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"Enhancing Strength Properties of Self-Compacting Concrete through Red Mud and Marble Powder Modification: An Experimental Investigation"

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KEYWORDS

Red Mud

Compressive Strength

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ABSTRACT:

Introduction: Concrete technologists worldwide are actively seeking innovative materials to either supplement or entirely replace cement, a primary ingredient in construction notorious for its energy-intensive manufacturing process. This pursuit stems from the urgent need to mitigate the adverse environmental impacts associated with cement production, including habitat destruction, air, and water pollution, and exacerbation of the carbon footprint.

Objectives: In this project our main objective is to study the influence of partial replacement of cement with marble powder, and to compare it with the compressive and tensile strength of ordinary M25 concrete. We are also trying to find the percentage of marble powder replaced in concrete that makes the strength of the concrete maximum. Nowadays marble powder has become a pollutant. So, by partially replacing cement with marble powder, we are proposing a method that can be of great use in reducing pollution to a great extent.

Methods: Red mud, also known as bauxite residue, is a byproduct of the Bayer process used in the production of alumina from bauxite ore. It is highly alkaline and contains various metal oxides, making its management a significant challenge. Here's a general method for managing red mud. Solid-Liquid Separation: The first step involves separating the solid components (mainly red mud) from the liquid fraction (sodium aluminate solution). This is typically done using settling tanks or thickeners where red mud settles at the bottom and clear liquor is decanted off the top.

Results: The different treatment methods applied to red mud, such as neutralization, solidification, or metal recovery. This might include data on the reduction of alkalinity, heavy metal content, or leaching potential achieved through various treatment processes. might indicate the amount of valuable resources recovered from red mud, such as alumina, iron, titanium, or rare earth elements. This could include data on extraction efficiencies, purity of recovered materials, or economic feasibility assessments. Results could pertain to studies evaluating the environmental impact of red mud disposal or treatment methods. This might include data on groundwater quality, soil contamination, ecosystem health, or air pollution associated with red mud management practices.

Conclusions: Upon analyzing the test results, several key conclusions can be drawn regarding the performance of fiber-reinforced concrete (FRC) with varying amounts of red clay replacement. Compressive Strength: FRC replaced with red clay exhibits increased compressive strength compared to FRC without red clay when the red clay content ranges from 0.5% to 8%.

1. Introduction

Concrete technologists globally are leading the charge in an ongoing pursuit of innovative materials poised to either partially or entirely supplant cement, a cornerstone in construction notorious for its substantial energy demands during production. In this endeavor, the utilization of industrial by-products such as red mud, fly ash, silica fume, ground granulated blast furnace slag,

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meta kaolin, and rice husk ash, all boasting pozzalonic properties, is gaining momentum as a viable substitute for cement. By incorporating these waste materials into concrete formulations, technologists seek not only to conserve diminishing natural resources but also to alleviate the environmental and ecological repercussions associated with the extraction and processing of raw materials for cement production. Furthermore, this approach offers a tangible solution to mitigate the carbon footprint generated during cement manufacturing processes. The sheer abundance of waste by-products suitable for cement replacement underscores the potential for substantial resource conservation achievable through sustainable practices. Notably, the production volume of these waste materials, such as slag, fly ash, and rice husk ash, far exceeds that of conventional cement. This surplus availability not only presents a viable alternative but also serves as a catalyst for fostering a circular economy wherein waste materials are repurposed and reintegrated into the production cycle. Red mud, a solid waste by-product of the Bayer process utilized in refining bauxite to produce alumina, has emerged as a promising candidate for cement substitution. While initial overseas investigations primarily focused on the geotechnical analysis of red mud and its settling characteristics in relation to grain size, domestic research has expanded to optimizing settlement methods based on grain size parameters. Furthermore, studies evaluating the fundamental properties of red mud, alongside shape dimension definitions, have revealed promising avenues for its utilization, bolstering both technological advancements and environmental stewardship. In essence, the exploration and implementation of alternative materials in concrete production represent a paradigm shift towards sustainable construction practices. By harnessing the inherent properties of industrial waste by-products, concrete technologists are not only diversifying material resources but also paving the way for a greener, more resilient built environment. This interdisciplinary approach, bridging scientific inquiry with environmental responsibility, underscores the pivotal role of innovation in shaping a sustainable future for the construction industry.

