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Experimental Study on Utilization of Industrial Wastes (Red mud and Copper slag) in Mortar and Concrete

[1]Kiran Kumar M S, [2]Raghavendra Naik

[1,2] Assistant Professor, Civil Engineering Department, Jain Institute of Technology, Davanagere, Karnataka, Visvesvaraya Technological University, Karnataka, INDIA

Abstract: **The aim of the present work is to investigate the possibility of replacing the part of Portland cement by red mud and fine aggregate by copper slag. Because of storing issues, the waste negatively affects the environment. To solve this problem, an attempt was made to check the effectiveness of red mud as a partial replacement of Portland cement. Portland cement was replaced up to 30 % Red mud by the weight of cement and checking the compressive strength of cement mortar cubes. Fine aggregate was replaced up to 60% copper slag and evaluating its compressive and splitting tensile strength of red mud concrete. The optimum gained after 7 and 28 days curing period was found to be 15% Red mud (for mortar) and for the combination of both Red mud and Copper slag was found to be 15% RM + 40% CS (for concrete).**

Keywords: **Industrial waste, red mud, copper slag, cement mortar, compressive strength, split tensile strength.**

I. INTRODUCTION

Cement in general sense of the word, can be described as a material with an adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact mass. This definition encompasses a large variety of cementing material. For constructional purposes the meaning of the term cement is restricted to the bonding materials used with stones, sand, bricks, blocks etc. Cement is the most important material in structural constructions as it is used at different stages of construction in the form of mortar or concrete.

In India, there is great demand of aggregates mainly from civil engineering industry for road and concrete constructions. But nowadays it is very difficult problem for available of fine aggregates. So researchers developed waste management strategies to apply for replacement of fine aggregates for specific need. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment.

1.1 Red mud:

Red mud is the iron rich residue from the digestion of bauxite. It is one of major solid waste coming from Bayer process of alumina production. In general, about 2-4 tons of bauxite is required for production of each tone of alumina (Al_2O_3) and about one tone red mud is generated. Since the red mud is generated in bulk it has to be stored in large confined and impervious ponds, therefore the bauxite refining is gradually encircled by the storage ponds. At present about 60 million tons of red mud is generated annually worldwide which is not being disposed or recycled satisfactorily.

1.1.1 Effect of red mud on environment:

In the last decade, the production of aluminium in spite of some stagnancy and set back periods has shown a steady rise of about 1%. The ecological consequences of aluminium production are well known; threatening of surface and underground water and air pollution by waste gases from aluminium electrolysis plant and rolling mills. The degree of damage inflicted to ground water and air during the single production stages from bauxite to aluminium depends on a couple of tact of which those connected with the alumina winning and red mud disposal.

1.1.2 Utilization of red mud:

As to the resource utilization of red mud, alumina companies have been carrying out many technical researches on production of construction material, especially cement production, glass production and production of road base. And they have made some progress, especially in the production of cement using red mud.

Production of Construction Materials from Red Mud

- Cement
- Brick
- Glass
- Aerated Concrete Block
- Road base Material

1.2 Copper Slag:

Copper Slag is a by-product material produced from the process of manufacturing copper. It is totally inert material and its physical properties are similar to natural sand. The slag is a mixture of lime, silica and alumina, the same proportion. For every tone of metal production, about 2.2 ton of waste slag is generated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. The Physical and mechanical properties of granulated copper slag shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass, tiles etc.

II. OBJECTIVES OF WORK

Basically this paper is based on the dissertation work carried out to overcome the problems created due exhaustion and obsolescence of raw material required for manufacturing of conventional building material and also minimize the thrust of Industrial waste on the environment by utilizing the same in the Construction Industry. Following are the objectives derived by exhaustive study of literature:

- To investigate the Utilization of Red mud as Supplementary Cementitious Material (SCM) and influence of this Red mud on the Compressive Strength of cement mortar.
- To Study the Effect of Red mud replacement to cement & Copper Slag Replacement to Fine Aggregate on Strength Parameters of concrete.

III. MATERIALS USED

A. Cement:

In this experimental work, Ordinary Portland Cement (OPC) 43 grade conforming to IS: 8112 – 1989 was used.

B. Sand (Fine Aggregate):

Locally available river sand belonging to zone II and passing through 4.75mm sieve of IS 383-1970 was used for the project work.

C. Coarse aggregate:

Locally available Quarried and crushed granites stone aggregates confirming to IS 383-1970 are used in this dissertation.

D. Red Mud:

The red mud is one of the major solid wastes coming from Bayer process of alumina production. At present about 3 million tons of red mud is generated annually, which is not being disposed or recycled satisfactorily. We collected red mud from Hindalco Industries Limited, Belgaum, and Karnataka (INDIA).

Table 1: Comparison of Red mud & Cement

Sl. No.	Material Property	Results Obtained (Red mud)	Results Obtained (Cement)
1	Specific gravity	**2.90**	**3.10**
2	Fineness	**4.10%**	**4%**

E. Copper Slag:

Copper slag is one of the materials that are considered as a waste which could have a promising future in construction Industry as partial or full substitute of either cement or aggregates. We collected Copper slag from local distributors of Coimbatore (Tamilnadu).

