Assessment of the Determinants of Wall Cracks in Buildings: Investigating the Consequences and Remedial Measure for Resilience and Sustainable Development

Ogundele Joseph OLUROTIMI
Department of Architectural Technology
Bida, Niger State,

Obamoh Hannah YETUNDE,
Department of Architectural Technology,
Federal Polytechnic Ukana
Akwa Ibom State

AND

ARC. Utibe AKAH
Department of Architecture
University of Uyo
Uyo, Akwa Ibom State

ABSTRACT

Cracks in the buildings develop whenever stress exceeds their strength. Stress in the building components could be caused by externally applied forces such as dead, live, wind, seismic loads, or foundation settlement or it could be induced internally due to temperature variations, moisture changes, and chemical actions. This paper examined the determinants of wall cracks in buildings, investigating the consequences and remedial measures for resilience and sustainable development. The study revealed that to address wall cracks and enhance building resilience, it is essential to implement remedial measures such as structural repairs, foundation stabilization, proper waterproofing techniques, and effective crack sealing. It focused on the concepts of wall cracks, the determinants of wall cracks in buildings, the consequences of wall cracks in buildings, the remedies for wall cracks in buildings, the effect of wall cracks on the sustainability of buildings, and the prevention of wall cracks in buildings. The study concluded that cracking in buildings can be the result of one or a combination of factors such as poorly designed or constructed foundations, expansive soils, inadequate soil preparation, and others. Therefore, assessing the determinants of wall cracks, investigating their consequences, and implementing remedial measures are vital for enhancing the resilience and sustainability of buildings. Continued research, awareness, and proactive maintenance practices in this area are essential for creating safer, more durable, and more efficient built environments. One of the recommendations made was that during the building construction, there should be structural integrity of buildings which leads to safety from hazards. This will help avert the structural deficiencies that brings about cracks and other issues with extensive repairs, retrofitting, or even demolition and reconstruction.

KEYWORDS: Determinants, Wall Cracks, Buildings, Consequences, Remedial Measures, Resilience and Sustainable Development

Introduction

Buildings are structures that serve as shelters for man, his properties, and his activities. They must be properly planned, designed, and erected to obtain the desired satisfaction from the environment. Durability, appropriate stability to prevent failure or discomfort to users,

resistance to weather, fire outbreaks, and other types of mishaps are all issues that must be considered during building design. With the introduction of new building materials and processes, architectural building styles are continually evolving. Consequently, the work involved in the design and construction stages of buildings is largely that of selecting materials, components, and structures that will meet the expected building standards and aesthetics on an economic basis.

Cracks in the building are universal problems faced throughout the world. Building components develop cracks whenever stress in the components exceeds their strength. Stress in the building components could be caused by externally applied forces such as dead, live, wind, seismic loads, or foundation settlement, or it could be induced internally due to temperature variations, moisture changes, and chemical actions. Cracks affect the building's artistic look, destroy the wall's integrity, affect the safety of the structure, and even reduce its durability (Pooja et al. 2015). Understanding the causes and effects of this phenomena requires a study of the factors that influence wall cracks in buildings. It is feasible to identify potential effects and create suitable corrective actions to improve building resilience by looking into the elements that cause wall cracks, such as structural problems, foundation settlement, or poor construction techniques. Implementing corrective measures, such as structural repairs, foundation stabilization, appropriate waterproofing techniques, and efficient crack sealing, is crucial to addressing wall cracks and improving building resilience. Building wall fissures can have a wide range of negative effects, including reduced structural integrity, water infiltration and moisture damage, energy loss, poor indoor air quality, decreased curb attractiveness, and decreased property value. These consequences can pose safety risks, lead to costly repairs, and impact the overall sustainability and livability of buildings.

Buildings' resilience and sustainability can be improved by analyzing the causes of wall cracks, looking into their effects, and taking corrective action. Building environments that are safer, more resilient, and more effective require ongoing research, education, and proactive maintenance practices. It is crucial to use suitable construction techniques and work with licensed, experienced building professionals to avoid cracks and other related issues. Building cracking may be caused by a single issue or a combination of factors, including inadequate soil preparation, expansive soils, or poorly designed or built foundations. Cracking cannot be purely prevented but it can be significantly reduced or controlled when the causes are taken into account and preventative measures and repair methods are taken.

