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An Experimental Study on Strength Evaluation of Concrete Using Red Mud as a Partial Replacement for Cement

Shrinath Rao Kundapura[1], Siraj[2]

[1]Associate Professor & HOD, Dept of Civil Engineering, Srinivas University Institute of Engineering and Technology, Mukka, Mangaluru, India
[2]Student, B.Tech (Civil Engineering), Dept of Civil Engineering, Srinivas University Institute of Engineering and Technology, Mukka, Mangaluru, India

Abstract
The high cost of conventional construction material affects the economy of structures. With increasing concern over the excessive exploitation of natural aggregates, synthetic lightweight aggregate produced from environmental waste is a viable new source of structural aggregate material. The use of structural grade lightweight concrete reduces considerably the self-load of a structure and permits larger precast units to be handled. Recently in the environmental issues, restrictions of local and natural access or sources and disposal of waste material are gaining great importance. Today, it becomes more difficult to find natural resources. Use of the waste materials not only helps in getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in land fill cost, saving in energy, and environment from possible pollution effects. It also helps in reducing the cost of concrete manufacturing. Due to this there has been reduction in the cost of each block and also helps in the reduction of solid waste and pollution. Red Mud is a byproduct of the Bayer Process; Red Mud contains toxic heavy metals and its high Alkalinity makes it extremely damaging to soil and it also pollutes ground water. Red Mud can be used as a supplement Cement material, by this it reduces the usage of Cement production and it saves natural resources and it also improves the concrete properties.

Keywords: Concrete, Red Mud, Green Material, Sustainable Development, Green Concrete

Introduction

Concrete is the world's most used construction material. The consumption of concrete has been increasing at a higher rate due to the demand placed by the development of infrastructure in both developing and developed countries. The negative consequences of increasing demand for concrete include depletion of aggregate deposits; environmental degradation and ecological imbalance. The possibility of a complete depletion of aggregate resources has rendered continued use of aggregates for construction unsustainable. In view of this challenge, researchers throughout the world have been investigating ways of replacing aggregates to make construction sustainable and less expensive. Research addressing environmental and sustainability issues in construction has generated lot of interest in the world. While wastes generated by industrial and agricultural processes have created disposal and management problems which pose serious challenges to efforts towards environmental conversation, their use contributes to resource conversation,

environmental protection and the reduction of construction costs, since waste materials can be obtained at little or no cost, while making significant contribution to the conservation of natural resources and maintenance of ecological balance. The potential of using agricultural wastes in civil engineering and building construction works have been investigated by various researchers. Red Mud is a byproduct of the Bayers process and Red Mud contains Toxic heavy metals and its high Alkalinity makes it extremely damaging to soil. Ground water polluted. Red Mud can be replaced with Cement so there will be an effective way for waste management and it reduces the Cement production and save natural resources.
In Asia, the construction industry is yet to realize the advantages of light weight concrete in high rise buildings. Red mud is not commonly used in construction industry and are often dumped as Industrial waste. The aim of this research is to spread awareness of using Red Mud as partial replacement of cement in concrete in concrete and determining its compressive strength and density. Until now, Industrial bi-products and domestic wastes have been utilized in concrete, but the use of industrial waste in concrete is in its infancy stage. Red Mud is an industrial waste. The materials are proportioned by their weights. The water cement ratio is obtained by conducting various workability tests. The obtained results are compared with that of conventional mix.

Green Concrete

Green concrete is an eco-friendly alternative to traditional concrete that is designed to reduce environmental impact. It is produced using sustainable materials such as industrial waste (like fly ash, slag, or recycled aggregates) and requires less energy during manufacturing. The concept is closely linked to Sustainable Construction and aims to make infrastructure development more environmentally responsible. Unlike conventional concrete, which heavily depends on cement (a major source of carbon emissions), green concrete partially replaces cement with recycled or less carbon-intensive materials. This not only conserves natural resources but also improves certain properties like durability and thermal resistance.

