AN EXPERIMENTAL STUDY UTILIZING FLY ASH AND RED MUD TO EXAMINE THE FLEXURAL PERFORMANCE OF FUNCTIONALLY GRADED CONCRETE

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Abstract

The ongoing changes in strength and other characteristics, environmental issues, rising cement prices, and the development of the construction industry, alternative materials are used to create Functionally Graded Materials (FGM), which in turn creates new materials for concrete known as Functionally Graded Concrete (FGC). This pre-sent document presents the results of a research employing fly ash and red mud on functionally graded concrete. This uses M20 grade concrete as regular concrete in the compression zone and M25 grade concrete in the tension zone, where flyash and red mud substitute cement to different degrees (3%, 6%, 9%, 12% and 15%, respectively).According to the results, the ideal proportion for a concrete beam is 12% red mud and 12% fly ash. Additionally, based on the load deflection curve, it is clear that functionally graded concrete beams are stronger and more durable than regular concrete. Both the fly ash and the red mud functionally graded concrete were subjected to scanning electron microscopy examination. It made it very evident which components had pores, which tend to make concrete stronger.

Keywords: M20 and M25 grade, Scanning electron microscope, Red mud andFlyash

1. Introduction

Concrete is mostly used in the building industry virtually everywhere in the globe. Portland cement concrete, sometimes referred to as conventional or ordinary concrete, is widely utilized because of its many benefits, including its inexpensive cost and great compressive strength. Concrete has some drawbacks due to its technical and environmental characteristics. Functionally graded materials (FGM) have grown significantly over the past few decades due to their potential for cost optimization and material performance increase [1]. FGM is the combination of two or more materials that have various fundamental characteristics. [2].

The foundation for the creation of Functionally Graded Concrete (FGC) is the idea of functionally graded materials.Numerous studies on the FGC have been conducted. During the optimization of the mechanical characteristics, a number of mechanical issues were discovered, including the behavior of crack propagation and other property determinations. Rubber is varied to create different thicknesses of sulfur concrete, which is then used to manufacture functionally graded products. These modifications lead to FGM optimization [3].

By gradually changing the material characteristics, functionally graded concrete materials (FGCMs) would be built in several layers. FGM is a very promising material that needs additional study for advancements since it may also boost the residual stress distribution, heat resistance, resistance to cracking, and minimize the stress intensity factor.According to the results, the ideal proportion for a concrete beam is 10% red mud and 10% fly ash. [4]

Additionally, based on the load deflection curve, it is clear that functionally graded concrete beams are stronger and more durable than regular concrete. Both the fly ash and the red mud functionally graded concrete were subjected to scanning electron microscopy examination. It made it very evident which components had pores, which tend to make concrete stronger. [5] Numerous studies have demonstrated that functionally graded concrete is more durable than ordinary concrete. [6].

The high compressive strength of the FGC mixture has been documented by experimental and computational investigations on the impacts of two concrete strength gradations of the FGC cylinder compressive strength. Even though FGM was first created using metal for use in spacecraft, it is now being researched for use in constructing components like plates, beams, and shells. [7] Given that functionally graded materials are used in infrastructure, aviation, and other engineering fields. Because of the increase in cement, fly ash improves workability, compressive strength, and flexural strength. [8]

Therefore, compared to regular concrete, the functionally graded concrete is more affordable. Among the materials used to create functionally graded concrete are fly ash, red mud, fiber-reinforced concrete, and natural fibers. [9] In the current study, red mud and fly ash were employed. RED MUD is the inorganic waste that is produced when alumina is extracted from bauxite. Red mud is often made from sodium hydroxide and bauxite reacting at high pressure and temperature [10].

Numerous studies have been conducted on the integration of red mud as a lightweight aggregate that may be disposed of cost-effectively in the building sector, similar to cement [11]. Fly ash is another byproduct of burning pulverized coal in power plant furnaces. It is a solid with fine grains that is utilized in functionally graded concrete. High volume fly ash concrete, which normally has 50–60% fly ash content, is utilized to promote the sustainable growth of the concrete industry [12]. The use of fly ash into concrete presents several benefits, including decreased water consumption, enhanced workability, reduced fracture pattern, and improved resistance to corrosion of reinforcing [13].