Concepts of Wall Cracks

Wall cracks are usually a sign of foundation movement but they do not necessarily mean there's structural damage. In other words, a foundation can move slightly and cause a wall crack, but that does not mean there's any structural damage requiring a foundation repair, (Egloff, 2022). Wall cracks are a common issue in buildings and can have various causes, including structural settlement, foundation problems, moisture, or construction defects. A crack on wall surfaces is nothing to be alarmed about. Wall cracks can be repaired easily. There are moments when a wall crack means there's a serious underlying issue. When that happens, foundation repair will be required (Medlock, (2022).

A wall crack can also be a sign of structural damage product. This structural damage might have been caused by expansive soil, vibration, drainage problems, seismic activity, a severe wind storm, or something else. Cracks caused by structural damage are almost always more noticeable. Fortunately, a foundation repair professional can fix the problem that caused the crack. Cracks in walls are unsightly, but they can also be an indicator of serious structural problems afoot in a home. It is essential to know if a wall crack can be easily fixed with a bit of

strategically-placed filler and a lick of paint or whether costly structural repairs to your home are called for. Underestimate the seriousness of cracks in walls and you might find yourself without a roof over your head, (Andrew Mackintosh, 2021).

Fig. 1: Images of wall cracks in buildings

A wall crack is serious when it is caused by structural damage. You can have movement in a foundation that causes a wall crack, but does not cause the kind of structural damage that requires a repair, (Bay Area Underpinning, 2022). Cracks are the presence of faults or breakage of building materials. In the field of architecture, the wall crack is mainly caused by the internal stress uneven or the stress concentration. The wall in the external environment (temperature and humidity) under different influences under different stress, demonstrates the ability of anti-stress is not the same, and it will, with the passage of time, have a different change. In the course of time, the pressure will be accumulated to a part of the wall increased rapidly, the site became the stress concentration area, when the wall structure cannot bear the stress, and there will be cracks and wall discontinuity. At this point, the wall structure alleviates the internal pressure through the fracture, deformation, (Luana, et al., (2017). Cracks may be uniform width throughout or may be narrow at one end gradually widening at the other end. Cracks may be straight toothed, toothed map pattern or random type and may be vertical, horizontal or diagonal. Cracks may be only surface and extend to more than one layer of materials (Researchwap.net, 2023).

Concept of Sustainable Development

Sustainable development is an organizing principle that aims to meet human development goals while also enabling natural systems to provide necessary natural resources and ecosystem services to humans. The desired result is a society where living conditions and resources meet human needs without undermining the planetary integrity and stability of the natural system. The Brundtland Report defines sustainable development as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs". The concept of sustainable development nowadays has a focus on economic development, social development and environmental protection for future generations. The overall goal of sustainable development (SD) is the long-term stability of the economy and environment; this is only achievable through the integration and acknowledgement of economic, environmental, and social concerns throughout the decision making process.

The concept of sustainable development aims to maintain economic advancement and progress while protecting the long-term value of the environment; it “provides a framework for

the integration of environment policies and development strategies". The key principle of sustainable development underlying all others is the integration of environmental, social, and economic concerns into all aspects of decision making. All other principles in the SD framework have integrated decision making at their core (Stoddart, 2011). It is this deeply fixed concept of integration that distinguishes sustainability from other forms of policy. Institutionally, government organizations are typically organized into sectoral ministries and departments. This works fairly well until the system encounters something very comprehensive and highly integrated in nature, such as sustainable development. In practice, sustainable development requires the integration of economic, environmental, and social objectives across sectors, territories, and generations. Therefore, sustainable development requires the elimination of fragmentation; that is, environmental, social, and economic concerns must be integrated throughout decision making processes in order to move towards development that is truly sustainable (The World Bank 2015).