Table 2: Comparison of Copper slag & Fine aggregate

Sl. No.	Material Property	Results Obtained (Copper Slag)	Results Obtained (Fine aggregate)
1	Specific gravity	**3.58**	**2.60**
2	Fineness Modulus	**3.19%**	**2.59%**

IV. METHODOLOGY DETAILS

The methodology adopted has been divided into two phases. The 1st phase covers the possibility of replacing part of cement binder with Red mud in mortar. The 2nd phase covers the study of fresh and hardened properties of concrete incorporated both Red mud & Copper slag (Replacement to Fine Aggregate).

Part I: Investigating the effect of replacing a part of the cement binder with Red mud in Mortar.

The mix proportion of the mortar was 1.0 (Portland cement): 3.0 (fine aggregate) and the water/cement ratio was 0.45. After mixing, a vibrating table was used to ensure efficient compaction. Mortars cubes containing distinct replacements of cement by red mud (5, 10, 15, 20, 25 and 30% by weight of cement) were prepared and tested as per Indian codal provisions.

Part II: To study the effect of Red mud & Copper Slag (Replacement to Fine Aggregate) on strength parameters of concrete.

After getting the optimum mortar cube strength from the part I, the next procedure is to design M30 grade as per IS 10262:2009 keeping the red mud percentage as constant(optimum obtained in part-I) and vary the copper slag percentage as 10%.20%,30%,40%,50% and 60% (replacement to fine aggregate). Further development mixes are studied for both fresh as well as hardened properties.

V. RESULT ANALYSIS OF COMPRESSIVE STRENGTH TESTING

Compressive strength of the mortar & concrete design mix was check by casting and testing of cubes (size 77 mm x 77 mm x77 mm) & (150mm *150mm *150mm) & Split tensile strength of concrete design mix was check by casting and testing of cylinders(150mm*300mm) after the curing periods of 3 days, 7 days & 28days.The obtained results are tabulated below.

Table 3: Compressive strength results of mortar cubes (Red Mud)

Replacement of cement by Red Mud (%)	3-Days (MPa)	7-Days (MPa)	28-Days (MPa)
Control Mix 0%RM	20.53	31.51	43.20
5%RM	21.40	31.70	43.28
10%RM	24.50	33.10	44.00
15%RM	**25.70**	**34.60**	**45.60**
20%RM	22.30	32.40	43.20
25%RM	19.80	29.70	40.40
30%RM	19.10	29.00	40.03

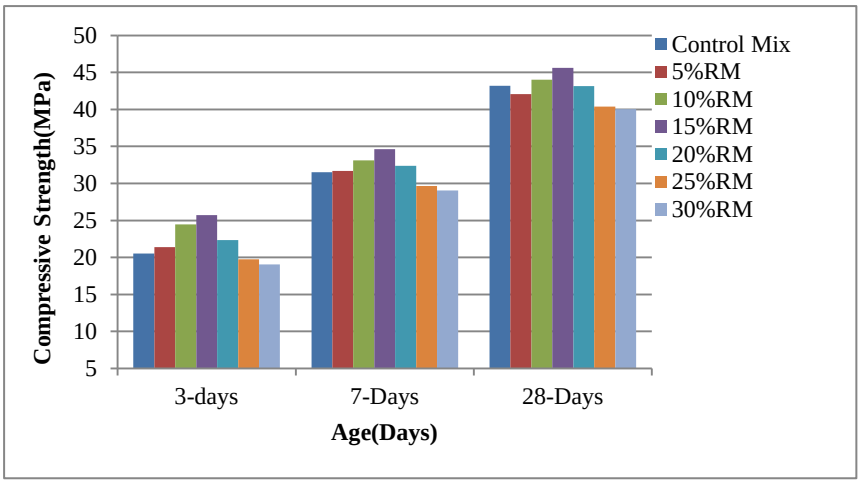

Figure 1: Compressive strength at 3days, 7days and 28days

Table 4: Overall compressive strength results after 7- days & 28-days

Replacement of Cement by Red Mud & Fine aggregate by Copper slag (%)	7-Days (MPa)	28- Days (MPa)
0% RM + 0% C S (Control mix)	22.00	35.94
0% RM + 10% C S	26.41	36.55
15% RM + 20% C S	27.17	37.22
15% RM + 30% C S	29.78	39.26
15% RM + 40% C S	**34.53**	**43.22**
15% RM + 50% C S	28.15	38.08
15% RM + 60% C S	26.00	36.00