Researchers discovered that adding fly ash to concrete greatly improved its compressive strength. When concrete mixes were created at a low weight/cement ratio, fly ash contributed more than when they were mixed at a high weight/cement ratio [14]. Compared to the control concrete, the strength of the fly ash-containing concrete is more susceptible to inadequate curing [15]. The behavior of the functionally graded concrete for the intended M20 and M25 mix is the main topic of this inquiry. Red mud is substituted for cement in different proportions: 5%, 10%, and 15%; fly ash is substituted in the same ways: 5%, 10%, and 15%. [16]

Using a scanning electron microscope (SEM), the cross section of the FGC for the red mud and fly ash is examined, and the compressive strength, tensile strength, and load carrying capacity of the concrete beam are also calculated for the FGC specimens. The specimens' bending behavior was observed with the application of two point loads. [17, 18]

2. Materials

2.1 Cement

Ordinary Portland cement, fine aggregate, coarse aggregate, fly ash, and red mud were the primary ingredients of the FGC. In the construction sector, cement, fine aggregate, and coarse aggregate are often utilized materials. According to IS 12269:1987, ordinary Portland cement of grade 53 is used, and it is classified as C150 (Type I) cement with a specific gravity of 3.15 by the American Society for Testing and Materials (ASTM). The coarse aggregate, which is hard blue granite stones from quarries and has a specific gravity of 2.78, is utilized in 20 mm size. The fine aggregate comes from a natural river and has a specific gravity of 2.67.

2.2 Flyash

Fly ash is a by-product of crushed coal, which is extensively utilized in concrete as a pozzolanic and cementitious element. Fly ash improves workability, compressive strength, and flexural strength because of its cementitious properties. The fly ash utilized in this project was taken from the Indian Mettur Thermal Power Station.

The results for the fly ash sample reveal a specific gravity of 2.27, indicating its density. The surface area is measured at 220 m^2/kg, offering insights into the material's available reactive sites. The pH of the fly ash is recorded as 7.6, suggesting a slightly alkaline nature. These findings are essential for understanding the physical and chemical properties of fly ash, influencing its suitability for various industrial applications, such as construction materials or environmental remediation. The moderate pH level indicates a potential compatibility with certain processes and environments, contributing to the material's versatility in different contexts.

2.3 Red Mud

Red mud, a byproduct of the alumina refining process, is a Bauxite residue that is produced when Bauxite reacts with Sodium Hydroxide at a high temperature. Because of its higher alkalinity, the waste produced by the alumina refining sector seriously pollutes the environment. The development of economically viable solutions that use some red mud will help to resolve these problems. The production of pottery, bricks, and raw materials for cement and road materials are the main uses for red mud. Therefore, different percentages of red mud are employed in the functionally graded concrete in this experiment.

The results indicate that the specific gravity of the red mud sample is measured at 2.5. Additionally, the surface area of the material is found to be 33650 m^2/kg. The pH level of the red mud is recorded as 12. These values provide crucial insights into the physical and chemical characteristics of the red mud, which can be significant in various industrial and environmental applications. The specific gravity reflects the density of the material, while the surface area measurement gives an indication of its available reactive sites. The alkaline pH value suggests a highly basic nature, impacting its potential applications and interactions in diverse contexts.

3. Experimental Works

The compressive strength of the functionally graded concrete cubes is investigated in this study at 7, 14 an 28 days after red mud and fly ash were placed, respectively, at 25 mm, 50 mm, and 75 mm from the concrete cubes' bot- tom. Additionally, after 28 days, the flexural strength of the FGC specimen is assessed by substituting M20 and M25 grade concrete for 5%, 10%, and 15% of the fly ash in the cement. A concrete beam with dimensions of 1100 x 100 x 150 mm is cast under two point loading circumstances in order to calculate the deflection.

