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Analysis of Concrete Strength Using Red Mud and Fly Ash, Metakaolin, GGBS Admixtures as Partial Replacements

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ABSTRACT

The research investigated concrete properties by replacing cement with red mud. Alumina manufacture from bauxite ore by the Bayer Process is energy-intensive and produces large amounts of dust-like, high-alkalinity red muck. Red mud, produced in nearly equal amounts as metallurgical alumina, is deposited in sealed or unsealed artificial impoundments, causing environmental problems. Iron, titanium, aluminum, silica oxides, and other minor components are present. Alumina and iron oxide are lacking in limestone, the cement basic component. Red mud offers them. Soda in red mud neutralizes pet coke sulphur and promotes cement setting in clinker processing. Red mud mining, storage, and disposal are emphasized globally for economic and environmental reasons. Several red mud collecting methods exist, but none are profitable. Aluminium red mud strength has been tested in the lab. Red mud for constructing is tested. Seven test groups were created using 3% mineral admixtures (1% fly ash, 1% metakaolin, and 1% GGBS) in M40 grade concrete with red mud replacement percentages of 0%, 10%, 20%, 30%, 40%, 50%, and 60%. Add hydrated lime for red mud's pozzolanic capabilities. This article suggests another way to use red mud

INTRODUCTION

1.1 General

The Bayer process for alumina manufacturing uses caustic soda and bauxite as raw materials, producing red mud, which is thrown at red mud yards due to its low industrial value. For years, the generated red mud remained unutilized. The storage of red mud and dikes occupied around 3.0 acres annually. A breakthrough occurred when MALCO identified the potential of red mud as a replacement for low-grade bauxite (LGB), which was used by the cement industry in cement production. They proposed testing red mud in the cement industry as an alternative to bauxite, given their similar compositions. The cement industry tried to make up for the lack of alumina in limestone. Red mud is an alumina production byproduct. Red mud is classified as Bayer or sintered depending on raw bauxite grade and alumina manufacture technique. Current methods create 0.8 to 1.76 tons of red mud per ton of alumina. China's three biggest alumina factories produce 3 million tons of red dirt. The Bayer process's main reactions are: $Al2O3 + 2NaOH + 3H2O \rightarrow Na2O{\cdot}Al2O3 + 4H2O$ + red muck

Red mud harbours significant quantities of hazardous pollutants, including industrial alkalis, fluorine, and heavy metals; hence, prolonged storage not only consumes land resources but also poses a substantial risk of severe contamination to the adjacent soil, air, and groundwater. The ongoing elevation of the storage yard may result in severe geological calamities. The investigation of the physical and chemical characteristics, as well as the complete usage of red mud, has emerged as a focal point in the realm of materials science and technology. Liu et al. shown via several studies that red mud pre-treatment, including particle size classification, is an effective recycling procedure. This study describes the physical and chemical properties of red mud at different temperatures and provides a theoretical basis for activation. Bayer red mud and sintered red mud have different physical and chemical properties according to their formations. To fully use red mud, crucial factors such chemical properties, mechanical performance, particle size, shape, and structure must be identified. XRD, SEM, TG, shear strength testing, particle size measurement, and hydrodynamic property assessment were

used to compare sintered red mud with Bayer red mud. Recommended is the broad

usage of Bayer red mud and sintered red mud separately.

Fig 1. 1 : Red mud produced in Bayer processing

Summary:

Red mud is a solid waste produced by aluminium refineries globally. Approximately 35 million tons of red mud are generated annually in Western nations. The intricate physic-chemical features of red mud provide a significant challenge for designers in identifying economical usage and safe disposal methods. This waste disposal was the first major hurdle for the alumina business following the Bayer process.

Since monsoon runoff may carry red muck to surface water bodies, pond disposal can harm the ecosystem. leading to groundwater pollution via leaching. The continued disposal of substantial volumes of red mud presents escalating storage challenges due to its significant spatial requirements. Numerous efforts have been undertaken over the years to identify a viable use for red mud, although none have shown economic feasibility.

