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TRANSPORT PROPERTIES OF CONCRETE USING DIFFERENT REPAIR MATERIALS

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ABSTRACT

Concrete structures are susceptible to degradation due to external forces and environmental factors, leading to the formation of cracking and spalling. Moreover, the deterioration of concrete, particularly the cover that protects the reinforcing bars, can be attributed to inadequate raw material selection, poor mixture design, and an irregular construction process. These faults reduce the longevity of the structure and result in the structure becoming unserviceable during operation. To successfully address these concerns, it is imperative to promptly undertake concrete repairs to reinstate the safety and functionality of the structures, hence prolonging their operational lifespan. This study aims to ascertain the mechanical characteristics of normal concrete for repair purposes and examine the transport qualities of concrete when applying various repair materials. The inquiry methodology consisted of two distinct phases. The first phase focused on analysing the physical and mechanical properties of concrete. The second phase consisted of investigating the mechanical properties of concrete after being exposed to environmental conditions for 60 days. Three distinct categories of repair materials were chosen, including epoxy, paint, and mortar It has been found that the performance of concrete varies depending on the exposure environment, such as water penetration, carbonation, and chloride immersion, while using different repair materials.

Keywords: *Repair, Material, Properties, Concrete, Defect*

INTRODUCTION

Transport properties of concrete are crucial considerations in the field of civil engineering, particularly when it comes to assessing durability and performance over time. These properties encompass factors such as permeability, diffusivity, and moisture movement within the concrete structure. When repairing concrete, the choice of repair materials can significantly impact these transport properties. Different repair materials offer varying characteristics that can influence the overall transport properties of the repaired concrete. One common repair material is epoxy-based resins, which are known for their impermeability and ability to adhere strongly to concrete surfaces. Epoxy resins can effectively reduce water permeability in repaired areas, enhancing the durability of the structure (Neville, 2011: Mehta, 2014)

On the other hand, cementitious repair materials like mortar and grout provide good compatibility with existing concrete but may not offer the same level of impermeability as epoxy resins. These materials can still improve the overall transport properties of concrete by filling cracks and voids, reducing the potential for moisture ingress and chemical attacks. Polymer-modified repair materials combine the advantages of both epoxy resins and cementitious materials. These materials typically consist of polymers that enhance adhesion and flexibility, improving the resistance to moisture penetration and external factors. Polymer-modified materials are often used for repairing concrete in harsh environments where durability is a primary concern.

When selecting repair materials for concrete structures, the consideration is not only the mechanical properties but also the transport properties to ensure long-term performance and durability. Understanding the specific requirements of the project and the environmental conditions will help in choosing the most suitable repair materials that enhance the transport properties of concrete effectively. The transport properties of concrete play a significant role in assessing the durability and performance of structures. By using appropriate repair materials such as epoxy resins, cementitious materials, or polymer-modified products, engineers can enhance these properties and prolong the lifespan of concrete structures. It is essential to consider the specific needs of each project to make informed decisions regarding the selection of repair materials and ensure the long-term integrity of concrete structures.

METHODOLOGY AND MATERIAL

The experimental process in the laboratory consists of two phases. The initial phase involves assessing the mechanical properties of concrete grade 20 through density testing and compressive testing for 28 days in water curing. The second phase of testing involves exposing concrete cubes to a tropical climate while implementing various remedial works. The protective coatings at surface treatments uses concrete hence, reducing water and ion ingress. Three types of remedial works have been applied epoxy resin, cement mortar, and white paint as shown in Figure 1. Control samples also were exposed to compare the performance of concrete with different repair materials. The compressive strength of each of these cubes was evaluated at 14 days, 30 days, and 60 days of following exposure.

Concrete grade 20 was examined utilising a notional mixture with a ratio of 1: 2: 4 due to the consideration of employing lower-strength concrete to apply remedial works to the surface of concrete structure. Physical observation of concrete before and after exposure for 14 days, 30 days, and 60 days to see the cube samples when exposed to rain and sun. The transport qualities of concrete were evaluated by performance over time. These qualities include permeability, diffusivity, and moisture movement inside the concrete structure. When repairing concrete, the materials used might have a considerable impact on its transport qualities.

Figure 1. Concrete with Different Repair Material were Exposed to Weather

RESULTS

Density of Concrete

The provided bar graph shown in Figure 2 shows the density changes of a material over three different durations: 7 days, 14 days, and 28 days. The data includes density measurements taken before and after a specific process or treatment. The density increases consistently over time, with the highest density observed at 28 days. This trend suggests that the material continues to gain density as it cures or undergoes the specified process. The increase in density from 7 to 14 days (0.05 kg) is slightly higher than from 14 to 28 days (0.04 kg). However, the total increase over the entire period from 7 to 28 days is 0.08 kg. The change from 7 days to 28 days is the largest, indicating a significant transformation occurring in the latter part of the process.

