates e) reinforce a cracked wall, and f) cementitious filler or sealant.

2. Methodology

2.1 The study area and location

Minna, the capital of Niger State is one of the 36 states of Nigeria, and it derived its initial growth and importance from the development of the Lagos-Kaduna rail line and the subsequent transfer of the local government headquarter from Kuta to Minna. Geographically, the town lies between latitude 90 38’ - 90 45’ N and Longitude 60 33’ - 60 39’ East and is about 140 km away from Abuja the Federal Capital Territory (FCT) south-west, see Fig. 2. In term of built-up area, the area coverage increased from 884 hectares in 1979 to 5336 hectares in 1983 and from 7070 hectares in 1993 to about 14,568 in 2012. The phenomenal growth of Minna after the establishment of FCT is quite tremendous and later aggravated by the political upheaval in the northern neighbouring states like Kano, Kaduna and Plateau from where people migrated into the State due to its relative peace. According to the 1991 census figure, the population was 143,896 people. But in 2025, it was estimated to be 532,497 including the main city and its suburban areas.

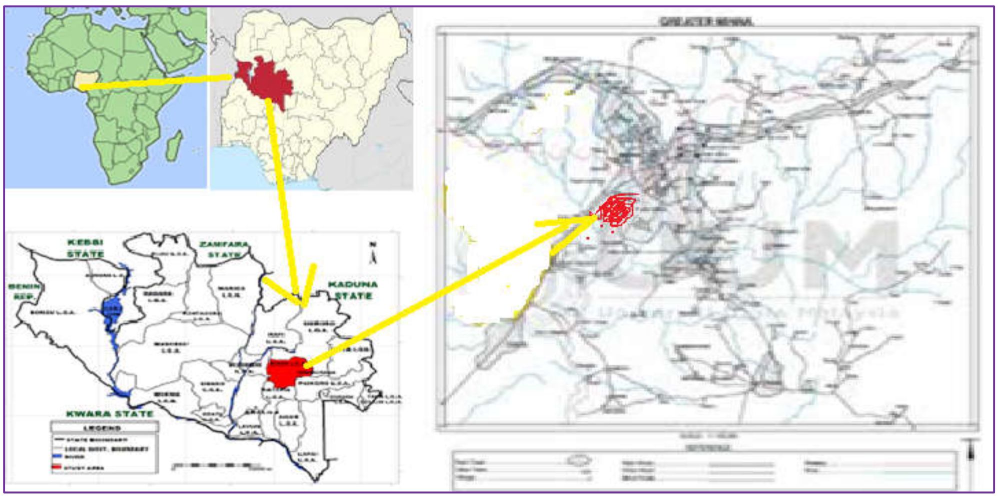

Figure 2. The study location.

Talba Housing Estate along Minna-Bida Road is the focus of study as its located on relatively high and gentle slope but facing building cracks and efflorescence challenges. The estate has an estimate of 500 housing units comprises of three (3) bedroom and two (2) bedroom bungalows as indicated in the map provided by State Housing Corporation (NSHC) see Fig. 3

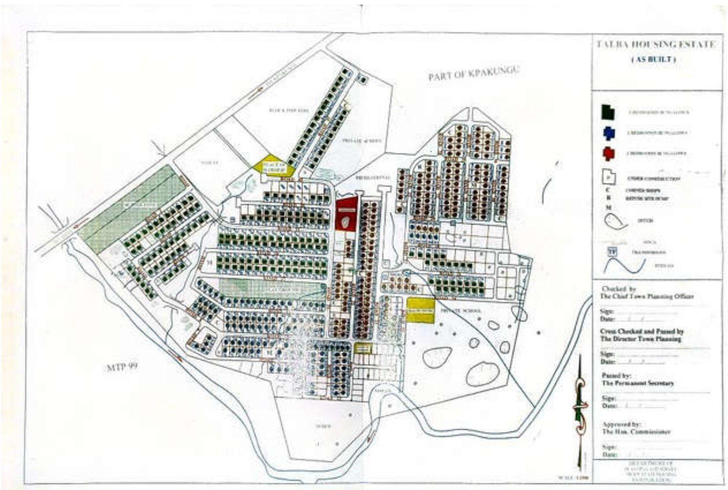

Figure 3. Talba Housing Estate (as built)
Source. Niger State Housing Corporation, 2025