4. Results and Discussion

4.1 Compressive Strength Test

The compressive strength test results for various concrete mixes at different curing durations are presented in Table 1. The 7-day compressive strength values range from 15.09 MPa for Mix 1 to 16.85 MPa for Mix 4, indicating an increasing trend in strength during the early stages of curing. At the 21-day mark, the compressive strength further improves, with values ranging from 21.01 MPa for Mix 1 to 23.46 MPa for Mix 4. This signifies continued development and maturation of the concrete. By the 28-day mark, the compressive strength continues to increase, with Mix 4 exhibiting the highest strength at 26.13 MPa, while Mix 1 shows a value of 23.40 MPa.

Overall, the results demonstrate a consistent and progressive enhancement in compressive strength as the curing duration extends. Mix 4 consistently outperforms the other mixes at all testing intervals, suggesting an optimized combination of constituent materials. Mix 2 and Mix 3 also display commendable strength characteristics, closely following Mix 4. Mix 5, while exhibiting competitive strength values, falls slightly behind Mix 4, showcasing the sensitivity of concrete properties to mix proportions. The findings emphasize the importance of careful mix design, curing protocols, and material selection in achieving desired concrete strength. These results hold significant implications for the construction industry, guiding engineers and builders in selecting appropriate concrete mixes for specific applications. The observed trends in compressive strength provide valuable insights into the material's performance over time, aiding in the optimization of construction schedules and the durability of structures. Figure 1 and 2 shows the graphical representation of compressive strength test for M20 an M25 grade concrete.

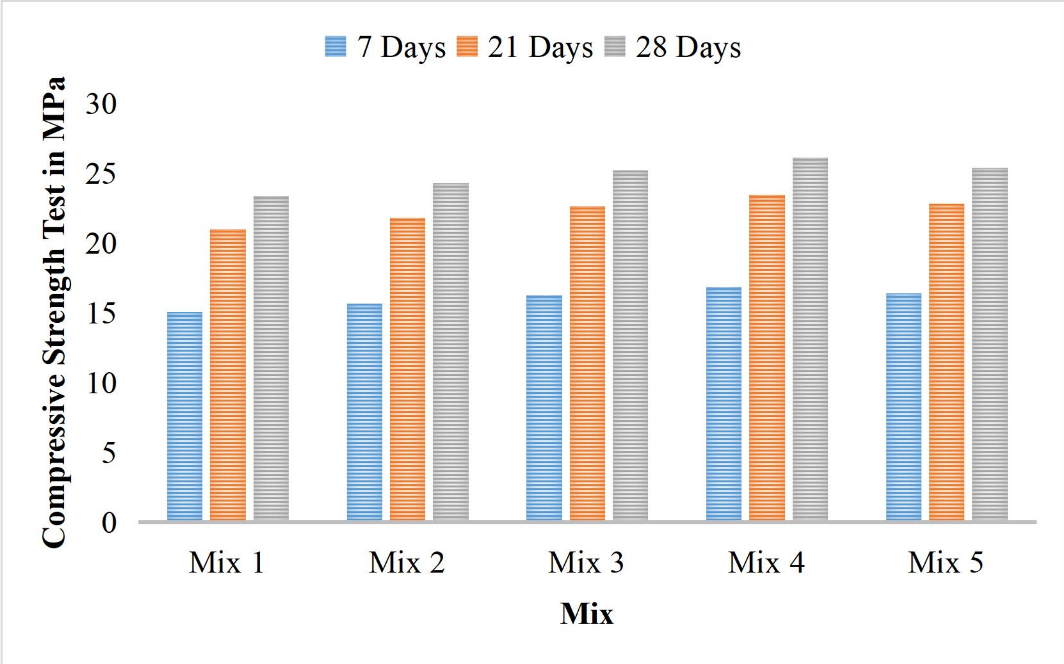

Figure 1 shows the graphical representation of compressive strength for M20 grade concrete