2. Objectives

The primary objective of our project is to investigate the impact of partially replacing cement with marble powder on the compressive and tensile strength properties of concrete, specifically comparing it to conventional M25 concrete. Additionally, we aim to determine the optimal percentage of marble powder replacement that maximizes the strength of the concrete.Marble powder, a byproduct of marble processing industries, has increasingly become a concern as it poses environmental challenges when disposed of as waste. However, through innovative approaches, such as partial replacement of cement in concrete, we can convert this waste into a valuable resource, thereby mitigating pollution.

3. Physical Properties of Red Mud

The fineness of red clay typically falls within the range of 1000-3000 cm2/g. Red mud samples were sourced from Hindalco Industries Limited in Belgaum, Karnataka, India. In this study, red soil that passed through a 300-micron I.S. sieve was selected as a substitute for cement.With a pH ranging between 10.5 to 12.5, red soil demonstrates an alkaline nature.The specific gravity of red soil has been measured at 2.51.

4. Fiber in concrete

Fibers are commonly integrated into concrete to mitigate plastic shrinkage cracking, drying shrinkage cracking, and to enhance strength. Additionally, they contribute to reducing concrete permeability, thereby bolstering its durability. Certain types of fibers offer superior impact, abrasion, and breakage resistance in concrete.In this study, cement is replaced with red mud alongside galvanized iron fibers across various proportions ranging from 0% to 20%. Fiber content is varied at 0.5% and 1% volume fractions. The concrete specimens are cured for 28 days, following which they undergo testing for compressive strength, tensile strength, shear strength, and additional assessments such as slump tests to gauge work ability.This research focuses solely on evaluating the impact of red clay-mixed galvanized iron fiber reinforced concrete on its strength characteristics. The study confines fiber content within the range of 0.5% and 1%, while red clay is incorporated into the cement matrix at fractions of 2% to 20%, with a 2% interval.

5. Materials Used

5.1 Cement

In this experimental study, 43 grade Ultra Tech cement is utilized as the primary binding material for all concrete

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mixes. The quality and characteristics of the cement are assessed in accordance with the Indian Standard IS: 8112-1989. The manufacturer's specifications for the cement properties are outlined in Table 1, providing crucial information regarding its composition, strength, and other pertinent factors.The specific gravity of the cement is an important parameter that influences its performance in concrete. It has been meticulously determined in the laboratory following the guidelines outlined in the IS code. The specific gravity of the cement is found to be 3.15, indicating its density relative to water. This measurement is essential for accurately proportioning the concrete mix and ensuring the desired strength and durability of the final product.By adhering to standardized testing procedures and manufacturer specifications, the properties of the cement are thoroughly evaluated to ascertain its suitability for use in the experimental concrete mixes. These meticulous assessments lay the foundation for robust and reliable experimentation, facilitating the accurate analysis of the performance of various concrete formulations and their respective properties.

Table 1. Properties of Cement

S.No	Particulars	Experimental Results	As per Standard
1	Normal consistency (%)	35	30-35
2	Fineness	250.25 m2/kg	Not less than 250m2/kg
3	Setting time (minutes)	-	-
	initial	190	Not less than 30 min
	Final	289	Not more than 600 min
4	Temperature during testing	29^{o}C	29^o C ±2%

5.2 Aggregate

In this experimental study, M-sand serves as the fine aggregate, passing through a sieve with a size of 4.75 mm, as per standard preparation protocols. M-sand, also known as manufactured sand, is carefully selected for its uniform particle size distribution and consistent quality. The specific gravity of the M-sand is determined to be 2.3 through laboratory testing. This parameter is crucial as it influences the density and strength properties of the concrete mix. For the coarse aggregate component, crushed granite stone with a particle size of 20 mm is utilized, sourced from local quarries. This coarse aggregate is subjected to rigorous testing to ensure its compliance with the relevant Indian Standard, specifically IS 383-1970. The specific gravity of the coarse aggregate is determined to be 2.82, indicating its density relative to water. Adhering to established standards and procedures for aggregate selection and testing is imperative to ensure the quality and consistency of the concrete mixtures used in the experimental investigation. These meticulous assessments lay the groundwork for accurate proportioning of aggregates and ultimately contribute to the reliability and reprehensibility of the experimental results.