2.2 Data collection

As case study research on an existing estate, systematic random sampling is adopted in the selection of samples with the aid of metrics. In other to calculate the required sample size, given the stated sample frame 500, an online sample size calculator (from calculator.net) was used using the metrics shown in Table 1 (Bhardwaj et al 2023). Using the sample size given by the calculator, a hundred and ninety-seven (197) units werel selected for the field survey to achieve a confidence level of 95% with a real value with plus or minus five (5) of the measured value. A sample interval of three (3) was adopted, meaning that the units will be selected at the of interval of three houses. The take-off point for this survey is unit number 001.

2.3 Instrumentation and observation

Crack Comparator Cards also known as crack width gauge was used in this study because of its effectiveness and user friendly in the field of civil engineering and construction for the assessment of cracks in structures like roads, pavements, bridges, and buildings. These cards are compact, pocket-sized, and made of durable plastic. They are marked with both inch and metric scales, capable of monitoring crack widths from 0.1 to 7.0mm (0.004 to 0.26in), see Fig. 4.

Figure 4 Crack Compactor Card

The Visual Inspection Procedure (VIP) was used in this study, The VIP adopts a data-centric approach, integrating empirical observations with construction forensics principles to trace the origins and predict the progression of non-structural cracks in line with Mushiri, et al (2018) investigation of structures. This approach is essential for developing targeted remediation strategies. To do this, series of planning and preparations on and off the site were done in other get the data required.

Comparative analysis of photographs was carried out throughout a lunar cycle, using visual evidence with established patterns and types of non-structural cracks from expert literature to monitor crack progressions, and to find similarities that can aid in identification of the cause and nature of the cracks (Singh, 2022; Mand et al., 2023). In the context of north-central Nigeria, the behaviour of non-structural cracks within concrete structures is influenced by a confluence of environmental conditions unique to the region. The geotechnical and geophysical characteristics of the area play a pivotal role in the manifestation and progression of such fissures. Key factors such as differential settlement, thermal fluctuations, hydration reactions, and geophysical properties coupled with the structural design and material quality, dictate the behaviour of non-structural cracks and hence will be taken into consideration in other to ensure a comprehensive approach to the evaluation and remediation of non-structural cracks that puts into account the region's distinctive environmental challenges.

Monitoring schedule every week for 14 days (two week) was carried out to re-inspect the cracks using the same crack comparator card at the end of every week to monitor changes in width or new crack formation. Compile recorded data, observations, and photographs into a comprehensive report was made, which include an assessment of the severity of the cracks, potential causes, recommended actions, and a plan for ongoing monitoring (Basham, 2011; ACI, 2007). These procedures helps to improve the chances of giving an accurate evaluation of non-structural cracks and make informed decisions regarding the remediation of these cracks in residential buildings.

3. Results

The visual inspection revealed that each building consists of structural frame members like beams, columns and walls. About 90% of all the buildings in the estate have an identical layout as far as the structural and engineering design is concerned, with slight changes in overall aesthetics. The cracks were of varying lengths and widths, and irregular patterns probably due to drying shrinkage, moisture ingress, and material degradation primarily at the lower part of the walls of the building. Those larger widths cracks were around the lintels, and close to ground floor slabs. Based on the crack pattern, they are mostly caused by minor settlement, contraction, foundation movement, and poor construction practices (like poor drainage system).

