



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Strength Properties Of Concrete By Using Red Mud And Fly Ash As Partial Replacement Of Cement With And Without Hydrated Lime

Ms. Mansi Dattatray Haralkar ¹, Mr. A.N.Shaikh ²

¹PG student, Department of Civil Engineering, M.S. Bidve Engineering College, Latur

²Professor, Department of Civil Engineering, M.S. Bidve Engineering College, Latur

Abstract

The increasing demand for sustainable construction materials has led to the exploration of industrial waste as potential alternatives in concrete production. This study investigates the feasibility of using red mud, a by-product of the aluminium industry, as a partial replacement for cement in concrete, along with hydrated lime to enhance workability and strength characteristics. Various concrete mixes were prepared by replacing cement with red mud at proportions of 5%, 10%, 15% by weight, with a constant percentage of hydrated lime. Comprehensive tests were conducted to evaluate the workability, compressive strength, split tensile strength, and durability of the mixes at different curing periods. The results indicate that the incorporation of red mud up to an optimal percentage, in combination with hydrated lime, can significantly enhance the mechanical properties of concrete while promoting the reuse of industrial waste. This experimental study demonstrates the potential of red mud as a sustainable material in cementitious applications, contributing to environmental conservation and resource efficiency in the construction sector.

The rapid growth of the construction industry has significantly increased the demand for cement, contributing to environmental challenges such as high energy consumption, greenhouse gas emissions, and depletion of natural resources. In response, this study explores the use of red mud—a highly alkaline industrial waste generated during the Bayer process of alumina extraction—as a partial replacement for cement in concrete. In addition, hydrated lime is incorporated to improve the pozzolanic reactivity and binding properties of the mix.

This experimental investigation involves the preparation of concrete specimens in which Pozzolanic Portland cement (PPC) is partially replaced with red mud in varying proportions: 0% (control mix), 5%, 10%, 15% by weight. A constant percentage of hydrated lime (typically 5%) is added to all mixes containing red mud. The mechanical and durability properties of the concrete are evaluated through standardized tests, including slump test for workability, compressive strength test, split tensile strength test, and water absorption test at 7 and 28 days of curing.

The results reveal that red mud can be effectively utilized as a supplementary cementitious material up to an optimum replacement level—typically around 10–15%—without compromising, and in some cases even enhancing, the strength and durability of concrete. The addition of hydrated lime contributes to improved binding and densification of the matrix, helping mitigate the reduction in early strength that can occur with red mud alone. Beyond the optimal percentage, however, further replacement leads to reduced mechanical performance due to increased porosity and lower cement content.

Overall, this research demonstrates that red mud, when used in combination with hydrated lime, offers a viable and eco-friendly alternative to partial cement replacement. This approach not only reduces the environmental burden associated with red mud disposal but also contributes to sustainable construction practices by lowering the carbon footprint of concrete production.

Key Words – Red mud, Fly Ash, lime, Hydrated lime, Cement

Introduction-

The global construction industry is experiencing rapid growth, driving an ever-increasing demand for cement—a key binding material in concrete. However, the manufacture of Portland cement is associated with significant environmental challenges, including the emission of approximately 0.9 tons of CO₂ per ton of cement produced, extensive energy consumption, and the depletion of natural limestone resources. As a result, the industry faces mounting pressure to adopt sustainable practices by reducing cement usage and incorporating alternative materials in concrete production.

In recent years, attention has turned to industrial by-products and waste materials that could serve as supplementary cementitious materials (SCMs) in concrete. Among these, red mud—a highly alkaline residue generated during the Bayer process for extracting alumina from bauxite ore—has emerged as a promising candidate. Globally, the production of red mud exceeds 120 million tons annually, with large volumes remaining stockpiled or disposed of, often resulting in environmental hazards such as land contamination, groundwater pollution, and tailing dam failures.

