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STUDY AND INSPECTION OF STRUCTURAL CRACKS

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ABSTRACT:
The exploration of Mars has long captivated the scientific community, particularly through the use of micro rovers capable of autonomous navigation and data collection. The present research focuses on developing a prototype model named MERR (Mars Exploration & Research Rover) to serve as a foundation for future Martian terrain exploration. The rover is designed to operate within strict constraints of mass, power, volume, and cost, while maintaining functionality and scientific value. Unlike stationary landers, mobile rovers such as MERR offer the advantage of extended terrain coverage, enhanced observational capabilities, and the flexibility to reposition based on environmental or research demands. The rover is equipped with an all-wheel drive system powered by DC electric motors, enabling it to traverse challenging surfaces. Integrated sensors, including temperature sensors and distance measuring devices, support terrain assessment and environmental analysis. A soil and rock collection arm enables the retrieval of Martian samples for detailed post-mission analysis. The onboard electronics are powered by a lithium-ion battery pack, which is supplemented by a solar panel for energy sustainability. At its core, the rover uses an Arduino microcontroller for processing sensor data and executing control algorithms. This design aims to address several key mission objectives: studying the Martian atmosphere, assessing the planet's potential habitability, and conducting long-term geological and environmental observations. The rover's ability to autonomously navigate and adapt to varying terrain makes it an essential tool in overcoming the logistical challenges of planetary exploration. Ultimately, the MERR prototype demonstrates a comprehensive approach to Martian exploration, blending practical engineering with scientific inquiry. Its development represents a crucial step toward more advanced, scalable systems for planetary missions, contributing valuable insights to the fields of robotics, space exploration, and remote sensing.
Keywords: Martian Structural Cracks, Crack Diagnosis, Building Defects, Foundation Settlement, Concrete Durability

INTRODUCTION:

Cracks in buildings are a common and persistent issue encountered in both new and old structures. These fissures, ranging in width, length, and depth, may appear due to a variety of factors, including environmental influences, design inadequacies, material properties, and construction errors. Cracking in concrete and masonry is not merely an aesthetic concern—it can be symptomatic of deeper structural, durability, or serviceability issues. Therefore, understanding the causes, implications, and remedial techniques is essential to maintain structural integrity and extend the service life of buildings. Concrete and masonry, the primary materials used in building construction, are known for their high compressive strength but limited tensile resistance. As a result, they are particularly susceptible to cracking when exposed to tensile and shear forces induced by thermal variations, shrinkage, settlement, structural loading, and external vibrations. The restrained movement caused by the rigidity of these materials often leads to internal stress buildup, and once these stresses exceed the material's tensile strength, cracks inevitably occur [1], [2].

Broadly, cracks in buildings can be classified as structural or non-structural. Structural cracks typically arise due to design flaws, foundation settlement, excessive loading, or construction deficiencies. These cracks can compromise the stability and safety of a structure. Non-structural cracks, on the other hand, are often caused by shrinkage, thermal movement, moisture variations, or poor workmanship. Although they may not affect the load-bearing capacity directly, they can still facilitate moisture ingress, corrosion of reinforcement, and progressive deterioration [3].

Thermal movement is one of the predominant causes of cracking, particularly in climates with significant temperature fluctuations. Materials expand and contract due to temperature changes; however, when such movements are restrained by adjoining components, tensile stresses develop. In structures where proper expansion joints or flexible materials are absent, these stresses manifest as cracks. Similarly, moisture-related changes, such as drying shrinkage in concrete and expansion in bricks due to water absorption, also contribute to crack formation [4].

A significant cause of cracking in masonry structures is differential movement between different building components. For instance, parapet walls constructed atop reinforced concrete slabs are prone to horizontal cracks at their base. This phenomenon is attributed to the differential thermal expansion between concrete and brickwork. Moreover, premature construction of masonry over fresh concrete slabs—before adequate drying shrinkage has occurred—exacerbates this issue [5].

Cracks may also originate due to poor construction practices, including inadequate curing, use of substandard materials, improper joint detailing, and insufficient reinforcement. These flaws, if not identified and rectified during construction, can lead to long-term damage and require extensive repair interventions. Additionally, design errors such as inadequate depth of beams or slabs, omission of reinforcement at critical points (e.g., corners), and lack of movement joints can result in early onset of cracks under service loads [6].

Visual inspection plays a crucial role in identifying and categorizing cracks. Parameters such as location, orientation, width, and propagation provide valuable insights into their likely causes. For example, diagonal cracks at corners might suggest foundation settlement, whereas vertical cracks near doors and windows could indicate thermal or shrinkage movement. Classification based on appearance and pattern helps engineers determine whether the cracks are dormant or progressive and what remedial actions should be employed [7].