The study further revealed that water capillary on the building walling and efflorescence are the major challenges facing the estate. The study also finds out that there were no provisions for proper drainage system for each housing unit. The only buildings that have any form of drainage were those close to the collector road that runs through the estate. This explains why many of these buildings are plagued with moisture ingress resulting in plaster degradation and net cracks as revealed in Fig.5

Figure 5. General building defects at Talba Estate in Minna, Nigeria.
Source. Author field survey 2025

3.1 Determination of the Nature and pattern of crack

The result of the form and dimension of the observed cracks in the study using the Crack Compactor Card is as displayed in table 1. Six (6) active cracks (20%) were identified in the estate, while twenty (24) were dormant cracks accounting for 80% of the sampled units. Twenty (20) vertical cracks accounting for 67% of the sampled units, while five (5) were of horizontal crack that is 16.7%. The width of the building cracks in the estate ranges between 4.7mm and 0.2mm. On the deepness of cracks in those buildings, 20 units of sampled structures have cracks that are limited to surface wall plaster that may be attributed to poor working material, unskilled workmanship, and efflorescence activities. This indicates that majority of the cracks observed are non-structural cracks

Table 1 Measured Cracks Dimensions and Patterns of Selected Housing Units

Unit/Location	View	Nature	Pattern/Direction	Width (mm)	Extent
1	External	Active	Map like	0.25	Plastered
9	External	Dormant	Hairline	0.2	surface plastered
21	External	Dormant	Horizontal	1	At block region
25	External	Active	Vertical	4.7	Door sep from lintel
29	External	Dormant	Horizontal	0.25	Plastered surface
33	External	Dormant	Vertical	0.35	Plastered surface

37	External	Dormant	Vertical	1.5	At block Region
49	External	Dormant	Vertical	0.4	Plastered surface
61	External	Active	Map like	0.3	Window lintel level
65	External	Dormant	Diagonal	0.25	Plastered surface
69	External	Dormant	Vertical	0.55	Plastered surface
53	External	Dormant	Random	0.45	Plastered surface
57	External	Active	Horizontal	0.6	Plastered surface
61	External	Dormant	Vertical	1.5	At window lintel level
65	External	Dormant	Vertical	0.2	Plastered surface
69	External	Dormant	Vertical	0.25	Plastered surface
73	External	Dormant	Vertical	0.4	plastered surface
77	External	Dormant	Vertical	2	Totally cracked
81	External	Dormant	Vertical	0.35	Plastered surface
85	External	Dormant	Vertical	0.45	Plastered Surface
89	External	Active	Vertical	0.6	At block region
93	External	Dormant	Vertical	0.35	Plastered surface
101	External	Dormant	Vertical	0.55	Plastered Surface
433	External	Dormant	Horizontal	0.4	Plastered Surface
437	External	Active	Random	0.6	Total ly cracked
441	External	Dormant	Vertical	0.45	Plastered surface
445	External	Dormant	Horizontal	0.55	Plastered Surface
449	External	Dormant	Vertical	0.35	Plastered Surface
453	External	Dormant	Vertical	0.4	Plastered Surface
485	External	Dormant	Vertical	0.95	Wall head to window

Source. Researchers field survey 2025.

The combined analysis of the extent of the cracks shows that 62.5% of the cracks are on plastered surfaces, which is be more manageable and less costly to repair compared to other types of cracks, because they do not require extreme remedial procedures. Application of surface and sealing materials like silicones and epoxy resins would be perfect for these types of cracks. 9.38% of the cracks are at block regions, 3.13% involve separation of door frames from top beams, 9.38% are at window lintel levels, and 6.25% are classified to have totally cracked. 3.13% of the cracks extend from the top of the wall to the window frame. A simple cost-effective remedial procedure for these types of cracks will be the application. Since these cracks have very small widths and depth, mere screeding will be adequate if carried appropriately on time. Although, many of the property owners subscribed to the use of wall tiles, and wall screeding to mitigate the impact of moisture ingress that causes cracking of the plastered surfaces.

It is however observed that the building occupant are more concerned with aesthetic outlook of the structures as long as the building structural integrity are guaranteed, the aesthetic symmetry is of major concern which is attributable to their sociocultural background and educational levels.