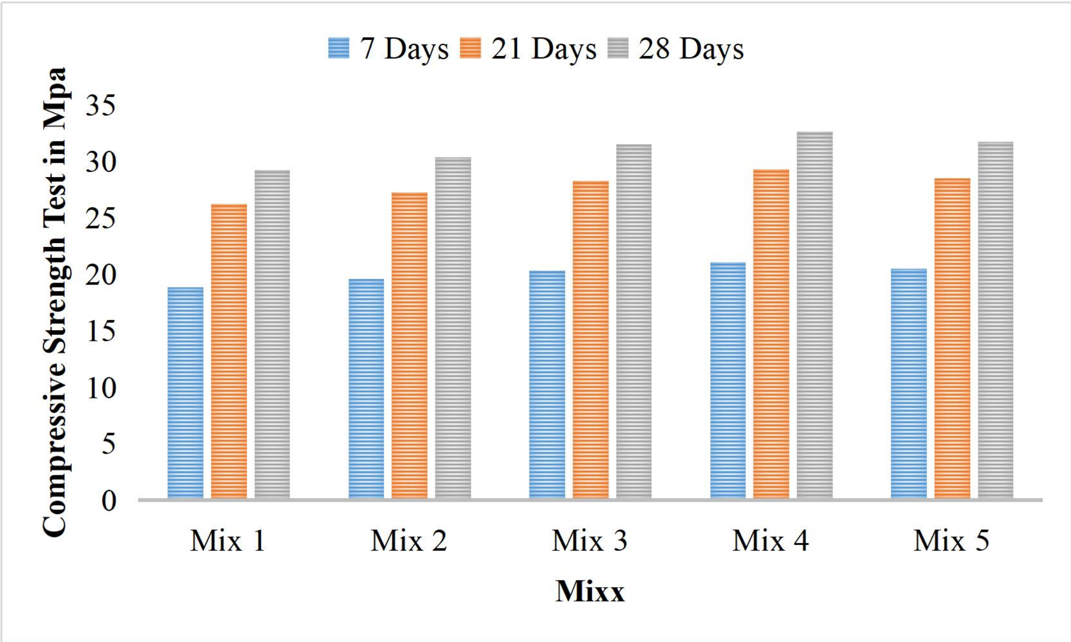

Figure 2 shows the graphical representation of compressive strength for M25 grade concrete

4.2 Split Tensile Strength

The split tensile strength results for various concrete mixes at different curing durations are summarized in Table 1. At the 7-day mark, the split tensile strength ranges from 2.61 MPa for Mix 1 to 3.11 MPa for Mix 5, illustrating an increasing trend in tensile strength during the early stages of curing. After 21 days, the split tensile strength continues to improve, with values ranging from 3.65 MPa for Mix 1 to 4.24 MPa for Mix 5. By the 28-day mark, the split tensile strength shows further enhancement, with Mix 5 demonstrating the highest strength at 4.87 MPa, while Mix 1 exhibits a value of 4.20 MPa. Mix 5 consistently demonstrates superior split tensile strength at all testing intervals, indicating an optimized mix combination. Mix 4 also shows commendable tensile strength characteristics, closely following Mix 5. Mixes 2 and 3 exhibit competitive tensile strength values, further underscoring the sensitivity of concrete properties to mix proportions. Mix 1, while demonstrating moderate tensile strength, falls slightly behind the other mixes.

These findings provide valuable insights for engineers and construction professionals in selecting concrete mixes based on their split tensile strength requirements. The observed trends highlight the importance of the curing duration in achieving optimal tensile strength, with continued improvement beyond the 7-day mark. The results also underscore the influence of mix design on the material's tensile properties, emphasizing the need for precision in formulation. In practical terms, the enhanced split tensile strength exhibited by Mixes 4 and 5 may be advantageous in applications where resistance to cracking and tensile forces is critical, such as in bridge components or structures subjected to dynamic loading. Figure 3 and 4 shows the graphical representation of split tensile strength test for M20 and M25 grade concrete.