Importance of Green Concrete

Adopting green concrete in construction isn't just a trend-it's becoming a necessity as the industry tries to balance growth with environmental responsibility. Here's why it should be widely used:

1. Cuts Down Environmental Damage: Traditional concrete production is a major contributor to Carbon Dioxide Emissions due to cement manufacturing. Green concrete reduces cement usage by replacing it with materials like fly ash or slag, significantly lowering pollution.
2. Promotes Sustainable Construction: Green concrete supports the principles of Sustainable Construction by using recycled and renewable materials. This helps meet global sustainability goals and reduces the environmental footprint of infrastructure projects.
3. Efficient Use of Industrial Waste: Instead of dumping industrial by-products into landfills, green concrete reuses them in construction. This reduces waste management problems and turns waste into valuable resources.
4. Conserves Natural Resources: It reduces the need for raw materials like sand, gravel, and limestone, which are being depleted rapidly due to excessive construction activities.

Energy Saving in Concrete Production

Energy saving in concrete production focuses on reducing the large amount of energy required to manu-

facture traditional concrete especially cement. Since cement production is energy-intensive and contributes heavily to Carbon Dioxide Emissions, improving energy efficiency is a key goal in modern construction.

KeyWays to Save Energy

1. Reducing Cement Content: Cement manufacturing consumes high energy due to heating in kilns. By partially replacing cement with materials like fly ash, slag, or silica fume, overall energy use is significantly reduced.
2. Using Supplementary Cementitious Materials (SCMs): SCMs are industrial by-products that require much less energy to process compared to cement. Their use not only saves energy but also improves concrete properties like strength and durability.
3. Efficient Manufacturing Processes: Modern plants use advanced technologies such as energy-efficient kilns, waste heat recovery systems, and automation to reduce energy consumption during production.
4. Recycling Materials: Using recycled aggregates from demolished structures avoids the energy required for mining, crushing, and transporting new raw materials.
5. Local Sourcing of Materials: Transporting raw materials consumes fuel. Using locally available materials reduces transportation energy and overall project cost.
6. Optimized Mix Design: Carefully designing the concrete mix ensures minimal material usage without compromising strength, which directly reduces energy consumption.
7. Use of Renewable Energy: Some plants are shifting to renewable energy sources like solar or wind power, reducing dependence on fossil fuels.

Benefits of Energy Saving

- Lower production costs
- Reduced environmental impact
- Improved sustainability in construction
- Compliance with green building standards

Objectives of the Research Work

This study focuses on delay in payment by the client to the contractor. The purpose of this study is to find various factors that cause payment problems in construction projects, their impact, and answers to issues. This research aims to identify the main causes of delays in payments by contractor by collecting data from contractors. The objectives of the study are to:

1. Reasons or Causation Factors for the delay in payment.
2. To determine the impact of the delay.
3. Recommendations for minimizing or controlling delay in payment.

Literature Review

P. Syam Sai this study is often cited for its focused approach on how bauxite residue influences the mechanical properties of concrete when substituted for cement. The study typically focuses on M30 grade concrete, examining the replacement of Ordinary Portland Cement (OPC) with Red Mud in increments (usually 5%, 10%, 15%, and 20%). Syam Sai's work emphasizes that Red Mud is not just "waste" but a functional additive. However, the study also warns that because Red Mud increases the water demand of

the mix, the workability (Slump) decreases as the percentage of Red Mud increases. This often necessitates the use of a superplasticizer to keep the concrete flowable without adding extra water that would weaken the final product.

Sowmyashree T research delves into how the chemical constituents of Red Mud—specifically the reactive silica and alumina—interact with the calcium hydroxide [Ca(OH)_2] produced during cement hydration. This study displays the effects of red mud as a replacement for cement in strength properties of the concrete. This study shows that replacement of red mud up to 30% shows the comparable compressive tensile and flexural strength values.

Sawant and Kumthekar research was which focused on the sustainable reuse of Red Mud (bauxite residue) in the construction industry. Their study is a significant contribution to "green concrete" research, specifically looking at how this industrial byproduct affects the structural integrity and durability of concrete. They concluded that a 15% replacement of cement with neutralized red mud serves as the "sweet spot." At this level, the concrete maintains its structural requirements while providing an eco-friendly disposal method for industrial waste.

