International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis of Concrete Durability Parameters Using Waste Red Mud as a Composite Material

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ABSTRACT:

In this paper we are going to explores the potential of using red mud, a byproduct of alumina production, as a partial substitute for Portland cement in concrete. Various tests, including compressive strength, acid resistance, water absorption, and carbonation, are conducted on concrete mixes with different percentages of red mud and hydrated lime replacements. Mix designs for M30 and M40 grades are prepared, with red mud replacing 5% to 30% of cement and hydrated lime replacing 5% of cement. Different water-cement ratios are also considered. The study includes concrete samples aged for 7 and 28 days, examining the effects of age, cement content, water-cement ratio, and slump on concrete properties.

Keywords: - Red Mud, Cement, Sand, Bauxite, Concrete,

Introduction:

The Red mud, also known as bauxite tailings, is leftover material from the process of making aluminum from bauxite ore. This process, called the Bayer process, involves mixing bauxite with sodium hydroxide to extract aluminum. Red mud is a mixture of fine particles and various minerals, rich in iron oxide and other elements found in bauxite. Its disposal has become a major environmental concern due to its complex composition and potential harm to the environment. Traditional disposal methods, like storage facilities, can lead to soil and water contamination, even causing environmental disasters. To tackle this issue, researchers and industry experts are exploring new ways to use red mud, such as in building materials or as soil amendments, and even extracting valuable elements from it. This ongoing effort aims to find sustainable solutions to manage red mud effectively, reducing its impact on the environment and society. Research into innovative applications and technologies for red mud is growing, with the goal of turning this waste product into a valuable resource and addressing environmental challenges associated with its disposal.

Methodology:

The methodology of redmud concrete involve systematic process to design better strength and the process is given below
The standard consistency test, we determine the optimal water-to-cement ratio needed for cement paste. This ratio affects how quickly the cement sets and its overall strength. To conduct this test, we use a device called a 'wicket machine.' The test involves creating a cement paste that allows a specific size hole to penetrate a certain depth in a mold. This depth is typically between 33-35mm from the top of the mold. By measuring the percentage of water needed to achieve this consistency, we can determine the standard consistency of the cement paste. This test helps ensure that the cement paste has the right thickness for proper performance in various applications.
The initial setting time test, according to IS: 4013-5 (1988), involves measuring the time it takes for a needle to penetrate a cement sample to a specific depth. We start by gently lowering the needle onto the surface of the sample and then quickly releasing it. Initially, the needle will sink into the sample freely. However, as the cement starts losing its plasticity, the needle can only penetrate to a depth of 33-35mm from the top. We record the time when the needle reaches this depth as the initial setting time. It's calculated using the formula: Initial setting time = 0.85 × P / 100 × Number of cement samples taken, where P is the required penetration time. This test helps us understand how quickly the cement sets, which is important for various applications.

Specific gravity test according to IS:2720-3-1 (1980)

- Lichatir flask should be free from moisture. It means that the flask is completely dry.
- Then weight the empty flask and note that it is W1.
- Take 50 grams of cement and add it to the flask. Next, weigh the top of the flask and record it as W2.
- Then pour kerosene in the sample up to the opening of the bottle. Mix thoroughly and make sure that no air bubbles remain in the flask. Note the weight of W2. Specific weight of cement (Sg) = W2-W1/(W2-W1) (W3-W4) x 0.79.

In the Sieve Analysis Test as per IS:460 (1962), we assess the size distribution of aggregates commonly used in concrete. These aggregates typically range from 4.75 mm down to 150 microns, with the portion between 4.75 mm and 150 microns termed as fine aggregate.

To conduct the test, we stack sieves of decreasing size on top of each other, with the finest sieve at the bottom. The sample is then sieved successively through these stacked sieves. The material that remains on each sieve after shaking represents grains of that specific size fraction.

We can perform sieving manually by shaking the sieve to allow particles to pass through until almost none remain. Alternatively, mechanical devices provide more systematic and efficient movement, ensuring thorough sieving.

The cumulative retention rate (K) is calculated using the formula: K = W1/1000 × 100%, where W1 is the weight of the retained material on the sieve in grams. The pass percentage is then determined as 100 minus the cumulative retention rate (pass = 100 - K). This test aids in understanding the gradation of aggregates, vital for ensuring concrete quality and performance in construction projects.

In the Specific Gravity Test outlined in IS:2386-3 (1963), we determine the specific gravity of aggregates, which is crucial for concrete mix design calculations. This test helps convert the weight of each component into solid volume, enabling us to calculate the theoretical yield of concrete per unit volume. Specific gravity is also essential for calculating the modulus of compaction and when dealing with light and heavy concrete.