Sustainable Development in Built Environment or Building

A sustainable built environment is circular, designed for longevity, flexibility, adaptability, assembly, disassembly, reuse and recoverability, and considers future climate risks. It uses low-carbon, low-impact, non-toxic materials and it recovers used resources (materials and products on-site or from other sites). According to Bramley (2009). Accepting that there can be no sustainable development without a sustainable environment. The built environment is a huge determinant of sustainability and, at the same time, a crucial element for the achievement of a truly sustainable society (Siu 2022). The alarming challenges it faces, including climate change, energy consumption, rapid urbanization, social inequality, population aging, and deteriorating infrastructure, urgently invite rethinking of conventional planning, design, and construction practices. Built environment refers to individual buildings extending in scale from a single-standing site to an area with multiple buildings and open space, accompanied by intensive socioeconomic interaction between users, affiliated facilities, and urban support services.

Structure of a Sustainable Building

Sustainable built environment is associated with concepts and ideas such as integration of renewable energy systems, BIPV, zero-energy buildings, vertical farming, adaptive building skins, affordable housing, integrative open public spaces and landscapes, age-friendly built environments, etc. The mechanisms and actions entail a careful, simultaneous consideration of various aspects and complex processes related to the built environment and its users, including inevitable balancing between environmental, economic, social and cultural sustainability, while enabling appropriate connectedness and harmonization between micro, meso and macro urban levels. Buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows (Gottfried, 2009). Sustainable development is the challenge of meeting growing human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and natural resources for future life and development. Sustainable development of buildings requires a change in the way the building industry and building owners approach the design, construction, and operation of structures. This leads public and private sectors of the building industry towards a new value in its work; that is environmental performance. The industry's growing sustainability ethic is based on the principles of resource efficiency, health, and productivity (Lippiatt, et, al. 2007). Successful sustainable design requires an integrated. Realization of these principles involves an integrated, multidisciplinary approach; one in which a building project and its components are viewed on a full life-cycle

basis. Effective building sustainability strategies and sustainable development plans can best be identified by ensuring that decision makers and developers are adequately briefed on sustainability issues, local characteristics and community needs.

This cradle to cradle approach, known as "green" or "sustainable" building, considers a building's total economic and environmental impact and performance, from material extraction and product manufacture to product transportation, building design and construction, operations and maintenance, and building reuse or disposal. Ultimately, adoption of sustainable building practices will lead to a shift in the building industry, with sustainability thoroughly embedded in its practice, products, standards, codes, and regulations (Longman, 2011). Sustainable building systems and operational practices are dependent on building site, solar access and light penetration, architectural design, and product specification. Sustainable buildings should take all of these factors into consideration on an integrated basis.

Fig. 2: A Structure of a sustainable building in a built environment

This is a circular and multi-dimensional approach. Sustainable development concepts (applied to the design, construction, and operation of buildings), can enhance both the economic well-being and environmental health of communities around the world. A building's life spans its planning; its design, construction and operation; and its ultimate reuse or demolition. Often, the entity responsible for design, construction, and initial financing of a building is different from those operating the building, meeting its operational expenses, and paying employees' salaries and benefits (Rodman, 2005). However, the decisions made at the first phase of building design and construction can significantly affect the costs and efficiencies of later phases (Romm, 2006). Studies have shown that sustainable building measures taken during construction or renovation can result in significant building operational savings, as well as increases in employee productivity.

Determinants of Wall Cracks in Building

Wall cracks in buildings can be influenced by various determinants, including structural factors, environmental conditions, material properties, and construction practices. Understanding these determinants is crucial for identifying and addressing the underlying causes of wall cracks. These are some of the key factors that contribute to the occurrence of wall cracks in buildings.

- **Structural Design and Load Distribution:** The structural design of a building plays a significant role in the formation of wall cracks. Inadequate structural calculations, improper load distribution, or insufficient reinforcement can result

in excessive stress concentrations on the walls, leading to cracks. Design flaws, such as insufficient wall thickness or inadequate support for heavy loads, can contribute to the development of cracks over time, (Mohd, et al., 2015).