5.3. Red Mud

The Red Mud utilized in this study as a replacement for cement is sourced from the Aluminum Industries Hindalco in Belgaum, obtained through the Bayer process. The characteristics of Red Mud are intricately linked to the nature of the bauxite ore from which it is derived. This process results in a material with unique properties that can significantly influence the behavior of concrete.In the laboratory, the specific gravity of the Red Mud is determined to be 2.93. This parameter is crucial as it provides insights into the density of the material relative to water, aiding in accurate proportioning during concrete mixing. The composition of Red Mud is diverse, with its chemical properties outlined in Table 2. Notably, Red Mud contains low levels of CaO, which typically denotes a lack of contentious properties. However, upon interaction with water and cement, it can exhibit contentious behavior. Additionally, the presence of silica in Red Mud plays a crucial role in enhancing the strength of the resulting concrete. Understanding the chemical composition and properties of Red Mud is essential for predicting its behavior when incorporated into concrete mixes. These insights inform the selection of appropriate proportions and aid in optimizing the performance of Red Mud-based concrete formulations. By leveraging the unique characteristics of Red Mud, researchers can explore its potential as a sustainable alternative to conventional cement, contributing to advancements in environmentally friendly construction practices.

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Table 2. Chemical composition of red Mud

Components	Weight %
Al_2O_3	20-22
Fe_2O_3	40-45
SiO_2	12-15
TiO_2	1.8-2.0
CaO	1.0-2.0
Na_2O	4-5

5.4 water

In the process of designing concrete mixes, potable water is utilized for water mixing. It's imperative that this water meets stringent quality standards, being devoid of any suspended solids and organic matter. The purity of the water used is crucial to ensure the integrity and durability of the concrete structure. Water used for both mixing and curing concrete must meet specific criteria to prevent any detrimental effects on the concrete or steel reinforcements. It should be free from harmful impurities such as acids, alkalies, oils, salts, or organic matter that could compromise the structural integrity or longevity of the concrete. Additionally, the water should be colorless and odorless, indicating its purity and suitability for use in concrete construction. Of particular concern are the levels of chloride and sulfate present in the water, as their presence can lead to corrosion of reinforcing bars within the concrete structure. Therefore, it's essential to monitor and control these levels to prevent potential damage to the reinforcement. The quantity of water required for mixing and curing concrete adheres to the standards outlined in IS 456-2000, ensuring consistency and reliability in concrete production. By employing high-quality water that meets stringent criteria, construction professionals can safeguard the structural integrity and longevity of concrete structures, mitigating the risk of corrosion and other potential issues.

5.5. Super plasticizer

Superstitious are chemical admixtures that are added to concrete mixtures to enhance their work ability and flow ability without compromising on strength or durability. These agents have remarkable super plasticizing properties, enabling concrete to be easily handled, placed, and compacted, even at lower water-cement ratios. Com-Plots SP 430 is a specific type of super plasticizing admixture commonly used in concrete production. It is carefully formulated to provide excellent dispersing and plasticizing effects, enabling the concrete mixture to achieve high levels of flow ability and work ability while maintaining optimal strength characteristics. Com-Plots SP 430 helps to reduce the water content required for achieving the desired consistency of the concrete mixture, thereby enhancing its overall performance and reducing the risk of segregation or bleeding. In addition to superstitious, galvanized iron fibers are often incorporated into concrete mixes to enhance their mechanical properties. These fibers, typically made from galvanized steel, are dispersed throughout the concrete matrix, providing reinforcement and improving resistance to cracking, impact, and fatigue. Galvanized iron fibers are known for their high tensile strength and corrosion resistance, making them ideal for use in a wide range of concrete applications, including pavements, floors, and precast elements.By incorporating superstitious like Com-Plots SP 430 and galvanized iron fibers into concrete mixtures, construction professionals can optimize the performance and durability of concrete structures, ensuring they meet the stringent requirements of modern construction projects while enhancing their long-term performance and resilience.2.6. Galvanized Iron Fibre (GI Fibre)