To perform the test, we start by weighing a clean, dry pycnometer with the cap attached (W1). Then, approximately one-third of the pycnometer is filled with water containing the sample, ensuring all air bubbles are removed. We measure the weight (W3) at this stage. Next, we remove the sample, fill the hydrometer completely with water, and weigh it to determine (W4).

The specific gravity (Sg) is calculated using the formula: Sg = ((W2-W1)/(W2-W1))-((W3-W4)). Here, Sg represents specific gravity, W1 is the weight of the empty hydrometer, W2 is the weight of the hydrometer with the sample, W3 is the weight of the hydrometer with the sample and water, and W4 is the weight of the pycnometer with water.

The average specific gravity of stone typically falls between 2.6 and 2.8. This test provides valuable data for concrete design and performance evaluation, ensuring the quality and durability of concrete structures.

In the Bulk Density Test according to IS:2386-3 (1963), we measure how densely aggregates are packed, which tells us about their shape and quality. This test helps us understand how much space the aggregate fills when packed in a standard way. The bulk density depends on the size and shape of the particles. Higher bulk density means less space is left unfilled by the aggregate or cement.

To perform the test, we start by collecting a specific amount of aggregate (W1). Then, we dry the samples in an oven at 100 to 110 degrees Celsius for 24 hours and let them cool (W2). Next, we add sand and a bit of water to the container, shake it well, and pour it into a graduated cylinder. After settling, we note the volume (h1) in milliliters.

We repeat this process, gradually adding more water and noting the corresponding aggregate volume (h2, h3, etc.) until the volume of discharged sand starts decreasing. Then, we add more water in larger increments until the sample is fully soaked. We note the flooded sand volume (h).

The apparent density is calculated using this formula: Apparent density = (sample mass (W1 - W) * 100) / container volume (W). Here, W1 is the initial mass of the sample, W is the final mass after soaking, and W is the volume of the container.

This test helps us determine the void content in bulk samples, which is essential for creating cost-effective and durable concrete mixes.

In the Specific Gravity test as per IS: 2720 -PART-3, SEC -1, we determine the specific gravity of red mud, which is essential for concrete mix design. Knowing the specific gravity of each component helps convert its weight into solid volume, aiding in calculating the theoretical efficiency and amount of concrete per unit volume. Specific gravity also helps calculate density coefficients for performance measurement and is important when working with light and heavy concrete.

To perform the test, we start by weighing a clean, dry pycnometer with a lid (W1). Then, we fill approximately one-third of the pycnometer with red mud and weigh it (W2). Next, we pour water containing the sample into the pycnometer, removing all air bubbles. We measure the weight (W3) at this stage. After removing the sample, we fill the hydrometer completely with water and measure its weight (W4).

The specific gravity (Sg) is calculated using the formula: Sg = (W2-W1)/(W2-W1)-(W3-W4). Here, Sg represents specific gravity, W1 is the weight of the empty pycnometer, W2 is the weight of the pycnometer with the sample, W3 is the weight of the pycnometer with the sample and water, and W4 is the weight of the hydrometer filled with water.

This test provides crucial information for concrete mix design, ensuring the quality and performance of concrete structures.

Testing the pH of red mud as per IS-2720-PART-26 involves several steps to ensure accurate results

- Prepare the material by sieving it through a 1/4-inch (6.3) sieve. Only material smaller than 1/4 inch (6.3) is used for testing.
- Weigh 30 grams of soil and place it in a glass beaker.
- Add 30 grams of distilled water to the soil sample to create a clay slurry. Stir the mixture and cover it with a watch glass. Let it sit for at least 1 hour, stirring every 10-15 minutes to stabilize the pH.
- After 1 hour, measure the temperature of the sample and adjust the pH meter's temperature controller accordingly. This should be done just before the test. If the meter has automatic temperature control, follow the manufacturer's instructions.
- Standardize the pH meter using the provided standard solution, ensuring the temperature is adjusted as mentioned earlier.
- Before dipping the electrode into the sample, stir it thoroughly with a glass rod. Then, place the electrode in the soil slurry solution and gently rotate the beaker to ensure good contact between the solution and the electrode. Avoid inserting the electrode into the soil; it should only be in the soil slurry solution.
- Allow the electrode to immerse in the sample for at least 30 seconds to stabilize the instrument. If the meter has automatic reading, it will signal when it's stable.