LITERATURE REVIEW

1Author(s): M. S. Reddy, A. K. Gupta, Investigating Red Mud as a Sustainable Cement Substitute

Summary:

This research examines the utilization of red mud, an industrial by-product, as a sustainable alternative to cement. Experimental studies evaluated concrete mixes where red mud replaced cement at varying percentages (10%, 20%, 30%) with and without hydrated lime. The study revealed that the addition of hydrated lime improved workability due to the finer particles of red mud, which require more water. The pozzolanic reaction between hydrated lime and red mud enhanced early-age compressive strength, particularly at a 20% replacement level. However, beyond 30% replacement, the strength declined significantly due to a dilution effect. Durability tests, including sulfate resistance and carbonation depth, indicated improved performance in mixes with hydrated lime. The study concluded that up to 20% red mud replacement with hydrated lime is optimal for structural applications. Source: International Research Journal of Modernization in Engineering, Technology and Scien

2. Author(s): K. Sharma, R. Singh, Mechanical Properties of Concrete with Red Mud and Lim
Summary:
This paper evaluates the mechanical properties of concrete incorporating red mud and hydrated lime. The study tested concrete mixes for workability, compressive strength, split tensile strength, and flexural strength. Results showed an increase in slump values as the red mud content increased, with hydrated lime further enhancing workability. The inclusion of lime compensated for the lower binding ability of red mud by forming secondary hydration products. The compressive strength of concrete was comparable to the control mix at 20% red mud replacement, with a slight reduction at higher replacement levels. Split tensile and flexural strength tests showed similar trends. Durability studies revealed that concrete with red mud and hydrated lime exhibited better resistance to carbonation and sulfate attacks. This highlights its potential for eco-friendly and durable construction practices.

SCOPE OF INVESTIGATION

This research examines the effects of replacing cement with red mud in M40 Grade concrete at 0%, 10%, 20%, 30%, 40%, 50%, and 60% with and without hydrated lime and 3% mineral admixtures. Casting and curing concrete cubes for 7 days, 28 days measured compressive strength. Prisms were cast for 7 and 28 days and tested for concrete flexural strength using red mud with and without hydrated lime. Cylinders were cured for 7 and 28 days for split tensile strength.

3.1 OBJECTIVES

The specific objectives of the present investigation are listed below.

Red mud is a novel waste material emerging in the concrete industry. The primary objective of this study is to utilize red mud as a cement substitute, both as an additive and a partial replacement, to examine its effects on various parameters of M40 grade concrete. The evaluation will focus on comparing the workability, compressive strength, split tensile strength, and flexural strength of M40 concrete incorporating red mud and hydrated lime against standard concrete.

To develop features of increased cement for M40 by expansion and fractional substitution, using controlled mix concrete. ¬ To maximize the use of red mud, hydrated lime, and mineral admixtures such as fly ash, GGBS, and metakaolin. ¬ The primary aim is to standardize the qualities of concrete including red mud material.

TEST PROGRAMME

In order to ascertain the effects of varied amounts of red mud, the cement in M40 Grade concrete is replaced with hydrated lime at a ratio of 0% and 5%. This is done in order to assess the outcome of the experiment. In order to investigate the effects of different proportions of red dirt, this particular procedure is carried out. In addition to the fact that all of the mixes include the same sorts of components, such as sand and electronic trash, they also all have the same proportions of fine particles in relation to the total aggregates. The parameter studies are comprised of the following: 1) The following is a breakdown of the proportionic quantities of red mud: This includes 0%, 10%, 20%, 30%, 40%, 50%, and 60%.
In hydrated lime, the percentages of mineral admixtures are one percent, five percent, and three percent, respectively.
For every possible combination, prisms with dimensions of 150 millimeters by 150 millimeters by 700 millimeters were cast and put through all of the tests. In addition, three cubes with dimensions of 150 millimeters by 150 millimeters and three cylinders with dimensions of 150 millimeters in diameter and 300 millimeters in height were cast.
Testing for compressive strength was carried out on cubes, split tensile tests were carried out on cylinders, and flexural strength tests were carried out on prisms. All of these tests were carried out for the purpose of the test program.

EXPERIMENTAL INVESTIGATION MATERIALS AND METHODOLOGY

3.1 MATERIALS USED

3.1.1. CEMENT

Materials that are calcareous, such as chalk or limestone, and materials that are argillaceous, such as shale or clay, are the raw ingredients that are necessary for the production of Portland cement. Processes are classified as either wet or dry, depending on whether the mixing and grinding of raw materials is carried out in a wet or dry state. Wet processes are more common than dry processes. A significant amount of lime, silica, alumina, and iron oxide are the primary components of the raw materials that are used in the production of cement. The high temperature in the kiln causes these oxides to interact with one another, which results in the formation of more complicated compounds.