Red mud is rich in oxides of iron (Fe₂O₃), aluminium (Al₂O₃), and silica (SiO₂), which endow it with pozzolanic characteristics under certain conditions. However, its high alkalinity, poor reactivity, and fine particle size can limit its performance when used alone in concrete. To address these limitations, hydrated lime (Ca(OH)₂) can be introduced as a reactive agent that enhances the pozzolanic reaction, thereby improving the binding and long-term strength development of the red mud–cement matrix.

This study aims to assess the feasibility of using red mud as a partial replacement for ordinary Portland cement (OPC) in concrete, in conjunction with hydrated lime, to form a more sustainable and environmentally benign construction material. By substituting cement with varying proportions of red mud (e.g., 5%, 10%, 15%, and 20%) and incorporating a fixed quantity of hydrated lime, the experimental program evaluates the impact on workability, compressive strength, tensile strength, and durability properties of concrete.

The research objectives of this study are as follows:

1. To examine the physical and chemical characteristics of red mud and determine its suitability as a cement replacement.
2. To develop concrete mix designs incorporating red mud and hydrated lime and evaluate their mechanical performance.
3. To identify the optimum replacement level of red mud that offers improved or comparable properties to conventional concrete.
4. To promote sustainable construction practices by utilizing industrial waste and reducing dependence on cement.

Through this investigation, the paper contributes to the broader goal of minimizing the environmental footprint of construction materials while simultaneously addressing the

challenges associated with red mud disposal. The findings are expected to benefit engineers, researchers, and policymakers aiming to develop low-carbon and eco-friendly alternatives in civil infrastructure development.

Literature Review

1) Rohit N. Bhosale, Dr. Nina R. Dhamge, Dr. Mukesh J. Chaddha [2021], The increasing global demand for sustainable construction materials has led researchers to explore industrial by-products like red mud as partial cement replacements in concrete. Red mud, a highly alkaline waste generated during alumina production, possesses pozzolanic properties that can potentially enhance concrete strength and durability when used appropriately. Various studies have indicated that the inclusion of red mud up to a certain percentage can improve compressive, tensile, and flexural strength of concrete due to its fine particle size and filler effects. Additionally, the incorporation of hydrated lime has been found to activate the pozzolanic reaction in red mud, further improving the binding characteristics of the concrete mix. Research by several authors has demonstrated that partial replacement of cement with red mud, typically ranging from 5% to 30%, shows positive results in strength development, especially when supplemented with lime to counteract the low calcium content of red mud. The synergistic use of red mud and hydrated lime not only enhances mechanical properties but also contributes to waste management and environmental conservation. However, the effectiveness of red mud depends significantly on its chemical composition, fineness, and the curing regime used. This study builds upon prior research and aims to evaluate and compare the mechanical behavior of concrete mixes using red mud as a partial cement replacement, with and without the addition of hydrated lime, under varying proportions and curing conditions.

2) Tejaswini C, Anupama Natesh [2019], The growing demand for sustainable construction practices has prompted significant research into the use of industrial waste materials as alternatives to traditional cement in concrete. One such material is red mud, a highly alkaline residue generated during the Bayer process of alumina extraction from bauxite. Red mud is rich in iron oxide, alumina, silica, and titanium dioxide, and although it is considered hazardous due to its high pH, its mineral composition indicates potential pozzolanic behavior when finely ground and used in controlled proportions. Several researchers have evaluated the incorporation of red mud into concrete, observing that partial replacement of binder content—typically ranging from 5% to 25%—can yield comparable or even improved strength characteristics if optimized correctly.

However, due to the relatively low calcium content in red mud, the addition of hydrated lime (Ca(OH)₂) has been proposed as a means to enhance its reactivity. Hydrated lime acts as a secondary activator, promoting pozzolanic reactions by providing additional calcium ions needed for the formation of calcium silicate hydrate (C-S-H), which is

responsible for strength development in concrete. Studies have shown that the combined use of red mud and hydrated lime not only improves compressive, tensile, and flexural strength but also enhances microstructural properties by reducing porosity and refining the pore structure. This leads to better durability against environmental attacks such as sulfate and chloride ingress.