- **Foundation Settlement and Soil Conditions:** Foundation settlement and soil-related issues are major determinants of wall cracks. Uneven settling of the building's foundation can exert uneven pressure on the walls, leading to cracks. Poor soil conditions, including expansive or collapsible soils, inadequate compaction, or improper soil preparation, can further exacerbate settlement issues and contribute to wall cracking, (Sinha, 2017).

- **Environmental Factors:** Environmental factors have a significant impact on the development of wall cracks. Temperature fluctuations, moisture variations, and exposure to harsh weather conditions can cause materials to expand and contract leading to cracking. Additionally, seismic activity, ground movement, or soil erosion due to water infiltration can induce structural movements and cracks in the walls, (Ghosh, 2018).

- **Construction Practices and Material Quality:** Quality of construction practices and materials used in the building process greatly influence the occurrence of wall cracks. Poor workmanship, improper mixing or curing of concrete, inadequate reinforcement or insufficient construction supervision can contribute to structural weaknesses and crack formation. Inappropriate material selection or the use of low-quality building materials may also increase the susceptibility of walls to cracking, (Sinha, 2017).

- **Building Movement and Settlement:** Building movement, whether due to settlement, expansion, or other causes, can result in wall cracks. (Priyanka & Bhardwaj (2019), this can include differential settlement between different parts of the building, thermal expansion and contraction, or structural movement induced by external factors. As the building shifts or moves, stress is exerted on the walls, potentially leading to cracking.

- **Chemical Reactions:** Certain chemical reactions in building materials result in appreciable increase in volume, developing internal stresses which result in outward thrust and formation of cracks. (Zeeshan, 2023), the materials involved in reaction also become weaker in strength. Sulphate attack on cement products, carbonation in cement based materials, corrosion of reinforcement in concrete and brickwork, and alkali aggregate reaction are the common chemical actions on building materials. This can also lead to cracks in building.

- **Trees in Close Proximity to the Property:** Trees often have invasive root structures that can also contribute to wall cracking. You should ensure that you do not have anything other than small shrubs or bushes in close proximity to your walls. Aside from destructive roots, trees can also contribute to wall cracking by removing water from the soil and affecting the soil's moisture content. The removal of a large tree from an area that is in close proximity to your walls may cause cracking because it can destabilise the soil in the space previously occupied by the root system. It can also lead to changes in the moisture levels of the soil or settling over time, (Mackintosh, 2021). Others are Brutal decoration, free to remove the load-bearing walls or holes, causing cracks, Fires caused by accidents, fires, mild earthquakes, etc.

- **Earthquake:** Crack may occur due to sudden shift in lower layer of the earth. The voids in the earth might have suddenly collapsed and be filled with soil from the above. Many geological events can trigger earth movements but is continuous movement.

Consequences of Wall Cracks in Buildings

Cracks have a number of negative effects on the building. For example, it will cause the heat bridge effect even weaken the wall insulation and thermal insulation properties. The existence of cracks reduces the durability, applicability, bearing capacity and seismic performance of buildings. (Linkedin 2021), If early-age cracking is not repaired properly it may lead to water ponding and allow penetration of aggressive substances like sulfate, chloride, and carbonation. These harmful substances cause steel reinforcement corrosion and reduce the lifespan of the structure. These consequences highlight the importance of addressing and remedying wall cracks in a timely manner to ensure the safety, durability, energy efficiency, indoor air quality, and overall value of buildings. Wall cracks can have several effects for the sustainability of buildings, including. Here are some consequences of wall cracks in buildings:

- **Structural Integrity:** Wall cracks can compromise the structural integrity of buildings, leading to potential safety hazards. Severe or progressive cracks may indicate foundation settlement, inadequate structural design, or other structural issues that require attention to prevent further damage, (Assi, L. (2018). Structural deficiencies can necessitate extensive repairs, retrofitting, or even demolition and reconstruction, resulting in additional resource consumption and waste generation, (Mohd, 2016).

- **Water Infiltration and Moisture Damage:** Wall cracks provide pathways for water infiltration, which can lead to moisture damage in building materials. (Revez and Sarja 2019), this can result in the deterioration of walls, including the growth of mold and mildew, rotting of wood, and corrosion of metal reinforcements.