- Read the pH value and record it to the nearest whole number. For values close to 100, use the rounding rules: If the hundreds digit is less than 5, leave it as is. If it's greater than 5, round up by one unit. If the hundreds digit is 5, round the tens digit to the nearest even number.
- Thoroughly rinse the electrode with distilled water and rub it with a tissue to remove any film. Be careful not to wipe the electrodes, as this can slow down the response time

Testing the pH of water as per IS:3025.11 (1983) involves simple steps:

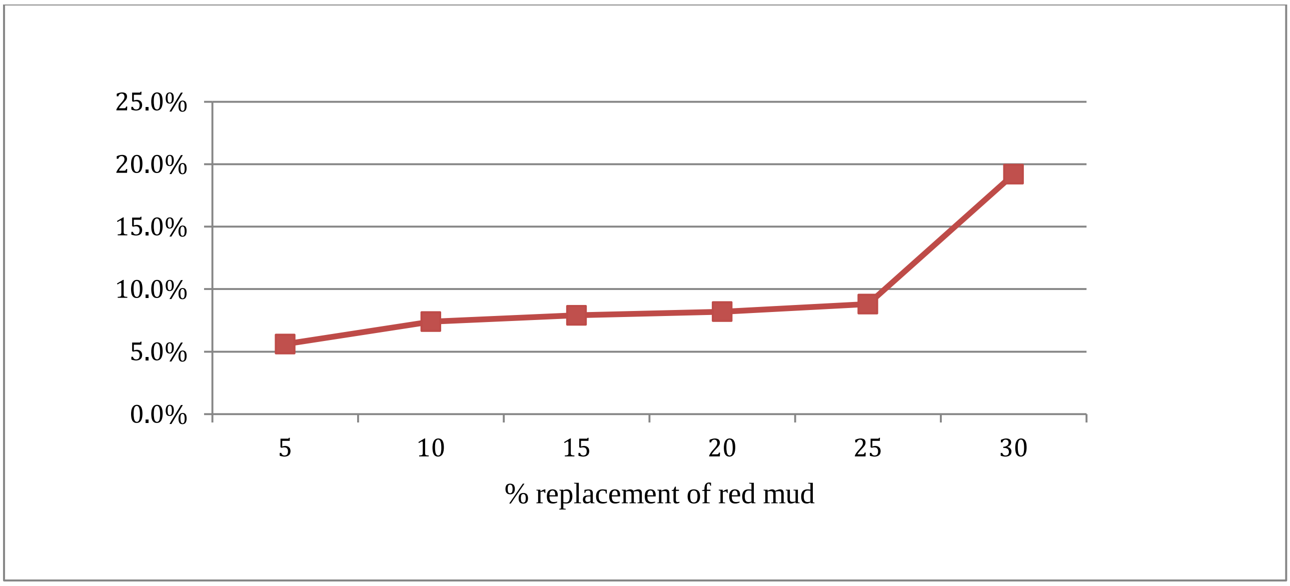
- Rinse each test tube with the water sample.
- Use gloves to prevent skin contact with the water.
- Hold the dropper bottle vertically and fill the test tube with a few milliliters of the water sample.
- Add 10 drops of the broad-spectrum indicator solution to the test tube.
- Cover the test tube and invert it several times to mix the solution.
- Place the tube in a wide-range pH comparator and bring it closer to a light source.
- Match the color of the sample with the color standard provided.
- Record the pH value.
- pH measures acidity or alkalinity on a scale of 0 to 14, where 7 is neutral. A pH below 7 indicates acidity, while a pH above 7 indicates alkalinity. The pH formula is pH = log10 (H+).

Results

SATURATED WATER ABSORPTION TEST

Table Test results on saturated water absorption for M30 Grade concrete after 28 days

Percentage replacement of Red Mud	Wt. of cubes before immersion W1(Kg)	Wt. of cubes after immersion W2(Kg)	SWA In %	Compressive Strength N/mm²	Loss in Compressive Strength
5%	8.37	8.48	1.01	32.60	5.6%
10%	8.42	8.54	1.01	34.50	7.4%
15%	8.47	8.56	1.01	35.10	7.9%
20%	8.53	8.61	1.00	34.78	8.2%
25%	8.57	8.68	1.01	31.12	8.8%
30%	8.62 8	8.69	1.00	31.02	19.2%



Saturated Water Absorption test M30 result after 28 days

Based on the test findings, the highest replacement rate of red mud and dried lime by cement is 20%.

a) Up to a 20% replacement, the amount of absorbed water remains relatively low. However, beyond this threshold, as the amount of red mud replaced increases, the absorbed water gradually increases.

b) The loss in cube compressive strength is calculated for all replacements. Once again, exceeding the optimal replacement ratio significantly increases the drop in compressive strength.

c) Test results for replacement rates of 5%, 10%, 15%, 20%, 25%, and 30% are presented in tables and graphs, showing the corresponding reduction in compressive strength.

Conclusion

The best replacement rate for red mud in cement is found to be 20% by weight. This is because, for both M30 and M40 grade concrete, adding red mud enhances the pozzolanic properties of the cement.

Concrete with 20% red mud replacement shows nearly identical results to regular concrete for both M30 and M40 grades. When red mud is mixed with cement, it not only maintains a similar setting time as regular cement but also improves the strength characteristics of M30 and M40 grade concrete by up to 20%.

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