Moreover, research findings indicate that the setting time and workability of concrete mixes containing red mud can be influenced by the dosage of both red mud and lime. Higher red mud content may increase water demand due to its fine particles and absorbent nature, but lime helps improve the mix consistency and bonding. Microstructural analyses using tools like SEM (Scanning Electron Microscopy) and XRD (X-ray Diffraction) in past studies have revealed that red mud-lime concrete exhibits a denser matrix and better crystallization of hydration products compared to control mixes.

In summary, existing literature supports the feasibility of using red mud as a partial binder replacement in concrete, particularly when combined with hydrated lime. This approach not only addresses the problem of red mud disposal but also reduces reliance on cement, thereby contributing to more environmentally responsible construction practices. The current study builds upon this background, aiming to systematically assess the mechanical properties of red mud concrete with and without hydrated lime under different replacement ratios to determine optimal performance and sustainability benefits.

3) P. Syam Sai, Chandana Sukesh [2017] , in this study experiments have been performed to evaluate the quality attributes of the Aluminum red mud. Test samples were made with the Replacement of 0- 20% at an interval of 50% of red mud and 5% of hydrated lime with cement bond in M40 and M50 Grade concrete. To impart cementations property of red Mud, hydrated lime is incorporated. This study emphasizes on the promising usage of red mud in the sustainable Development.

4) P. Ashok, M.P. Suresh kumar, et., al. [2010], were Explained the Bayer Process for the production of Alumina from Bauxite ore is characterized by low Energy efficiency and it results in the production Of significant amounts of dust-like, high alkalinity Bauxite residues known as red mud. Currently red Mud is produced almost at equal mass ratio to Metallurgical alumina and is disposed into sealed or Unsealed artificial impoundments(landfills), leading To important environmental issues. It comprises of Oxides of iron, titanium, aluminum and silica along With some other minor constituents. Presence of alumina and Iron oxide in red mud compensates the deficiency of the same components in limestone Which is the primary raw material for cement Production. Presence of soda in the red mud which When used in clinker production neutralizes the sulfur Content in the pet coke that is used for burning Clinker enrooted cement production and adds to the Cement's setting characteristics. Based on Economics as well as environmental related issues, Enormous efforts have been directed worldwide Towards red

mud management issues i.e., of Utilization, storage and disposal. Different avenues of Red mud utilization are more or less known but none Of them have so far proved to be economically viable Or commercially feasible. Experiments have been Conducted under laboratory condition to assess the Strength characteristics of the aluminum red mud. The project work focuses on the suitability of red Mud obtained for construction. ([3] P. E. Tsakiridis, S. Agatzini-Leonardou, and P. Oustadakis,)Five test Groups were constituted with the replacement Percentages 0%, 5%, 10%, 15%, 20% of red mud and 5% of hydrated lime with cement in each series. To Achieve Pozzolan property of red mud, hydrated Lime was added. This paper points out another Promising direction for the proper utilization of red Mud.

Material Used-

1.Cement

Cement, one of the most important building materials, is a binding agent that sets and Hardens to adhere to building units such as stones, bricks, tiles, etc. Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum), and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. The raw ingredients are processed in cement manufacturing plants and heated to form a rock-hard substance, which is then ground into a fine powder to be sold. Cement mixed with water causes a chemical reaction and forms a paste that sets and hardens to bind individual structures of building materials.

2. Fine Aggregate

Fine aggregates are small-sized particles, each with a specific fine aggregate size classification, used extensively in construction. They typically consist of sand, crushed stone, or crushed slag with a diameter of less than 9.5 mm. These aggregates are essential In mixing concrete and mortar to give the mixtures a smoother consistency. Fine aggregates also help fill the tiny gaps between larger stones in concrete, improving the structure's overall stability and appearance. They are crucial for achieving the right texture and strength in various construction projects.