Galvanized iron (GI) wire is readily accessible in a variety of gauges within the market. For this particular study, GI wire with a diameter of 1 mm is selected and then cut into small segments measuring 50 mm in length. These dimensions are chosen to ensure uniform dispersion and optimal reinforcement within the concrete matrix. The density of GI fiber is determined to be 78.50 kn/m3. In the concrete mixtures, GI fiber is incorporated based on volume fraction, specifically at concentrations of 0.5% and 1% of the total sample volume. This controlled approach to volume fraction ensures consistency in the reinforcement properties and allows for systematic evaluation of the effects of GI fiber on the performance of the concrete.

5.6 Marble

Marble, a metamorphic rock originating from the transformation of pure limestone, boasts its distinctive color and aesthetic charm thanks to its inherent purity.

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This unique stone undergoes a remarkable journey from its formation to its application in various fields. Marble powder, a valuable byproduct of marble processing operations such as cutting, shaping, and polishing, is extracted during the refinement of this exquisite stone. Pure limestone, composed solely of calcite (100% $CaCO_3$), exhibits a pristine white hue, contributing to the visual allure of marble. Renowned for its resilience and timeless elegance, marble finds widespread use in both construction and decoration, adorning structures and interiors with its inherent beauty.From a chemical standpoint, marble features a crystalline structure primarily composed of calcite, dolomite, or serpentine minerals, with additional mineral constituents varying based on its geographical origin. With a specific gravity of 2.52, marble showcases both durability and aesthetic appeal, making it a sought-after material for architectural and artistic endeavors. Locally sourced marble powder emerges as a practical and eco-friendly alternative for partially substituting fine aggregate in concrete compositions. Its incorporation into concrete not only enhances its practical utility but also aligns with sustainable construction practices. By utilizing marble powder in concrete mixes, construction professionals can reduce waste and environmental impact while capitalizing on its beneficial properties, thereby contributing to the advancement of Eco-conscious building methods.

6. Tests Conducted

In this comprehensive study, an array of strength tests has been meticulously conducted on a total of 20 concrete mixes, comprising a substantial dataset of 198 test samples derived from three distinct reference mixes. These reference mixes serve as benchmarks for evaluating the effectiveness of various concrete formulations and additives. The first reference mix represents a traditional design mix for plain cement concrete, providing a baseline for comparison against modified formulations. This mix serves as the control group, allowing researchers to assess the inherent strength characteristics of conventional concrete without any additives or reinforcements. The second reference mix introduces a novel element: 0.5% galvanized iron (GI) fiber incorporated into the plain cement concrete (PCC) design. This addition aims to enhance the mechanical properties of the concrete, particularly its tensile strength and resistance to cracking. By introducing GI fibers at a specified volume fraction, researchers can evaluate the impact of this reinforcement on the overall performance of the concrete. Similarly, the third reference mix incorporates a higher dosage of GI fiber, set at 1% volume fraction within the PCC design. This elevated concentration of fibers is anticipated to further improve the strength characteristics of the concrete, offering insights into the dose-response relationship between GI fiber content and concrete performance. Through systematic testing, encompassing compressive, tensile, and shear strength assessments, researchers aim to comprehensively evaluate the structural integrity and mechanical properties of each concrete mix. By analyzing the results derived from these tests, researchers can draw meaningful conclusions regarding the efficacy of GI fiber reinforcement in enhancing the strength and durability of concrete structures. Additionally, insights gained from this study may inform future concrete design practices, facilitating the development of optimized formulations tailored to specific performance requirements and environmental considerations.