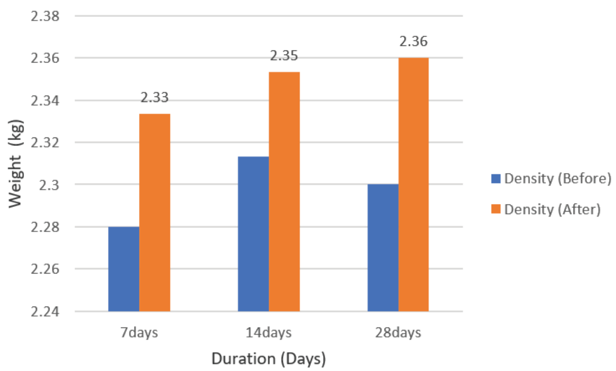

Figure 2. Density of Concrete Cube for 28 Days of Curing
Source: Author, 2025

The increase in density could be due to the material becoming more compact and less porous over time. A consistent increase in density often implies better structural integrity and durability of the material. Density changes can be an important quality control measure, ensuring that the concrete reaches the desired properties before being exposed to weather.

Compressive Strength in Water Curing

Figure 3 shows the results of compressive strength testing over three different durations: 7 days, 14 days, and 28 days. The compressive strength of the material increases consistently over time. The strength at 7 days is 18.33 MPa, which increases to 21.87 MPa at 14 days and reaches 24.87 MPa at 28 days. This upward trend indicates continuous improvement in the material's ability to withstand compressive forces. The increase from 7 to 14 days is slightly higher compared to the increase from 14 to 28 days, suggesting that the rate of strength gain may be decelerating as the material continues to cure or set. In proper curing will be adequate to reduce porosity and enhance hydration process of concrete development.

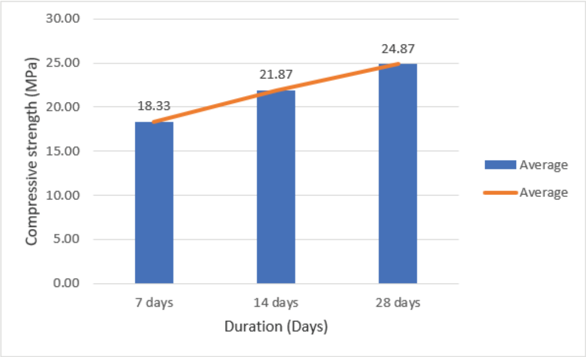

Figure 3. Compressive Strength of Concrete Cube for 28 Days of Water Curing
Source: Author, 2025

The increase in compressive strength is likely due to the ongoing curing process of the material. As it cures, the material's internal structure becomes more robust and attain higher compressive strength. The hydration process of cement particles contributes to the increase in compressive strength. Over time, the continued hydration leads to the formation of additional calcium silicate hydrate (C-S-H) gel, which enhances the strength (Bentz, 1991).

Compressive Strength at Weather Exposure

Figure 4a until Figure 4h shows the result of the compression test on concrete cubes with different repair materials after exposure to weather for 60 days before and after. The control and paint samples likely had smoother and flatter surfaces, contributing to their increased compressive strength.

A uniform and level surface ensures an even distribution of force during compression testing, reducing stress concentrations that can cause premature failure. The application of paint can effectively conceal minor surface imperfections, providing a consistent layer that enhances the structural integrity of the concrete. Research indicates that protective coatings, such as paint, can improve surface quality, leading to better performance during compression tests (Bashandy, A.A.,2020)

The epoxy-treated sample as shown in Figure 4(d) initially exhibited a rough surface with visible cracks. For epoxy to reach its full strength, proper surface preparation and adequate curing time are essential. The initial lower strength and subsequent improvement at 30 days suggest that the epoxy needed more time to fully cure and form a strong bond with the concrete. The rough surface may have caused uneven weight distribution, resulting in reduced initial strength. As curing progressed, the bonding capacity of the epoxy increased, leading to greater strength. Research by Smith et al. (2018) highlights how insufficient curing time can impact the early effectiveness of epoxy repairs, often requiring longer durations to achieve optimal strength.

The cracking and damage observed in the epoxy sample indicated uneven bonding across the surface. Inadequate curing resulted in weak areas within the concrete, lowering its overall compressive strength. The findings emphasize that the performance of epoxy is heavily dependent on proper surface application and thorough preparation (Chen, Z., & Ma, X, 2017)

The mortar sample showed the most significant surface degradation, with a rough and uneven texture both before and after testing in Figures 4 (e) and 4(f). Mortar's inherently higher porosity compared to other repair materials may lead to poor bonding and increased susceptibility to moisture infiltration and environmental damage. The rough surface likely caused uneven load distribution, reducing the sample's compressive strength. The severe deterioration observed at 60 days indicates that the mortar struggled to maintain its structural integrity over time. Studies suggest that the high porosity of standard mortar can negatively affect its effectiveness as a repair material (Kim, S.H., & Lee, J.Y, 2019)

The poor bonding in the mortar sample may be attributed to its high porosity and rough surface. Effective concrete repair requires materials that adhere well to the substrate, creating a smooth surface capable of withstanding compressive forces. Research by Taylor et al. (2016) emphasizes the importance of using low-porosity materials to ensure better bonding and structural integrity.