3. Coarse Aggregate

Coarse aggregates are granular materials. It is often used in construction for concrete making. Its major composition includes crushed stone, gravel, or recycled concrete. Coarse aggregates typically accounts for more than 60-80% of the volume of the concrete. Their durability depends on the quality of the coarse aggregate, significantly impacting the strength and workability of the concrete. Coarse aggregates are classified as those larger than 4.75 mm according to sieve analysis, with a common diameter range between 3/8 inch (approximately 9.5 mm) and 1.5 inch

4.Red Mud

Red mud, also known as bauxite residue, is a waste product of the aluminum production process. Red mud is a brownish-red slurry that contains metal and silicon-rich oxides, rare earth elements, and iron. It's produced when bauxite ore is refined into alumina using the Bayer Process, which uses caustic soda to dissolve the aluminum silicate.

Advantages

1.Construction material

Red mud can be used in the production of concrete, bricks, mortar, and ceramics. It can also be used as a supplementary cementitious material to replace cement. Red mud can improve the strength and durability of concrete, and reduce its permeability. It can also help with earthquake resistance, acoustics, and energy use.

2.Environmental remediation

Red mud can be used to treat wastewater, remediate soil, and purify flue gas. It can effectively remove heavy metals, organics, bacteria, and anions from liquid and solid wastes.

3.Metal recovery

Red mud is rich in iron and other valuable metals, and can be a potential resource if the metals can be extracted.

4.Catalyst

Red mud can be used as a catalyst for various processes, including hydrocarbon oxidation, hydrogenation, and hydrodechlorination.

5. Decorative material

Red mud can be used as a decorative material that prevents early fading of color.



Red mud

5.Fly Ash

Fly ash is a fine powder that is produced as a byproduct of burning pulverized coal in electric power plants. It is one of the most commonly generated industrial wastes in the world, with millions of tons being produced every year. Fly ash is composed of a mixture of inorganic and organic materials, including silicon dioxide, aluminum oxide, Iron oxide, calcium oxide, and Magnesium oxide. The chemical composition of fly ash varies depending on the type of coal being burned, the combustion conditions, and the type of emission control equipment used. The disposal of fly ash is a significant environmental concern, as it can contaminate air and water resources if not handled properly. Fly ash can also

be a valuable resource when used as a cement replacement in The construction industry, due to its pozzolanic properties. It has been used in a variety of applications, such as making concrete, bricks, and road construction.fly ash is a fine powder that is a byproduct of burning pulverized coal in electric power generating plants. It is typically composed of oxides of silicon (SiO₂), aluminum (Al₂O₃), iron (Fe₂O₃), calcium (CaO), and magnesium (MgO), along with smaller amounts of other compounds. Fly ash is usually collected from the flue gases by electrostatic precipitators or bag filters.

Advantages

1.Concrete production:

Fly ash can be used as a partial replacement for cement In concrete production. It improves the strength, durability, and workability of Concrete, and reduce the amount of cement required.

2.Soil stabilization:

Fly ash can be used to stabilize soil and improve its Engineering properties, including strength, permeability, and compressibility.

3 Reduced greenhouse gas emissions:

By using fly ash in concrete production, Less cement is required, which reduces the carbon footprint of the construction Industry.

4) Cost-effective:

Fly ash is an inexpensive by-product that can be used as a Substitute for expensive materials, such as cement and lime.

5) Reduced waste:

Fly ash is a by-product of coal combustion that would Otherwise be disposed of in landfills. By using fly ash, waste can be reduced,And resources can be conserved.

6) Improved quality of construction:

Fly ash improves the quality of concrete by Reducing permeability and shrinkage, which improves the durability and Longevity of concrete structures.

7) Improved workability:

Fly ash makes concrete more workable, which allows For easier placement and finishing of concrete.



FLY ASH

6. Hydrated lime

Hydrated lime (calcium hydroxide) is a dry, colorless crystalline powder manufactured by treating calcium oxide (quicklime) with water, in a process called “slaking.” Also known as slack Lime, builders lime or pickling lime, hydrated lime is used in the production of mortars, plasters, Cements, paints, hard rubber products.

Advantages

1. Soil stabilization

Hydrated lime can improve soil structure, increase pH, and help with water retention. It Can also help control weeds and suppress disease, which can lead to healthier plants and higher crop yields.