3.2 Remediations Costs and discussion

Potential remedial procedures include stitching, grouting, or epoxy injection for the cracks extending from the top of the wall to the window frame. Application of reinforcement bars, re-plastering will be a suitable remedial procedure for structural elements that are totally cracked. The general cost estimate below is subject to market price forces that is highly dynamic (Darwin et al 1984; Ajagbe, and Tijani 2016)..

i. Plastered Surface Cracks: Remedial procedure includes surface sealing and wall screeding with an estimated costs ranging from ₦3,600 to ₦10,800 per square meter.
ii. Block Region Cracks**:** Stitching will be more appropriate for this with an estimated cost ranging from ₦18,000 to ₦36,000 per square meter.
iii. Window lintel level cracks: Remedial procedure will involve structural reinforcement, and grouting with an estimated cost ranging from ₦25,200 to ₦54,000 per square meter.
iv. Rebating: This involve reinforcing the cracked area with steel bars, with costs ranging from ₦21,600 to ₦46,800 per square meter.
v. Shotcrete: This involve applying a layer of concrete using a high-pressure hose, costing around ₦28,800 to ₦57,600 per square meter.
vi. Curing and protecting: Ensuring the repaired area is properly cured and protected, will cost around ₦3,600 to ₦10,800 per square meter.
vii. Potential impact of neglecting structural issues may result into progressive deterioration of the building fabric, causing more extensive damage such as crack propagation, concrete spalling, and embedded reinforcement corrosion. Consequently, repair costs may surge to 2-3 times the initial estimate and jeopardize the structural integrity of the building.
viii. Health risks: Cracks in building often enhances the growth of mould that can in turn causes respiratory problems, allergies, and other health issues upon exposure.

Generally, poverty and poor maintenance culture is the bane ghetto and shanti town sprawling with the attendant risk exposure. More so, the failed governance and environmental injustice in most African countries is the housing delivery challenge that makes affordable-liveable housing-for-all of the UN-Habitat a mirage. Nevertheless, the primary goal should be to construct buildings with long-term durability. The life span of building structure is noticeably dwindling due some of the afore mention factors that calls for re-awakening of all the stakeholders in the built environment.

Conclusion

Building structures are the centre for all human activities and one of the necessities of life. This study on non-structural cracks in Talba Housing Estate revealed that many of the observed cracks were not attributable to loading failures, structural design flaws, foundation settlement, natural disasters, but more of non-structural cracks that can be explain off using behavioural theories. Simple preventative measures such as comprehensive soil analysis before construction to determine the site soil's bearing capacity, proper foundation design incorporating damp-proof membranes (DPM) and damp-proof courses (DPC), implementation of effective property-wide drainage systems, and utilization of waterproof construction materials that deter moisture ingress can mitigate those crack formation.

The appropriate remediation for non-structural crack failures necessitates thorough investigation and identification of their nature and causes before initiating repairs; otherwise, cracks treated incorrectly may re-emerge over time. However, the investigation of non-structural crack causes should prioritize understanding what led to the issue, rather than assigning blame.

Recommendations

The findings from this study of Talba Housing Estate in Minna, can be remedied before, during and after the crack identification through the following suggestions:

i. Public education on the reality of climate change and the need for integrated adaptation among the stakeholders in the built environment
ii. That a comprehensive geotechnical analysis be conducted before embarking on permanent construction to ascertain the site's subsurface conditions and ensure the foundation design is compatible with the soil's bearing capacity as evidence in the work of Agbede, (2015) and Ajay et al (2024) on housing subsidence.
iii. There is the need to implement site-wide hydrological management systems, including French Drains and surface grading, is crucial to control water flow and prevent hydrostatic pressure build-up around the foundation, thereby reducing the risk of moisture-induced cracking.
iv. Establishing a preventive maintenance protocol, including regular structural inspections and timely remediation of emerging cracks, is necessary to prevent minor defects from escalating into significant structural issues.
v. Prioritizing proactive design strategies over reactive repairs is crucial in line with Wang et al (2023). Understanding the aetiology of non-structural cracks and addressing them during the design and construction phases can significantly mitigate their occurrence

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