6.1 Compressive Strength

Standard cube specimens, measuring 150x150x150 mm, are meticulously cast and cured for a duration of 28 days within immersion tanks to ensure optimal strength development. Following the curing period, these specimens undergo rigorous testing on a compression testing machine with a capacity of 3000 kn, adhering to the guidelines outlined in IS 516-1959.The investigation focuses on red clay concrete cubes, with varying percentages of galvanized iron (GI) fiber content incorporated into the mix. Notably, it is observed that the compressive strength of fiber-reinforced concrete (FRC) with red clay exhibits a significant increase, particularly at an 8% replacement of red clay. Remarkably, both 0.5% and 1% GI fiber content ratios demonstrate substantial enhancements in compressive strength. Specifically, at an 8% red clay replacement, the compressive strength of FRC red clay concrete experiences a remarkable surge. The increase in compressive strength is notable, with a 14.55% enhancement observed for the 0.5% GI fiber content mixture, while the 1% GI fiber content mixture exhibits an even more impressive increase of 18.90%. This finding underscores the effectiveness of incorporating GI fibers into red clay concrete mixes, particularly at optimal replacement levels. The

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significant improvement in compressive strength highlights the potential of GI fiber reinforcement to enhance the structural performance and durability of red clay concrete structures, offering promising avenues for future research and practical applications in construction projects.

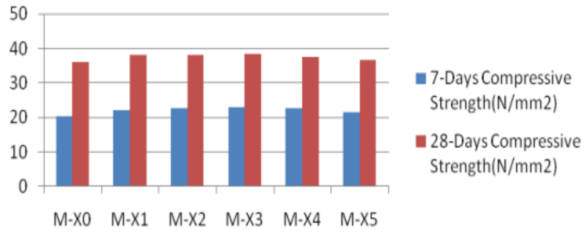

Fig. 1. Compressive strength comparison on 7 days and 28 days

6.2 Split tensile Strength Test

Cylindrical specimens, measuring 150 mm in diameter and 300 mm in length, are meticulously prepared for testing. The focus of this investigation is on evaluating the split tensile strength of fiber-reinforced concrete (FRC) incorporating red clay as a key component. The testing protocol adheres to the standards outlined in IS 5816-1999, employing a compression testing machine with a capacity of 3000 kn. Notably, the results reveal a significant enhancement in split tensile strength with the addition of both 0.5% and 1% galvanized iron (GI) fiber content to the concrete mixtures. This improvement is most pronounced at an 8% replacement of red mud within the mixture. Remarkably, the observed increase in split tensile strength is substantial. For the concrete mix containing 0.5% GI fiber content, the enhancement in split tensile strength reaches an impressive 37.67%. Similarly, the concrete mix with 1% GI fiber content exhibits an even more remarkable increase, with split tensile strength surging by 54.45%. These findings underscore the effectiveness of incorporating GI fibers into red clay concrete mixes to enhance their split tensile strength. Such improvements hold significant implications for the structural integrity and durability of concrete structures, suggesting promising avenues for the utilization of fiber reinforcement in construction applications. These results contribute valuable insights to the field of concrete technology, informing future research endeavors and practical applications aimed at optimizing concrete performance and longevity.

6.3 Shear Strength Test

The study involves L-shaped specimens, as described in ASCE Publications Journal, Volume 03, on pages 48-51, and illustrated in Figure 10. These specialized specimens are subjected to testing on a compression testing machine with a capacity of 3000 kn. The loading arrangement is carefully configured to apply direct shear force specifically on the short arm of the 'L' shaped specimen, covering an area of 150 mm x 60 mm.The focus of the investigation lies in evaluating the shear strength of fiber-reinforced concrete (FRC) incorporating red clay as a constituent material. Notably, the results reveal a remarkable enhancement in shear strength with the addition of both 0.5% and 1% galvanized iron (GI) fiber content to the concrete mixtures. This enhancement is most prominent at an 8% replacement of red clay within the mixture. The observed increase in shear strength is substantial and holds significant implications for the structural performance of concrete elements subjected to shear forces. Specifically, for the concrete mix containing 0.5% GI fiber content, there is an impressive increase of 34.45% in shear strength. Similarly, the concrete mix with 1% GI fiber content exhibits an even more remarkable enhancement, with shear strength increasing by 46.74%. These findings underscore the effectiveness of incorporating GI fibers into red clay concrete mixes to enhance their shear strength characteristics. Such improvements offer valuable insights for optimizing the design and performance of concrete structural elements, contributing to advancements in construction practices aimed at ensuring safety, durability, and resilience.