2. Water and wastewater treatment

Hydrated lime can help remove impurities, soften water, and neutralize acids. It can also Help with the following:

a. Disinfection: Hydrated lime can inhibit pathogens and prevent the spread of infections.

b. Settling: Hydrated lime can help suspended solids coagulate and settle more quickly.

c. Odour control: Hydrated lime can neutralize foul odors by chemically reacting with odor-causing compounds.

d. Phosphorus removal: Hydrated lime can help precipitate phosphorus, which is a major pollutant in effluents.

3. Construction

Hydrated lime can be used in construction for building, soil stabilization, and asphalt.

4. Shrinkage prevention

When used with correct moisture control techniques, hydrated lime can help prevent Shrinkage cracks in mortar and render.

5. Breathability and moisture regulation

Lime plaster is a popular choice in modern architecture because it allows air to flow in and out of walls, which helps regulate humidity levels.



HYDRATED LIME

AIM

A Study and analysis of concrete strength parameters using Red Mud and Fly Ash as Partial replacement of cement with and without Hydrated lime.

OBJECTIVES

1. To study the workability, compressive quality and flexural quality of M30 Evaluation of cement by utilizing red mud, fly ash and hydrated lime with standard Cement.

2. The principle point of this work is use of red mud as bond which is blended With concrete to explore the effect of these waste materials on different Parameters of solid evaluation.

3. To guarantee the ideal utilization of red mud, fly ash and hydrated lime.

4. Production of more durable and sustainable concrete.

5. To achieve sustainable development.

6. Reduction in emission of CO in cement manufacturing by replacing it with some cementations materials.

7. The essential goal is to sum up the properties of cement with the utilization of red mud Material.

Concrete Mix

The physical properties of blended cement (Portland cement replaced by 0%, 2.5%, 5%, 7.5% With constant water ratio concrete design mix of grade M25 was prepared and design mix was studied for compressive.

Cement	Fine Aggregate	Coarse Aggregate	Water
1	2.23	3.89	0.45
330.6 (kg)	738.15 (kg)	1288.05 (kg)	148.8 (kg)

Test for concrete

Compressive Strength

The compressive strength test on concrete cubes is one of the most commonly used methods to assess the load-bearing capacity and overall quality of concrete. This test involves casting standard cube specimens, usually of size 150 mm × 150 mm × 150 mm, using freshly mixed concrete. The cubes are filled in three layers, each layer compacted either manually with a tamping rod or using a vibration table to remove air voids. After casting, the specimens are kept at room temperature for 24 hours and then cured in water for specified periods, typically 7, 14, and 28 days. Once the curing period is complete, the cubes are taken out, allowed to surface dry, and tested using a compression testing machine (CTM). The cube is placed centrally in the machine, and a

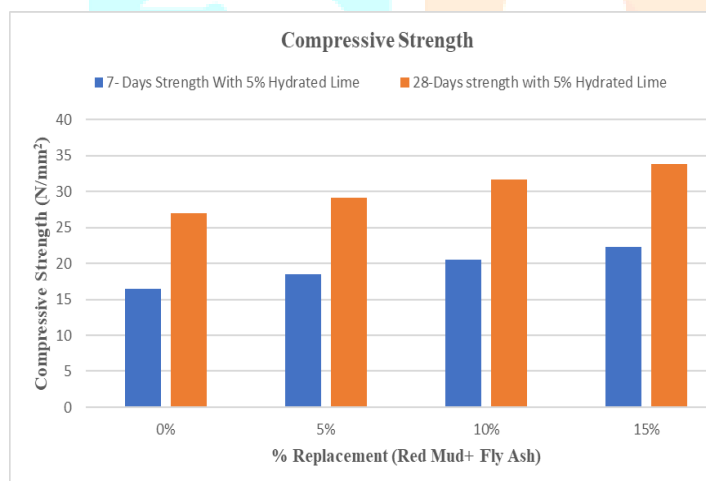
gradually increasing compressive load is applied until the specimen fails. The maximum load at failure is recorded, and the compressive strength is calculated by dividing this load by the cross-sectional area of the cube. The results help determine whether the concrete mix meets the required strength specifications for structural applications. Usually, the average strength of three cubes is taken for accuracy, and results are compared against standard values based on the concrete grade, such as M20 or M25, as per codes like IS 516 or IS 456.