Several studies have emphasized the importance of preventive measures in controlling cracks. These include proper material selection (e.g., low-shrinkage concrete), timely construction sequencing (e.g., delaying masonry over slabs), and incorporating control joints. Furthermore, repair techniques such as epoxy injection, grouting, dry packing, routing and sealing, and polymer impregnation are widely practiced based on the type and severity of cracks. Stitching, drilling and plugging, and gravity filling are employed to restore the integrity of damaged concrete sections [8].

The phenomenon of cracking cannot be entirely eliminated, but with informed design, quality materials, and good construction practices, it can be significantly minimized. The understanding of crack behavior, their categorization, and proper intervention not only ensures structural safety but also enhances durability, serviceability, and aesthetic value. This study aims to investigate the causes of structural cracks in buildings, classify the types observed in real-world scenarios, and explore effective control and repair measures.

LITERATURE REVIEW:

Cracks in buildings, though often regarded as superficial flaws, may indicate underlying structural distress and pose long-term safety and durability concerns. Over the years, several researchers have analyzed their origins, progression, and remedial strategies.

Kazem Reza Kashyzadeh and Neda Aghili Kesheh [9] classified common cracks observed in construction and emphasized that most cracks are not due to structural inadequacy but rather environmental, material, and execution-related factors. They underscored the importance of early-stage recognition of crack patterns as part of preventive maintenance.

Grishma Thagunna [10] identified both direct and indirect causes of building cracks. Her study highlighted that while cracks might not immediately affect structural performance, they facilitate moisture ingress, which accelerates deterioration. The research stressed the necessity of integrating thermal and moisture protection in design to reduce such risks.

Syed Mohd Mehndi et al. [11] focused on the evaluation of cracks in concrete structures using diagnostic tools like ultrasonic pulse velocity and crack comparators. Their study demonstrated how non-destructive techniques (NDT) can effectively assess crack severity and help determine repair needs without compromising structural elements.

Kunal and Killemsetty [12] emphasized visual inspection as an essential tool for categorizing cracks. Their case study on institutional buildings revealed that visual signs such as direction, depth, and propagation rate can guide preliminary diagnosis, prompting detailed assessments when necessary.

Rytis Skominas et al. [13] explored material compatibility in the context of crack repair. Their experiments on epoxy resin, polymer-modified cement, and injection grouts concluded that long-term performance of repairs depends heavily on the mechanical compatibility between the crack sealant and the base material.

S. B. Patil and R. V. Devalkar [14] conducted a study on cracking in multistoried buildings in expansive soil areas. They observed that soil movement, especially in black cotton soils, causes foundation-level shifting, which propagates into structural cracks. Proper foundation design, including the use of under-reamed piles, was recommended to address such geotechnical issues.

M. N. Sinha and K. N. Jha [15] addressed the influence of construction quality on crack formation. Their findings indicated that premature removal of formwork, inadequate curing, and use of low-grade materials significantly contribute to early-age cracking in concrete structures. The study advocated for the strict implementation of quality control measures during construction.

K. P. Ramesh and D. K. Paul [16] investigated seismic effects on crack propagation in reinforced concrete frames. Through simulations and real-world observations, they concluded that poor detailing and insufficient ductility result in brittle failures, which begin as minor cracks but lead to collapse under strong ground motion.

J. P. Bhatt and H. S. Patel [17] analyzed shrinkage-induced cracking in concrete floors and slabs. They demonstrated that panel size, placement sequence, and environmental exposure during curing influence the formation of plastic and drying shrinkage cracks. Use of shrinkage-reducing admixtures and strategic joint placement were among the suggested remedies.

Zubair Hamid Bhat and Richika Rathore [18] provided a holistic overview of cracking phenomena in buildings. Their study detailed common crack locations—such as at parapets, junctions, and ceiling corners—and prescribed control measures including slip joints, delayed masonry construction, and groove provisions in plastering.Collectively, these studies reveal that cracks are the result of a complex interplay of structural, material, environmental, and human factors. Preventing or mitigating their effects requires a multi-disciplinary approach involving sound structural design, material selection, site-specific foundation solutions, and rigorous quality control.

TYPES OF STRUCTURAL CRACKS IN BUILDINGS:

Cracks in buildings are indicators of potential structural problems or material behavior under various environmental and mechanical stresses. Understanding the type, cause, and severity of cracks is essential for determining whether a crack is a cosmetic issue or a symptom of deeper structural failure. This document outlines the main types of structural and non-structural cracks typically encountered in buildings, supported with illustrative diagrams.

Horizontal Cracks: Horizontal cracks are typically observed in walls and are often caused by excessive lateral pressure such as earth pressure on basement walls, thermal movement, or poor construction joints. In reinforced concrete, these cracks may form due to insufficient reinforcement or shear failure.