- **Energy Loss and Increased Costs:** Wall cracks contribute to air leakage, leading to energy loss and increased energy consumption. (Sharmin and Pathan, 2020), the infiltration of outside air affects the heating and cooling efficiency of buildings, resulting in higher energy bills. Addressing and sealing wall cracks can help improve energy efficiency and reduce operational costs. Air leakage through cracks can result in heat loss during colder seasons and heat gain during warmer seasons, (Khan, and Abbasi 2018). This increased energy demand for heating and cooling negatively impacts the sustainability of buildings and contributes to higher energy consumption and greenhouse gas emissions, (Alves, et al., 2017).

- **Indoor Air Quality and Health Concerns:** Wall cracks can allow the entry of outdoor pollutants, allergens, and contaminants into the indoor environment. This can negatively impact indoor air quality and occupants' health, leading to respiratory issues, allergies, and other health concerns. Proper sealing and maintenance of wall cracks can help mitigate these risks, (Afroz, 2018).

- **Aesthetic and Property Value Reduction:** Wall cracks can significantly impact the aesthetic appeal and perceived value of a building. Cracked walls can give the impression of poor maintenance and structural problems, potentially

affecting the property's resale value and market perception, (Al-Enezi, and Dawood 2019). According to Sousa et al., (2015), wall cracks can impact the visual appearance of buildings, affecting their aesthetic value. This can have implications for the overall perception of the building and its market value. The need for aesthetic repairs or treatments to address wall cracks may involve the use of additional materials and resources.

Remedies to Wall Cracks in Building

- **PU injection grouting:** Polyurethane injection grouting, also known as PU injection grouting, is a waterproofing technique that injects polyurethane, a fluid resin, to prevent water leakage through cracks or gaps in the concrete. When in contact with water or moisture, this fluid resin will react and expand up to 10 times its original volume to fill up the existing gaps until there is no more space to stop water from flowing through structural joints and crack lines. This non-invasive and cost effective technique is often implemented to repair cracks and stop water seepage on walls, floors, etc. It offers significant advantages, as it is easy to apply and very durable.

- **Waterproofing Membrane:** A waterproofing membrane is a thin layer of water-tight material that is applied onto the wall water leakage areas to stop water ingress. There are many different types of waterproofing membranes and each has its varying functions. Some types include cementitious membrane, clear penetrative waterproofing treatment and polyurethane waterproofing membrane. The most commonly used product in the market would be the cementitious waterproofing membrane which adheres to concrete and masonry surfaces. The coating can resist both internal and external water vapour pressure, creating a barrier to water entry. It offers significant advantages as it is strong, flexible, tear-resistant and elastic. It is commonly used to waterproof floors and walls, achieving strong non-corrosive bonding to concrete and masonry surfaces. Crack stitching is a permanent solution to cracks in masonry walls. It involves embedding stainless steel helical bars into horizontal slots into the mortar bed joints of your wall to restore structural integrity.

- **Gravity Filling:** Low viscosity monomers and resins can be used to seal cracks with surface widths of 0.001to 0.08 in. by gravity filling. High molecular weight methacrylates, urethanes, and some low viscosity epoxies have been used successfully.

- **Routing And Sealing:** In this method, the crack is made wider at the surface with a saw or grinder, and then the groove is filled with a flexible sealant. This is a common technique for crack treatment and it is relatively simple in comparison to the procedures and the training required for epoxy injection.

- **Stitching:** This method is done to provide a permanent structural repairs solution for masonry repairs and cracked wall reinforcement. It is done by drilling holes on both sides of the crack, cleaning the holes and anchoring the legs of the staples in the holes with a non-shrink grout

- **Dry Packing:** It is the hand placement of a low water content mortar followed by tamping or ramming of the mortar into place and also helps in producing intimate contact between the mortar and the existing concrete.

- **Polymer Impregnation:** Monomer systems can be used for effective repair of some cracks. A monomer system is a liquid consisting of monomers which will polymerize into a solid. The most common monomer used for this purpose is methyl methacrylate.