6.4 Comparison of experimental and finite element findings

The analysis reveals that utilizing the medium mesh configuration yields optimal results in terms of ultimate load and deflection values, as depicted in Table 10. Moreover, this configuration demonstrates acceptable computational time compared to alternative mesh setups. The finite element (FE) estimates for the experimental final weight ratio fall within the range of 0.94 to 0.97. In comparison to the experimental results, the load-deflection curves obtained from numerical simulations exhibit increased rigidity post the initiation of the first crack, potentially attributed to mass scattering phenomena and the inherent tensile strength of

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concrete.During the finite element testing, cracks develop in some of the beams, highlighting the load-deflection relationship between the numerical model and experimental findings. On average, the ratio of experimental to FE ultimate load stands at 0.96, while the ratio of experimental to FE mid-span displacement averages slightly lower. Theoretical finite element outcomes generally surpass experimental values, which may be attributed to minor human measurement errors during experimentation. Moreover, the assumption of an ideal bond between the concrete surface and reinforcement bars could contribute to a stiffer finite element model. Nonetheless, the overall agreement between experimental findings and FE simulations is robust, affirming the validity and reliability of the numerical analysis.

7.Testing Procedures for Specimens:

7.1. Fresh Properties Testing

Fresh properties tests are crucial assessments conducted on freshly mixed concrete to evaluate its work ability, consistency, and flow characteristics. These tests provide valuable insights into the behavior of concrete during placement and ensure that it meets the desired performance criteria for various construction applications. One of the primary tests conducted is the Slump Flow Test, which measures two key parameters: Total Spread and T50 Time. Total Spread indicates the horizontal flow diameter of the concrete, reflecting its ability to flow and spread under its own weight. T50 Time, on the other hand, measures the time taken for the concrete to reach a specific degree of flow, providing information on its viscosity and work ability over time. The L-Box Test evaluates the passing ability and flow segregation resistance of concrete by simulating the flow through an L-shaped mold. This test helps assess the homogeneity and uniformity of the concrete mix as it flows through narrow openings and around obstacles. The J-Ring Test assesses the passing ability and stability of self-consolidating concrete (SCC) by measuring the segregation resistance of the concrete mix. The J-Ring device consists of a specially designed ring that is placed on top of a slump cone during testing. The test evaluates the ability of the concrete mix to maintain uniformity and avoid segregation as it flows through the J-Ring. Lastly, the V-Funnel Test is employed to assess the flow ability and viscosity of self-consolidating concrete mixes. The V-Funnel apparatus consists of a funnel with a standardized opening, through which the concrete flows freely. The time taken for the concrete to flow through the funnel provides insights into its viscosity and ability to flow easily without segregation. Overall, these fresh properties tests play a crucial role in ensuring that concrete mixes meet the desired performance requirements for specific construction applications. By evaluating work ability, consistency, and flow characteristics, these tests help optimize concrete mix designs and enhance construction efficiency and quality.