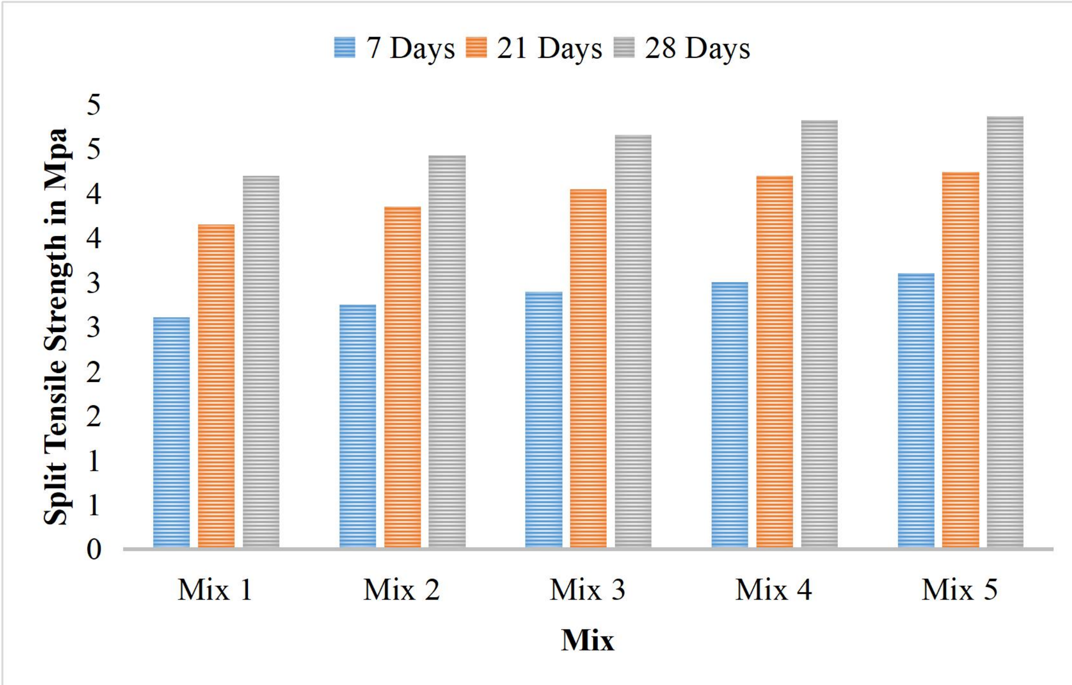

Figure 3 shows the graphical representation of split tensile strength for M20 grade concrete

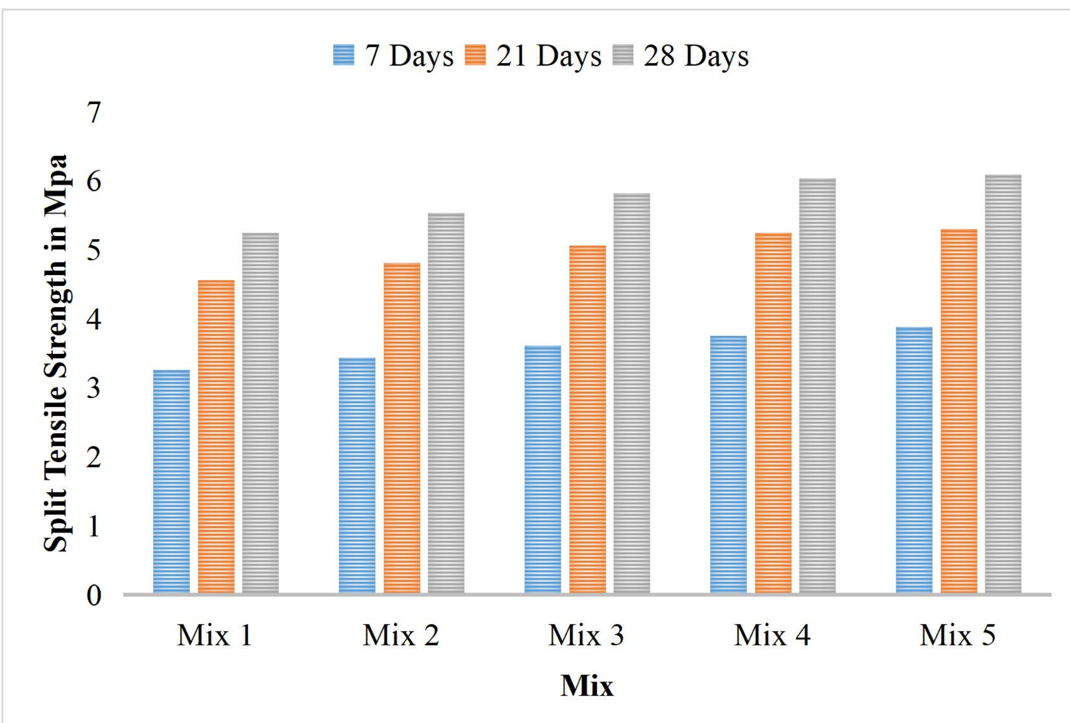

Figure 4 shows the graphical representation of split tensile strength for M25 grade concrete