Sithar Pateliya research focus regarding Red Mud (also known as bauxite residue) involves its application as a partial replacement for cement in concrete. Pateliya's research explores the mechanical and durability properties of concrete when cement is swapped for varying percentages of red mud.

K. Deepika's uses red mud as a primary replacement for cement. Research work typically focuses on the structural and chemical feasibility of reusing this industrial byproduct. Studies suggest that red mud can replace 10% to 20% of cement without significantly compromising strength. Beyond 25%, the compressive strength usually starts to decline.

Mix Design

Concrete Mix Design

Trials of mix design are carried out on the general guidelines of IS 10262-2009. The basic tests for all the ingredients of concrete are carried out for determining the mix-design parameters. The details of the mix are tabulated in table below.

Strength properties of concrete mixes depend on variety of factors associated with quality and proportions of materials, production methods, curing regimes and loading conditions. This is true whether fully virgin aggregates are used or they are replaced, partially (or fully) by any new ingredient materials.

Stipulation for Proportioning

1.	Grade designation	=	M30
2.	Type of cement	=	OPC 43 Grade to IS 8112
3.	Maximum nominal size of aggregate	=	10 mm
4.	Maximum water cement ratio	=	0.50
5.	Workability	=	100 mm Slump
6.	Exposure Condition	=	Mild
7.	Maximum Cement content	=	450 Kg/m^3

Test Data for Materials

A.	Cement used	=	OPC 43 Grad to IS 8112
B.	Specific Gravity of Cement	=	3.15

C. Specific Gravity of
1. Coarse Aggregate = 2.7
2. Fine Aggregate = 2.6
D. Water Absorption
1. Coarse Aggregate = 0.31
2. Fine Aggregate = 2.83

Mix Design for M25

Mix Design	M25
Type of Cement	OPC 53 grade conforming to IS-1269-1987
Maximum Nominal Size of Aggregate	20 mm
Minimum Cement Content	300 Kg/m^3
Maximum Water Content	0.47
Tye of Aggregate	Crushed Angular Aggregate
Maximum Cement Content	419 Kg/m^3
Degree of Supervision	Good
Exposure Condition	Severe
Slump	100 mm

Methodology

First, a literature review was conducted to know about the strength analysis of concrete with red mud. This helped to focus on the problem definition and possible solution for the same. Following methodology was adopted in this project work:

- Collection of Materials required OPC (Ordinary Portland Cement), Fine Aggregate, Coarse Aggregate, and Red Mud
- Mix Design was done and the concrete was prepared for the proportion of 1 : 1.25 : 1.76
- M25 Grade Concrete was casted and a total of 4 stages of concreting was done
- In each stage, 9 concrete cubes, 3 cylinders & 3 beams were casted
- In the first stage, normal concrete was produced and cubes, beams and cylinders were casted
- In the second stage, cement was replaced by 15% of red mud, and cubes, beams and cylinders were casted
- In the third stage, cement was replaced by 25% of red mud, and cubes, beams and cylinders were casted
- In the fourth stage, cement was replaced by 30% of red mud, and cubes, beams and cylinders were casted
- Compressive Strength Test was conducted for all the concrete mix at the end of 7, 14 and 28 days of curing, whereas Split Tensile Test and Flexural Strength Test were conducted at the end of 28 days of curing
- All the values of the results were compared and a graph were plotted

Experimental Investigation

Weighing of Cement

Casting of Cubes, Beams and Cylinders

Vibration of Moulds

Drying of Moulds after Casting

Results

The compressive strength at 7, 14 and 28 days after curing are evaluated and discussed. The compressive test was carried out for different mix proportions.