7.2. Cube Compression Testing

The compression testing of concrete cubes is a fundamental procedure conducted to assess the strength and durability characteristics of concrete over time. In this process, concrete cubes are subjected to compressive loads at specific intervals, typically at 7 and 28 days, using a compression testing machine designed to apply uniformly increasing loads.During the testing procedure, each concrete cube is carefully positioned between rigid steel plates, ensuring uniform distribution of the applied load. These steel plates, positioned both above and below the specimen, serve to transmit the compressive forces evenly across the surface of the cube.As the testing process commences, the compression testing machine gradually applies increasing loads to the concrete cube. This loading continues until the specimen undergoes deformation, commonly indicated by the cessation of needle deflection. At this point, the concrete cube reaches its maximum compressive strength, and the final reading is recorded.The recorded data obtained from compression testing at 7 and 28 days provides valuable insights into the compressive strength development of the concrete over time. By comparing the results obtained at different ages, engineers and researchers can assess the rate of strength gain and the overall performance of the concrete mix. Overall, the compression testing of concrete cubes using a compression testing machine with rigid steel plates ensures accurate and reliable evaluation of concrete strength characteristics, contributing to the quality assurance and optimization of concrete mix designs in various construction projects.

7.3. Beam Testing

In the experimental setup, beams underwent two-point load testing, a standard method used to evaluate the

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structural behavior and load-carrying capacity of beams. The testing apparatus consisted of a frame designed to accommodate specimens of varying sizes and capacities. Each beam specimen was divided equally into three sections, with the two-point loads applied at the ends of the middle third portion. This configuration is commonly employed to simulate real-world loading conditions and assess the response of the beam under bending forces.Load application was facilitated through cylindrical iron pieces strategically positioned beneath the dial gauge. These iron pieces served as the points of contact for the applied loads, ensuring uniform distribution of force across the beam's cross-section. Additionally, the use of cylindrical iron pieces helped to minimize any localized stress concentrations and provided stable support during testing.Throughout the testing process, the applied loads were gradually increased until the beam reached its ultimate load-carrying capacity or failure point. The dial gauge, positioned above the beam, recorded deflection measurements at specific load increments, allowing for the characterization of the beam's behavior under varying levels of applied load. By subjecting the beams to two-point load testing within a controlled experimental setup, researchers were able to assess key structural parameters such as bending strength, stiffness, and deformation characteristics. The results obtained from these tests provide valuable insights into the performance of the beams and inform the design and optimization of structural systems in civil engineering applications.

7.4. Cylinder Compression Testing

In the testing process, cylinders were subjected to compression testing using a specialized compression testing machine designed to apply gradually increasing loads. This procedure is fundamental in assessing the compressive strength and durability characteristics of cylindrical concrete specimens. The compression testing machine is equipped with a hydraulic system that allows for precise control over the application of loads. The cylindrical specimens are carefully positioned within the testing machine, ensuring proper alignment and contact with the loading surfaces. As the testing begins, the compression testing machine gradually applies increasing loads to the cylindrical specimens. The loading process continues until the specimen reaches its ultimate compressive strength or undergoes failure. Throughout the testing, data such as load and displacement are continuously monitored and recorded. The gradual increase in load allows for the observation of the behavior of the cylindrical specimen under different levels of stress. This enables researchers and engineers to assess the compressive strength, deformation characteristics, and overall performance of the concrete material. By analyzing the data obtained from compression testing, valuable insights can be gained into the quality of the concrete mixture, the effectiveness of curing methods, and the suitability of the concrete for specific construction applications. These insights play a crucial role in optimizing concrete mix designs, ensuring structural integrity, and enhancing the durability of concrete structures.

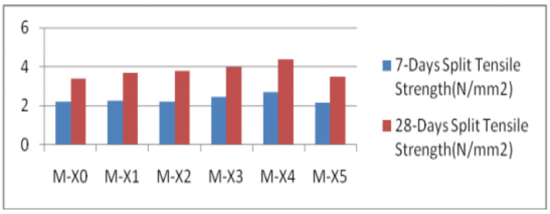

Fig. 2. Shear strength comparison on 7 days and 28 days

8. Results

Chemical Composition Analysis: Results might include detailed data on the chemical composition of red mud, including percentages of major constituents such as iron oxide, aluminum oxide, silica, and various trace elements. This analysis helps in understanding the potential environmental impacts and the feasibility of various treatment and utilization methods.Physical Properties: Results could provide information on the physical properties of red mud, such as particle size distribution, specific surface area, density, and porosity. These properties influence the behavior of red mud in various applications and treatment processes. Heavy Metal Content: Analysis results might indicate the concentrations of heavy metals present in red mud, such as chromium, nickel, lead, and arsenic. Understanding the levels of these contaminants is crucial for assessing the environmental risk associated with red mud disposal and utilization. Alkalinity and pH: Results may reveal the alkalinity and pH levels of red mud, which are important factors in determining its corrosives and potential impact on soil and water quality. Leaching Studies: Results from leaching studies can provide information on the mobility of contaminants from red mud under different