Calculations

Compressive Strength = P/A

Compressive Strength

%Replacement (Red Mud + Fly Ash)	7days Compressive Strength with 5%Hydrated lime (N/mm ²)	28days Compressive Strength with 5% Hydrated Lime (N/mm ²)
0%	16.40	26.96
5%	18.53	29.09
10%	20.46	31.63
15%	22.29	33.82



Tensile Strength

The tensile strength of concrete is commonly determined using the split tensile strength test, which is an indirect method due to the difficulty of applying a pure tensile load on concrete. Although cylinders are the standard specimen type, concrete cubes can also be used in this test with some adjustments. In this method, the cube is placed horizontally in a compression testing machine, and a compressive load is applied along one of its vertical diameters. As the load increases, it induces tensile stress perpendicular to the loading direction, ultimately causing the specimen to split vertically.

Where P is the maximum applied load in Newtons, L is the length of the specimen (in mm), and d is the width (in mm). For cube specimens, L and d are typically equal (e.g., 150 mm for a 150 mm cube). This formula assumes the tensile failure

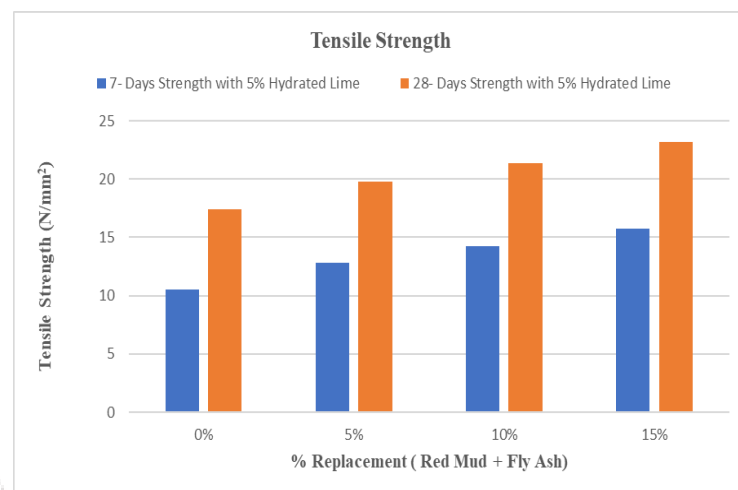
occurs along the vertical plane due to the induced lateral tension. The result gives the indirect tensile strength of the concrete, which is essential for understanding how the material will perform under cracking or flexural stresses in real structures. This method is simple and effective, providing a good approximation of tensile strength for quality control and research purposes.

#Calculation

Tensile Strength = $0.642P/A$

Tensile Strength

%Replacement (Red Mud + Fly Ash)	7days Tensile Strength with 5% Hydrated Lime (N/mm ²)	28days Tensile Strength with 5% Hydrated Lime (N/mm ²)
0%	10.56	17.37
5%	12.84	19.76
10%	14.21	21.38
15%	15.74	23.15



Flexural strength

The flexural strength test, also known as the modulus of rupture test, is performed to determine the ability of concrete to resist bending or flexural tension. This test is typically carried out on concrete beam specimens, usually measuring 100 mm × 100 mm × 500 mm or 150 mm × 150 mm × 700 mm. After proper casting and curing, the beam is placed in a flexural testing machine where a load is applied either at one-third points (two-point loading) or at the center (single-point loading), depending on the standard being followed (e.g., IS 516 or ASTM C78). As the load increases, the beam experiences tension at the bottom and compression at the top. The specimen eventually fails due to tensile stresses at the bottom surface.