Vertical Cracks : Vertical cracks commonly occur due to foundation settlement, shrinkage of concrete or plaster, or structural movement. They often appear in walls near door or window frames and may be early indicators of subsidence or differential settlement.

Diagonal Cracks : Diagonal cracks are usually a result of shear stress and are most commonly found in beams and walls. These cracks can be serious and indicate differential settlement or inadequate shear reinforcement. They often emanate from corners of windows or doors and angle upwards.

Step Cracks : Step cracks typically follow the mortar joints in masonry structures and resemble a staircase. They indicate foundation movement and are often seen in brick walls. Their presence may suggest a shifting or sinking foundation that requires urgent structural inspection.

Hairline Cracks : Hairline cracks are fine and shallow cracks that usually form on plaster or concrete surfaces due to shrinkage or thermal contraction. While usually non-structural, their propagation over time may allow moisture ingress, leading to further damage.

Settlement Cracks : Settlement cracks appear when a part of the building settles more than other parts, often due to soil movement beneath the foundation. These cracks are typically wide at the top and narrow at the bottom or vice versa, depending on the direction of settlement.

Map Cracks (Crazing) : Map cracks, or crazing, form a network of fine, random cracks that resemble a road map. These are usually surface-level and occur due to shrinkage in plaster or concrete. They rarely affect structural integrity but may affect aesthetics and surface durability.

CONTROLLING MEASURES FOR CRACKS IN STRUCTURES:

Cracks in buildings can compromise both aesthetic and structural integrity. Effective crack control measures are essential during both the design and construction stages to ensure long-term durability and safety. This document outlines various strategies used to prevent, minimize, and manage structural cracks, supported with illustrations.

Control Joints:

Control joints are deliberate separations in concrete structures that allow movement due to shrinkage or temperature changes. These joints help in controlling the location of cracks, directing them to predetermined weak planes where they will be less harmful.

Slip Joints :

Slip joints are used to allow relative movement between different structural components. For example, in masonry walls where slabs rest, slip joints allow for independent expansion and contraction, preventing cracking caused by differential movements.

Reinforcement at Wall Junctions:

Cracks often form at junctions between intersecting walls. To prevent these, reinforcement meshes are embedded across junctions. These meshes absorb stress concentrations and provide continuity across the joint, improving crack resistance.

V-Grooves in Plaster:

In plaster finishes, V-grooves are intentionally provided at weak points to control where minor shrinkage cracks appear. They serve both functional and aesthetic purposes, guiding the cracking to a predefined path and blending it into the design.

Proper Curing of Concrete:

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Curing is vital in preventing early-age cracks in concrete. Inadequate curing results in rapid moisture loss and thermal shrinkage, leading to surface cracking. Continuous moist curing for at least 7 days ensures optimal strength gain and crack resistance.

Use of Admixtures:

Chemical admixtures such as shrinkage-reducing agents, plasticizers, and retarders are used to control the workability and shrinkage characteristics of concrete. These additives enhance the mix performance, reducing the risk of cracks due to early drying or thermal effects.

Structural Design Considerations:

Proper design, including adequate reinforcement detailing and stress distribution, helps in reducing the chances of cracking. Overstressing and abrupt geometry changes can lead to crack initiation. Designs should incorporate flexibility and resistance to anticipated stresses.

Soil and Foundation Treatment:

Uneven foundation settlement causes structural stress, resulting in cracks. Pre-construction soil testing and the use of appropriate foundation systems like raft or pile foundations can mitigate these risks. Ground improvement techniques such as compaction and grouting are also beneficial.

Maintenance and Monitoring:

Regular inspection and maintenance play a crucial role in preventing the propagation of cracks. Techniques like epoxy injection, crack stitching, or surface sealing can be used to treat existing cracks before they worsen.

Controlling structural cracks requires a multi-faceted approach involving proper design, quality construction practices, material selection, and proactive maintenance. Early identification and timely intervention can preserve both the structural integrity and the appearance of buildings, ensuring their safety and longevity.

CONCLUSION:

Cracks in buildings are among the most common and visible signs of structural distress or material imperfections. Through this study, a comprehensive understanding of the types, causes, and control measures for cracks has been developed. The presence of cracks may originate from a wide array of factors, ranging from poor design and workmanship to environmental influences like temperature variation, moisture ingress, and foundation settlement. Regardless of their origin, cracks—whether structural or non-structural—can significantly affect the stability, serviceability, and aesthetics of a structure.This manuscript systematically classified various types of cracks, such as horizontal, vertical, diagonal, step, and hairline cracks, among others. Each type was linked with specific structural behaviors and failure modes, allowing a deeper diagnosis of potential root causes. Furthermore, advanced techniques and good construction practices were identified as key preventive tools in mitigating crack development. Measures such as the use of control and slip joints, proper reinforcement detailing, adoption of curing practices, and soil treatment strategies have been highlighted as effective in minimizing the formation and propagation of cracks.