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environmental conditions. This data is essential for assessing the long-term environmental impact of red mud disposal and identifying appropriate containment and management strategies. Treatment Efficiency: If studies involve treatment methods for red mud, results could include data on the effectiveness of various treatment techniques in reducing alkalinity, immobilizing heavy metals, or improving the physical properties of red mud for reuse or disposal. Utilization Potential: Results might demonstrate the feasibility and performance of red mud in various applications, such as construction materials, ceramics, wastewater treatment, or as a source of valuable metals. This includes data on the mechanical properties, durability, and environmental benefits of using red mud-based products compared to traditional materials. Environmental Impact Assessment: Results could include findings from environmental impact assessments, such as risk assessments, life cycle assessments, or ecological studies, which evaluate the potential environmental consequences of red mud disposal and utilization practices. Regulatory Compliance: Results might indicate the degree to which red mud management practices comply with regulatory standards and environmental regulations, including data on pollutant concentrations, leaching rates, and other relevant parameters. Overall, results from studies on red mud provide valuable insights into its characteristics, behavior, and potential applications, helping to inform decision-making processes for its sustainable management and utilization.

9. Discussion

Red mud, or bauxite residue, is a byproduct of the Bayer process used to extract alumina from bauxite ore. It is characterized by its high alkalinity, fine particle size, and complex chemical composition. Red mud typically contains iron oxide, aluminum oxide, silica, and various trace elements, along with residual sodium hydroxide and other process chemicals. Understanding these characteristics is crucial for assessing its environmental impact and exploring potential reuse options.Red mud disposal has historically been associated with environmental challenges due to its alkalinity and potential to release heavy metals and other contaminants into the surrounding environment. Improper management practices, such as disposal in open ponds, can lead to soil and water pollution, affecting ecosystems and human health. Leaching of alkaline substances and heavy metals from red mud can contaminate groundwater, disrupt soil pH balance, and harm aquatic life. Therefore, mitigating the environmental impact of red mud is a critical concern. Management Strategies: Various management strategies have been proposed to address the environmental challenges associated with red mud. These include: Solidification/Stabilization: Treating red mud to immobilize contaminants and reduce leaching.

Land filling: Proper containment and engineered land filling to minimize environmental exposure. Utilization: Finding beneficial uses for red mud, such as in construction materials, ceramics, and wastewater treatment. Resource Recovery: Extracting valuable metals from red mud through recycling and recovery processes. Utilization Avenue: Exploring potential applications for red mud is an area of active research and development. Red mud has been investigated as a raw material in various industries, including: Construction: Incorporating red mud into concrete, bricks, and tiles to improve strength and durability.

Ceramics: Using red mud as a substitute for traditional raw materials in ceramic production. Adsorbents: Utilizing red mud as an adsorbent for wastewater treatment, particularly for removing heavy metals and organic pollutants. Metallurgy: Extracting valuable metals such as iron, aluminum, and rare earth elements from red mud for recycling. Challenges and Future Directions: Despite its potential benefits, challenges remain in the widespread adoption of red mud utilization practices. These include technological barriers, economic feasibility, regulatory constraints, and public perception. Future research efforts should focus on developing cost-effective and environmentally sustainable methods for managing red mud, as well as promoting awareness and acceptance of its potential as a valuable resource. In conclusion, the discussion surrounding red mud encompasses its characteristics, environmental impact, management strategies, potential utilization avenues, and future directions for research and development. Addressing the challenges associated with red mud management requires interdisciplinary collaboration and innovative approaches to ensure its sustainable utilization and minimize its environmental footprint.

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