3. Flexural Strength Test

The flexural strength test results for various concrete mixes at different curing durations are presented in Table 1. At the 7-day mark, the flexural strength ranges from 3.00 MPa for Mix 1 to 3.57 MPa for Mix 5, indicating an increasing trend in strength during the early stages of curing. By the 21-day mark, the flexural strength continues to improve, with values ranging from 4.20 MPa for Mix 1 to 4.88 MPa for Mix 5. At the 28-day mark, the flexural strength exhibits further enhancement, with Mix 5 demonstrating the highest strength at 5.60 MPa, while Mix 1 exhibits a value of 4.83 MPa. Mix 5 consistently demonstrates superior flexural strength at all testing intervals, showcasing an optimized mix combination. Mixes 2, 3, and 4 also exhibit commendable flexural strength characteristics, following Mix 5 closely. Mix 1, while demonstrating moderate flexural strength, falls slightly behind the other mixes.

These results hold significant implications for construction applications where flexural strength is crucial, such as in beams and slabs. The observed trends highlight the importance of the curing duration in achieving optimal flexural strength, with continued improvement beyond the initial stages of curing. The findings also emphasize the influence of mix design on the material's flexural properties, underscoring the need for precision in formulation. In practical terms, the enhanced flexural strength exhibited by Mixes 5, 2, 3, and 4 may be advantageous in structures subjected to bending and flexural stresses. The continuous improvement in flexural strength over the curing period suggests the maturation and strengthening of the concrete matrix. Figure 5 and 6 shows the graphical representation of flexural strength test for M20 and M25 grade concrete.