- **Underpinning:** This is the best solution whereby the footings of the building are underpinned with either concrete, masonry or piles to carry the load of the building down to a more stable stratum (e g rock or soils below the reactive zone).This solution is usually the most costly, particularly if there are access difficulties or if internal walls require underpinning, which may require lifting internal floors.

Prevention of Wall Cracks in Building

Prevention of wall cracks in buildings involves implementing various measures to minimize structural movement and stress on the walls. Preventing wall cracks in buildings is crucial for maintaining their structural integrity and longevity. Here are some preventive measures that can help minimize the occurrence of wall cracks:

- **Strong foundation:** Buildings are only as strong as their foundations. A building's foundation plays a crucial role in its durability, but if they are not built properly, the building's durability and resilience can suffer. Naturally, the structure will only last for a short while without a solid foundation underneath. (Roar engineering 2022), improperly constructed structures are dangerous to their occupants and the surrounding neighbourhood. Because concrete is versatile, it is commonly used as a foundation material. Building foundations prevent moisture from entering, provide insulation, and keep the earth from moving around them.

- **Reduce Water Content in Concrete:** A low water cement ratio will affect the quality of concrete. W/C ratio is weight of water to the weight of cement used. A lower w/c ratio leads to high strength in concrete and lesser cracks. W/C ratio shall not exceed 0.5 in concreting, which reduces the workability of concrete which can be covered by use of plasticizer or superplasticizer.

- **Proper Curing of Concrete:** Stop rapid loss of water from surface or drying of concrete due to hydration (liquid concrete converts to plastic and then to solid state) causes drying of the slab, so it's recommended to cure the slab for several days. As soon as the concrete on slab sets its general practice to make boundary with mortar on the slab and keep it filled with water. Cover slab with cotton mats soaked with water or spray on a curing compound also prevents loss of water. The concrete should not be subjected to load during the curing period, which can last up to one month, (The constructor 2021).

Conclusion

The study concluded that cracks in buildings can be as a result of one or a combination of factors such as poorly designed or constructed foundations, expansive soils, inadequate soil preparation, and others. Therefore, assessing the determinants of wall cracks, investigating their consequences, and implementing remedial measures are vital for enhancing the resilience and sustainability of buildings. Continued research, awareness, and proactive maintenance practices in this area are essential for creating safer, more durable, and more efficient built environments. The study revealed that it is important to practice proper construction methods and engage with qualified professional building contractors so that the cracks and problems associated with them can be prevented.

Recommendations

1. During the building construction, there should be structural integrity of buildings which leads to safety from hazards. This will help avert the structural deficiencies that brings about cracks and other issues with extensive repairs, retrofitting, or even demolition and reconstruction.

2. Crack can be controlled if proper consideration is given to construction materials and technique to be used.

3. Buildings foundation should be constructed on firm ground to avoid destabilization of the building.

REFERENCES

Afroz, R., Al-Hamadani, M. & Adnan, M. (2018). Impact of Building Envelope Cracks on Indoor Air Quality of Office Buildings. *Sustainability*, 10(9), Pp.3073.

Al-Enezi, M. & Dawood, M. (2019). Impact of Cracks on the Aesthetic Quality of Buildings in Kuwait. *Journal of Engineering Research and Technology,* 6(1), Pp.59-69.

Assi, L. (2018). The Effects of Cracks on the Durability and Structural Integrity of Concrete Structures: A Review. *Structures*, 15, Pp.309-321

Bay Area Underpinning (2022) Wall Cracks: Foundation Problem or Something Else? Available at: https://bayareaunderpinning.com/wall-cracks-foundation-problem-or-something-else/

Bramley, G. & Power, S. (2009) Urban form and social sustainability: the role of density and housing type. Environment and Planning B: Planning and Design, Vol.36, No.1, pp. 30–48, ISSN 0265-8135

Egloff, S. (2022) Wall Cracks: Foundation Problem or Something Else? Available at: https://bayareaunderpinning.com/wall-cracks-foundation-problem-or-something-else/

Ghosh, S., & Ghosh, S. K. (2018). Causes and Effects of Cracks in Buildings: A Review. *International Journal of Innovative Research in Science, Engineering and Technology*, 7(4), 4822-4831.