Sl. No.	Red Mud %	Mix Design	Compressive Strength in N/mm^2		
			7 Days	14 Days	28 Days
1	0%	CM	15.89	19.44	23.64
2	15%	RM15	14.72	20.27	18.99
3	25%	RM25	16.40	24.80	27.51
4	35%	RM35	13.17	19.82	23.31

Table 1 - Compressive strength of the specimens with Red Mud as partial replacement for cement

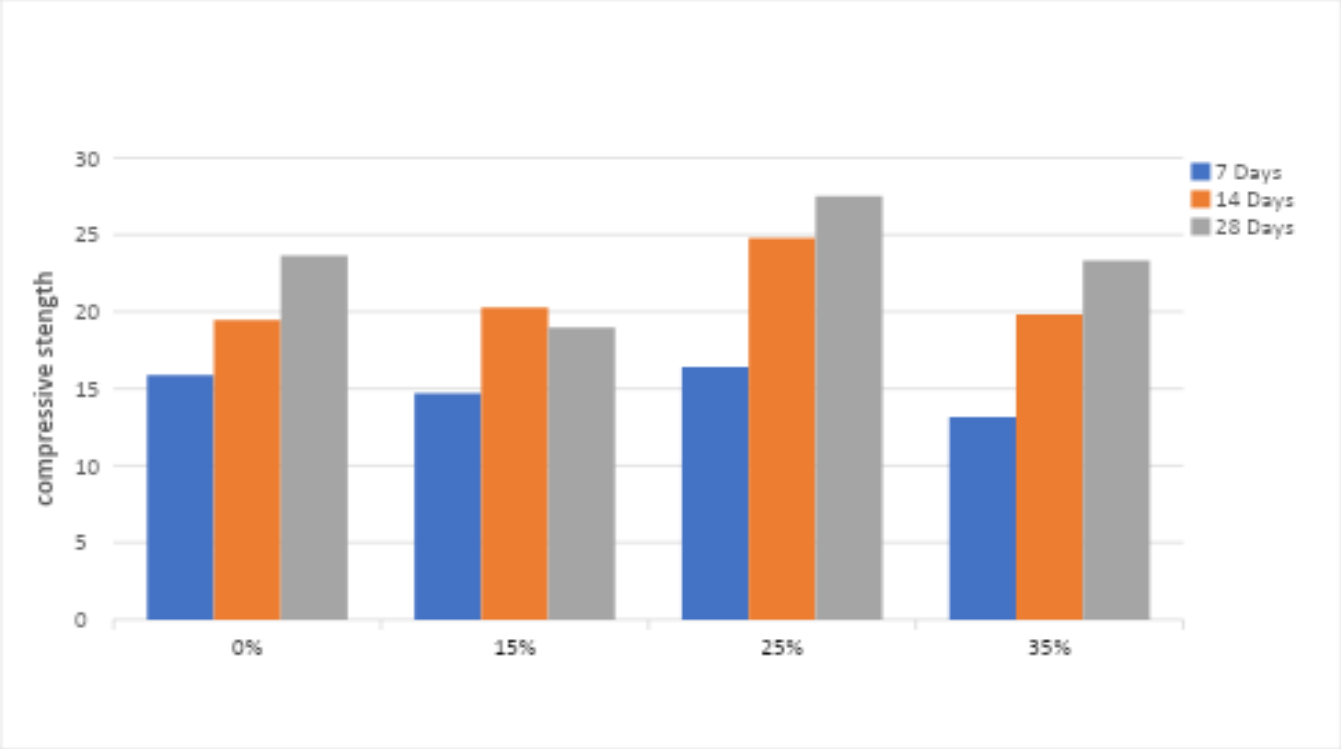

Figure:1.2 Analysis of compressive strength

Conclusion and Recommendation

The main aim of this research work was to find the impact of red mud as partial replacement to cement in concrete. In the present study, tests were done to check the durability properties of concrete by utilizing red mud as partial replacement to cement. The conclusion of the study is as follows:

- It was seen from the test consequences of fresh properties that affinity to water increments with the increasing the amount of red mud. This expansion in demand of water is expected to the way that the red mud being marginally lighter in weight has better particles and possesses more volume which needs more water for a similar consistency.
- It was seen that incrementing the content of red mud reduces the strength properties of the concrete; however, there is possibility of utilizing red mud in concrete in sustainable development.
- The optimum content of the red mud replacement is 25%.
- The results concludes that the red mud can be used for both structural and non-structural works.
- The use of red mud in concrete can be a best option to reduce the environmental pollution and the reduction of carbon foot print by the construction industry.

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