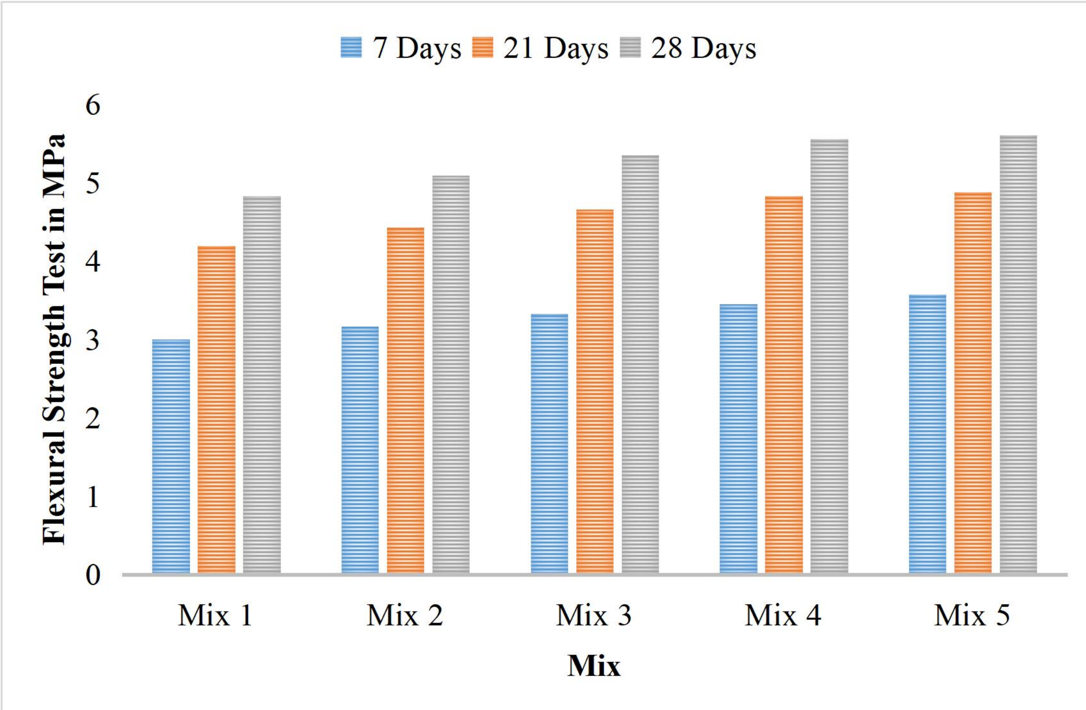

Figure 5 shows the graphical representation of flexural strength for M20 grade concrete

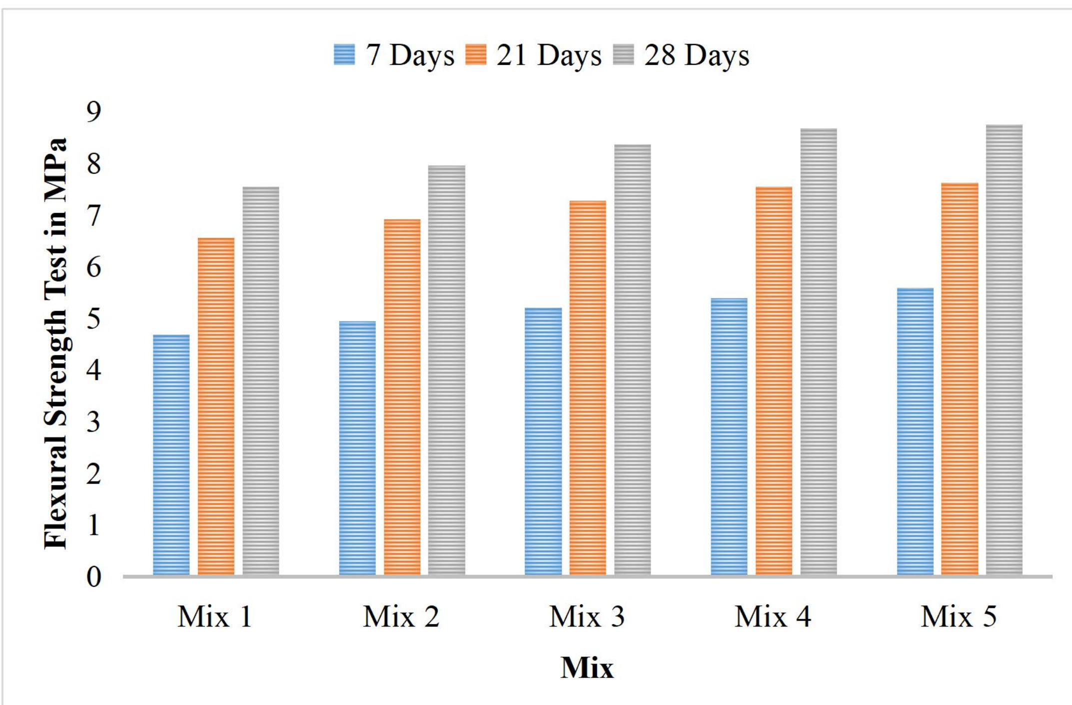

Figure 6 shows the graphical representation of flexural strength for M25 grade concrete

5. Conclusion

Overall, the results demonstrate a consistent and progressive enhancement in compressive strength as the curing duration extends. Mix 4 consistently outperforms the other mixes at all testing intervals, suggesting an optimized combination of constituent materials. Mix 2 and Mix 3 also display commendable strength characteristics, closely following Mix 4. Mix 5, while exhibiting competitive strength values, falls slightly behind Mix 4, showcasing the sensitivity of concrete properties to mix proportions. The findings emphasize the importance of careful mix design, curing protocols, and material selection in achieving desired concrete strength. These results hold significant implications for the construction industry, guiding engineers and builders in selecting appropriate concrete mixes for specific applications. The observed trends in compressive strength provide valuable insights into the material's performance over time, aiding in the optimization of construction schedules and the durability of structures.

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