Gottfried, D., (2009), The Economics of Green Buildings, Sustainable Building Technical Manual: Green Building Design, Construction, and Operations, *Public Technology Inc.*, USA, pp. 16-24.

Linkedin (2021) Effects of Unrepaired Early-age Cracking in Concrete Structure. Available at: https://www.linkedin.com/pulse/effects-unrepaired-early-age-cracking-concrete-limited.

Lippiatt, B. & Norris, G., (2007), Selecting Environmentally and Economically Balanced Building Materials, Sustainable Building Technical Manual*:* Green Building Design, Construction, and Operations, *Public Technology Inc.,* USA, pp. 25-31.

Longman, J., (2011). Acoustics, Sustainable Building Technical Manual: Green Building Design, Construction, and Operations, *Public Technology Inc.*, USA, pp. 155-160.

Luana, H., Kanga, Q. &Liub, T. (2017) Cause Analysis and Control Measures of Cracks in FillingWall of Reinforced Concrete Structure Available at: https://www.aidic.it /cet/17/59/089.pdf

Mackintosh, A. (2021) what causes cracks in walls? action property inspections. Retrieved from: https://actioninspections.com.au/what-causes-cracks-in-walls-action-property-inspections/

Mackintosh, A. (2023) What Causes Cracks in Walls? Action Property Inspections Available at: https://actioninspections.com.au/what-causes-cracks-in-walls-action-property-inspections/

Medlock, E. (2022) Crack on Wall: Cause and Effect. Retrieved from: https://www.homedit.com /cracked-wall/

Mohd, R. H., Ibrahim, N., & Yusof, Z. M. (2015). Causes and Types of Cracks in Masonry Buildings: A Review. International Journal of Integrated Engineering, 7(3), 1-8.

Pooja Nama, Ankush Jain, Rajat Srivastavaand Yash Bhatia (2015). *Int. Journal of Engineering Research and Applications*, 5(5), (Part -2) May2015, pp.119-12

Priyanka, P. S., & Bhardwaj, R. (2019). Causes and Repairing Techniques for Cracks in Building Structures: A Review. *International Journal of Engineering Research and Technology*, 12(9), 1344-1351.

Rajabather, A. (2016) investigation of cracks in buildings Retrieved From: https://www.researchgate.net/publication/319630328_INVESTIGATION_OF_CRACKS_IN_BUILDINGS

Researchwap.net (2023) Investigation into the Causes of, Effects, and Prevention of Cracks Building Available at: https://researchwap.net/civil-engineering/pru35Q1cL29RvD

Revez, A., & Sarja, A. (2019). Wall Cracks and Moisture Damage in Multifamily Buildings. *Buildings,* 9(2), Pp.44.

Rodman, D. & Lenssen, N., (2005). A Building Revolution: *How Ecology and Health Concerns Are Transforming Construction,* Worldwatch Paper 124, Washington, D.C

Romm, J. & Browning, L (2006), Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design, Rocky Mountain Institute, Snowmass, Colo.

Sharmin, R., & Pathan, A. (2020). Impact of Building Envelope Cracks on Energy Performance of Office Buildings. *Energies*, 13(10), Pp.2625.

Sinha, D. (2017). Causes and Prevention of Cracks in Buildings: A Comprehensive Study. International Journal of Civil Engineering and Technology, 8(7), 673-683.

Siu, K. (2022). Sustainable Built Environment. Available at: https://www.mdpi.com/topics/Sustainable_Built_Environment.

SWC Construction (2020) Causes and Remedies of Wall Cracks. Available at: https://swcconstruction.com.sg/blogs/causes-and-remedies-of-wall-cracks/The World Bank (2015). *World Development Indicators*. Retrieved September 2, 2015, from http://data.worldbank.org/data-catalog/world-development-indicators.

Zeeshan T (2023) 7 Major Causes of Cracks in Buildings. Retrieved from: https://www.yourarticlelibrary.com/building-engineering/7-major-causes-of-cracks-in-buildings/85630