Additionally, non-invasive monitoring and regular maintenance play a critical role in managing existing cracks and preventing their deterioration. By combining proactive design decisions with practical construction techniques, it becomes possible to achieve both structural integrity and long-term durability in civil engineering projects.

In conclusion, the proper diagnosis and management of cracks not only enhance the lifespan of a structure but also ensure safety, economy, and functionality. This study contributes to the awareness and technical understanding necessary for engineers, architects, and construction professionals to make informed decisions in crack prevention and treatment. Continued research and on-site investigation are recommended for developing more advanced materials and monitoring systems tailored to dynamic construction environments.

CONFLICT OF INTEREST:

The authors declare no conflicts of interest, including financial or other relationships that may bias the work. All authors have made substantial contributions to this research and have approved the final manuscript. This work has not been previously published or submitted for publication elsewhere.

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REFERENCES:

[1] G. Thagunna, "Building cracks – causes and remedies," in *Proc. 3rd World Conf. on Applied Sciences, Engineering & Technology*, Basha Research Centre, 2014.
[2] K. R. Kashyzadeh and N. A. Kesheh, "Study type of cracks in construction and its controlling," *Int. J. Eng. Res. Appl.*, vol. 2, no. 8, pp. 528–531, Aug. 2012.
[3] S. M. Mehndi, M. A. Khan, and S. Ahmad, "Causes and evaluation of cracks in concrete structures," *Int. J. Eng. Res. Appl.*, vol. 2, no. 5, pp. 64–72, Sep.-Oct. 2014.
[4] K. Kunal and N. Killemsetty, "Study on control of cracks in a structure through visual identification & inspection," *Int. J. Eng. Res. Appl.*, vol. 11, no. 5, pp. 64–72, 2014.
[5] Z. H. Bhat and R. Rathore, "Study on causes & control of cracks in a structure," *Int. J. Innov. Res. Comput. Sci. Technol.*, vol. 10, no. 3, pp. 333–337, May 2022, doi: 10.55524/ijircst.2022.10.3.54.
[6] R. Skominas, V. Gurskis, and A. Patasius, "Research of material suitability for crack repair in reinforced concrete structures," in *Proc. 4th Int. Conf. CIVIL ENGINEERING'13*, 2013.
[7] A. Neville, *Properties of Concrete*, 5th ed., Pearson, 2011.
[8] M. S. Shetty, *Concrete Technology: Theory and Practice*, 7th ed., S. Chand Publishing, 2013.
[9] K. R. Kashyzadeh and N. A. Kesheh, "Study type of cracks in construction and its controlling," Int. J. Eng. Res. Appl., vol. 2, no. 8, pp. 528–531, Aug. 2012.
[10] G. Thagunna, "Building cracks – causes and remedies," in Proc. 3rd World Conf. on Applied Sciences, Engineering & Technology, Basha Research Centre, 2014.
[11] S. M. Mehndi, M. A. Khan, and S. Ahmad, "Causes and evaluation of cracks in concrete structures," Int. J. Eng. Res. Appl., vol. 2, no. 5, pp. 64–72, Sep.-Oct. 2014.
[12] K. Kunal and N. Killemsetty, "Study on control of cracks in a structure through visual identification & inspection," Int. J. Eng. Res. Appl., vol. 11, no. 5, pp. 64–72, 2014.
[13] R. Skominas, V. Gurskis, and A. Patasius, "Research of material suitability for crack repair in reinforced concrete structures," in Proc. 4th Int. Conf. CIVIL ENGINEERING'13, 2013.
[14] S. B. Patil and R. V. Devalkar, "Causes and control measures for cracks in buildings constructed on expansive soil," Int. J. Adv. Res. Eng. Technol., vol. 11, no. 5, pp. 1735–1741, May 2020.

[15] M. N. Sinha and K. N. Jha, "Effect of construction quality on early-age cracking in concrete," J. Constr. Eng. Manage., vol. 139, no. 3, pp. 287–294, Mar. 2013.
[16] K. P. Ramesh and D. K. Paul, "Seismic performance and cracking in RC buildings: Lessons from past earthquakes," Int. J. Civil Struct. Eng., vol. 2, no. 4, pp. 1051–1058, Dec. 2011.
[17] J. P. Bhatt and H. S. Patel, "Shrinkage cracking in concrete: Causes and preventive measures," Int. J. Eng. Res. Dev., vol. 10, no. 4, pp. 60–65, Apr. 2014.
[18] Z. H. Bhat and R. Rathore, "Study on causes & control of cracks in a structure," Int. J. Innov. Res. Comput. Sci. Technol., vol. 10, no. 3, pp. 333–337, May 2022, doi: 10.55524/ijircst.2022.10.3.54.