For single-point loading, where P is the maximum applied load (N), L is the span length between supports (mm), b is the width, and d is the depth of the beam. In two-point loading, a different formula is used depending on the loading points. This test provides valuable data for the design of concrete

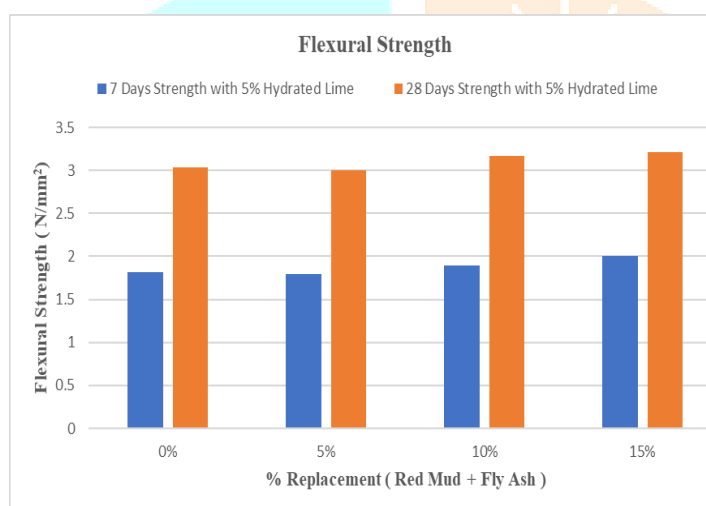
pavements, beams, and other structural elements subjected to bending. Flexural strength is typically 10% to 20% of compressive strength, and although concrete is weak in tension, this test helps predict its cracking behavior under flexural loads.

#Calculation

$$\text{Flexural Strength} = PL/BD^2$$

Flexural Strength

%Replacement (Red Mud + Fly Ash)	7days Flexural Strength with 5% Hydrated Lime (N/mm ²)	28days Flexural Strength with 5% Hydrated Lime (N/mm ²)
0%	1.79	3
5%	1.82	3.03
10%	1.89	3.17
15%	2	3.31



Conclusion

1. Compressive Strength of M25 grade of concrete for 7days at 0%,5%,10%,15% with 5% hydrated lime is 16.40N/mm2, 18.53N/mm2, 20.46N/mm2, 22.29N/mm2.
2. Compressive Strength of M25 grade of concrete for 28days at 0%,5%,10%,15% with 5% hydrated lime is 26.96N/mm2, 29.09N/mm2, 31.63N/mm2, 33.82N/mm2.
3. Tensile Strength of M25 grade of concrete for 7days at 0%,5%,10%,15% with 5% hydrated lime 10.56N/mm2, 12.84N/mm2, 14.21N/mm2, 15.74N/mm2.
4. Tensile Strength of M25 grade of concrete for 28days at 0%,5%,10%,15% with 5% hydrated lime 17.37N/mm2, 19.76N/mm2, 21.38N/mm2, 23.15N/mm2.
5. Flexural Strength of M25 grade of concrete for 77days at 0%,5%,10%,15% with 5% hydrated lime 1.79N/mm2, 1.82N/mm2, 1.89N/mm2, 2N/mm2.
6. Flexural Strength of M25 grade of concrete for 28days at 0%,5%,10%,15% with 5% hydrated lime 3N/mm2, 3.03N/mm2, 3.17N/mm2, 3.31N/mm2.

Reference

- 1.Rohit N. Bhosle , Dr. Nina R. Dhamge, Dr. Mukesh J. Chaddha “A Study and analysis of concrete strength parameters using Red Mud as Partial Replacement of cement with and without Hydrated Lime “ irjmets, issue 4 April 2021
- 2.Tejaswini. C, Anupama Natesh “Study and Analysis of Concrete Strength Parameters Using Red Mud as Partial Replacement of Binder Content with and without Hydrated Lime” IJSR Vol. 8 Issue 7, July 2019.
- 3.P. Syam Sai, Chandana Sukesh (2017) “Strenght Properties of Concrete By Using Red Mud as a Replacement of Cement with hydrated Lime” IAEME Vol. 8, Issue 3, March 2017
- 4.P. Ashok, M.P. Sureshkumar (2010) “Experimental Studies On Concrete Utilising Red Mud As A Partial Replacement Of Cement With Hydrated Lime,” IOSR Journal of Mechanical and Civil Engineering, pp. 01-10.