The term "hydration of cement" refers to the chemical processes that take place when cement is combined with water when it is used. There are two different methods that one might view the hydration of cement. The first method is the solution mechanism, which involves the dissolution of cement to cause the production of a super saturated solution, which then leads to the precipitation of hydrated products. When it comes to cement compounds, the second issue is that water assaults them from the surface all the way down to the interior throughout the course of time. An exothermic reaction occurs when cement is combined with water. The reaction results in the release of a very high amount of heat. The term "heat of hydration" refers to the release of heat in this manner.

RESULTS AND DISCUSSIONS

Concrete is the most frequently used and exploited building material. Concrete's versatility allows it to be accurate in readily available cement, aggregate, and water. Using expanded concrete may worsen the situation. To achieve the fair tangible criteria in the field, relevant components must be reinstalled in adequate amounts.

Red mud concrete is not suitable for building standard buildings due to aggregate-cement bonding. However, it easily fills mold corners and packed reinforcing areas.

4.1 MIX DESIGN OF CONCRETE

The process of selecting the proper components of cement and the relative amounts of those components is known as concrete mix configuration. The objective of this approach is to produce cement that has a minimum strength, desired functionality, and solidity while maintaining the lowest possible cost (value designed) as was wise.

Due to the fact that I have decided to go with a solid blend configuration, it is

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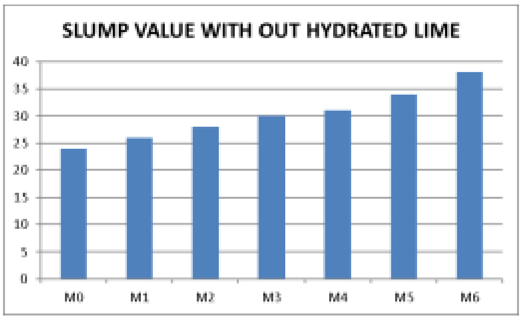
important that you collect the following information in advance since there are a few outline specifications that are frozen depending on these details. This research is primarily centered on the development of typical building upgrades that are of the M40 grade of red mud concrete, which is of average quality. At a weight-to-cement ratio of 0.40, the final trial mix for M40 grade concrete is 1:1.52:2.21.

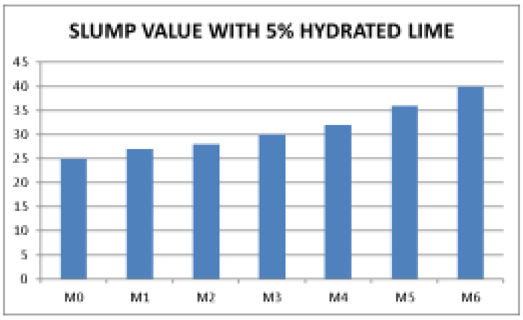
Conventional Concrete Mix Design

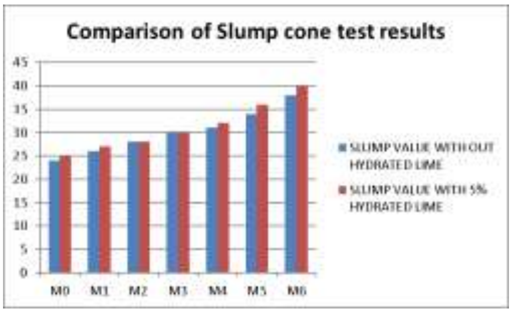
M40 grade of conventional concrete mix was done by using IS456-2000 and IS 10262:2009 codes.

Mix Proportions

In the following table, you can find the various kinds of mixes, along with their % relative proportions and blend proportions of component ingredients.







CONCLUSIONS

After the study, these conclusions were reached:

1. Red mud and hydrated lime may partially replace cement, allowing us to turn waste into useful material.
2. Red mud and hydrated lime may be used as cementitious materials, eliminating landfill waste and reducing pollution.
3. Red mud concrete has a lower density than normal concrete, resulting in a lighter construction and reduced costs.
4. Slump increases from 0% to 60% red mud, independent of hydrated lime application.
5. Regardless of hydrated lime application, the compaction factor rises as red mud

increases from 0% to 60%.

After curing 10% red mud for seven and twenty-eight days, compressive strength reached its peak. Concrete compressive strength drops dramatically beyond 10%.

At 10% red mud, split elasticity was highest seven and twenty-eight days after repair. At 10%, concrete split strength decreases.

The optimal, or maximum, flexural strength was determined at 0% red mud for seven days and 28 days of curing.

Concrete loses 0% compressive strength.

9. This experiment shows that red dirt and hydrated lime may boost concrete strength.

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