(a)Control (before)　(b)Control (After)


(c) Epoxy (before)　(d) Epoxy (After)


(e) Mortar (before)　(f) Mortar (After)

(g) Paint (before)

(h) Paint (After)

Figure 4a-h. Compressive Test of Concrete Cube after Exposure to Weather After 60 Days with Different Repair Materials

Source: Author, 2025

The provided graph in Figure 5 illustrates the compressive strength development of different repair materials (Paint, Control, Epoxy, and Mortar) in 60 days of outdoor exposure. Both Paint and Control have the highest compressive strengths, which suggest low permeability and high resistance to water and chloride ingress. These are beneficial for structures exposed to harsh environmental conditions as they help prevent deterioration and prolong the service life. High compressive strength in Paint at 43Mpa and Control sample at 39.1 Mpa likely correlates with reduced porosity and better performance against environmental factors such as radiation and chemical attacks. These properties are crucial for ensuring the long-term durability of concrete structures.

Epoxy samples show a moderate increase in compressive strength, peaking at 31.3 MPa. Although lower than Paint and Control, epoxy-based materials are known for its resistance to chemicals and excellent adhesive properties. Epoxy's performance in terms of transport properties is generally good. Its lower permeability makes it effective in sealing cracks and protecting against moisture and chloride penetration. This is particularly important for repairs in aggressive environments.

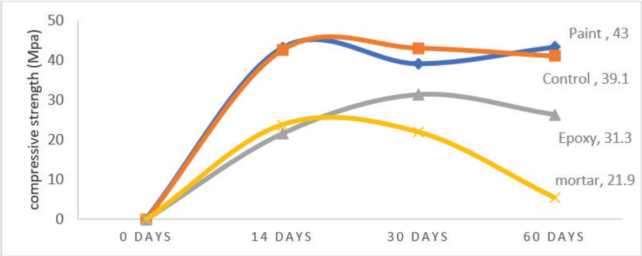

Figure 5. Compressive Strength of Concrete with Remedial Works After Exposure to Weather

Source: Author, 2025

Mortar samples exhibit the lowest compressive strength among the tested materials, stabilizing at 21.9 MPa. This suggests higher permeability and lower resistance to environmental factors compared to Paint, Control, and Epoxy. Mortar's higher permeability may lead to susceptibility to water and chloride ingress, making it less suitable for applications where high durability and resistance to environmental factors are critical. However, it remains a cost-effective option for less demanding repair applications.

DISCUSSION

Different repair materials offer varying characteristics that can influence the overall transport properties of the repaired concrete. For environments with high exposure to moisture and severe environments, remedial materials like Paint and Control samples with higher compressive strength and likely better transport properties are preferred. Polymer-modified repair materials combine the advantages of both epoxy resins and cementitious materials. These materials typically consist of polymers that enhance adhesion and flexibility, improving the resistance to moisture penetration and external factors. Polymer-modified materials are often used for repairing concrete in harsh environments where durability is a primary concern. Epoxy, while having a moderate compressive strength, provides excellent protection due to its low permeability and high adhesion, making it suitable for crack injection and surface protection in aggressive environments. Epoxy-based resins are known for their impermeability and ability to adhere strongly to concrete surfaces. Epoxy resins reduce water permeability in repaired areas and enhance the structure's durability. However, remedial material of mortar might be more suitable for non-critical repairs where cost-effectiveness is a primary concern and exposure conditions are less severe with its lower compressive strength.

On the other hand, cementitious repair materials like mortar provide good compatibility with existing concrete but may not offer the same level of impermeability as epoxy resins and paint. These materials can still improve the overall transport properties of concrete by filling cracks and voids, reducing the potential for moisture ingress and chemical attacks. In conclusion, the transport properties of concrete play a significant role in assessing the durability and performance of structures. By using appropriate repair materials can enhance these properties and prolong the lifespan of concrete structures. It is essential to consider the specific needs of each project to make informed decisions regarding the selection of repair materials and ensure the long-term integrity of concrete structures.

CONCLUSION

The transport properties of concrete are critical determinants of its durability and longevity. Permeability, diffusivity, and sorptivity each play distinct yet interconnected roles in governing the movement of fluids and ions within the material. By understanding the mechanisms behind these properties and the factors influencing them, engineers and researchers can develop more durable concrete mixes and design strategies to enhance the performance of concrete structures. Continued research and advancements in measurement techniques will further improve our ability to predict and mitigate deterioration processes, ensuring the resilience and sustainability of concrete infrastructure.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to the conception, design, analysis, and writing of this article. They reviewed and approved the final manuscript prior to submission.

CONFLICT OF INTEREST

The authors affirmed that there is no conflict of interest to disclose regarding the publication of this paper.

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