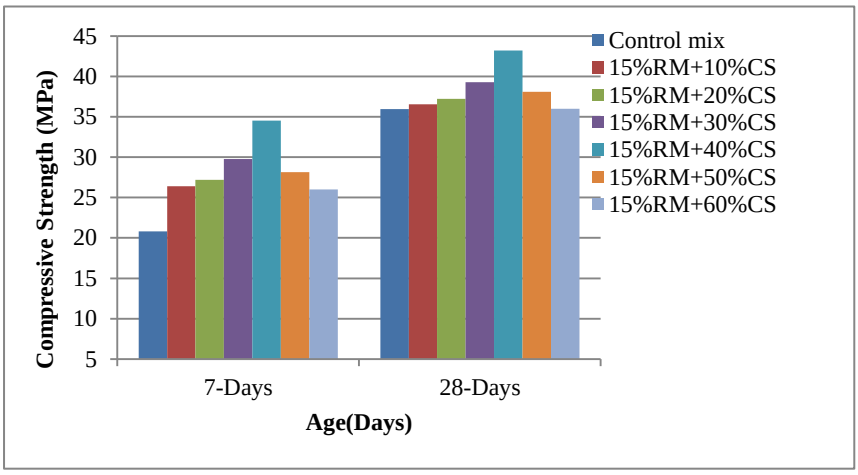

Figure 2: Variation of overall compressive strength

Table 5: Overall Split tensile strength results after 7- days & 28-days

Replacement of Cement by Red Mud & Fine aggregate by Copper slag (%)	7-Days (MPa)	28- Days (MPa)
0% RM + 0% C S (Control mix)	2.20	3.42
0% RM + 10% C S	2.31	3.51
15% RM + 20% C S	2.52	3.89
15% RM + 30% C S	2.80	4.01
15% RM + 40% C S	**3.10**	**4.41**
15% RM + 50% C S	2.53	3.91
15% RM + 50% C S	2.62	3.53

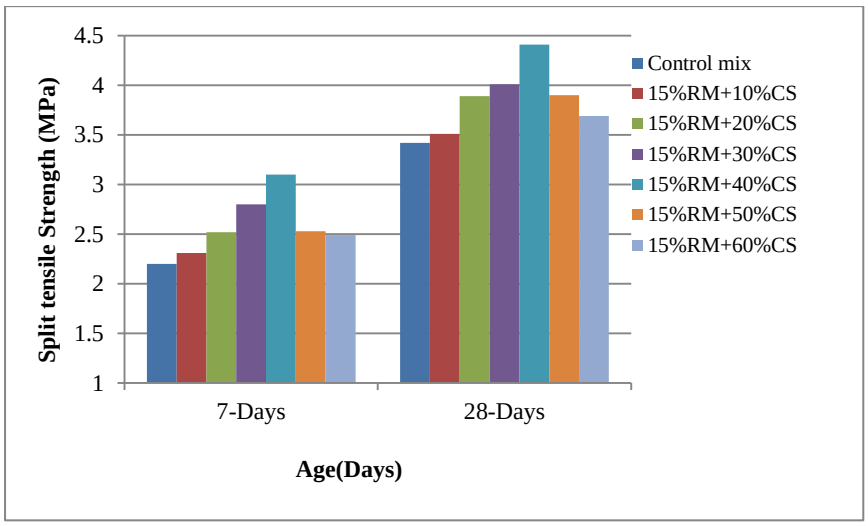

Figure 3: Variation of overall Split tensile strength

VI. DISCUSSIONS ON

A. Effect of Replacement of Cement by Red mud on Compressive strength of mortar cube

Blended cement samples, six in number are prepared with replacement of cement by Red mud with increment of 5 percent (i.e. 5%, 10%, 15%, 20%, 25%&30%) by the weight of cement.

From the graph it can be observed that, there was an initial decrease in the compressive strength for 5 % replacement of cement by Red mud. But from the next replacements i.e. for 10 % and 15 % the compressive strength was increased with the increase in the percentage replacement of cement by Red mud. Then after, for 20 %, 25 %& 30% replacement of cement by Red mud there was a decrease in the compressive strength as the % replacement of cement by Red mud increased.

Hence by observing graph I of mortar design mix, it can be said that the 15 % replacement of cement by Red mud gives the maximum compressive strength as compare with the control mix after 3 days, 7 days & 28 days curing period.

B. Effect of Replacement of Cement by RM and fine aggregate by CS on Compressive strength of red mud concrete

The above graph II indicates the compressive strength of concrete mixes with various replacements of cement by red mud (constant 15%) & fine aggregate by copper slag. The optimum strength gained after 7 and 28 days curing period is at 15%RM+40% CS Waste replacements to cement and fine aggregate.

C. Effect of Replacement of Cement by Red mud and fine aggregate by Copper slag on Split strength of concrete

The above graph III indicates the split strength of concrete mixes with various replacements of cement by red mud (constant 15%) & fine aggregate by copper slag. The optimum strength gained after 7 and 28 days curing period is at 15%RM+40% Copper slag replacements to cement and fine aggregate.

VII. CONCLUSIONS

From this experimental study following points can be drawn:

- After testing cement mortar samples (5% to 30% replacement of Cement by Red Mud) with an increment of 5 %, it can be said that the optimum use of red mud (RM) is 15% as a partial replacement of cement by RM.
- The specimen with Red mud and Copper slag as waste material was found to be good in compression which has compressive strength of 16.84% more than that of conventional concrete after 28-days curing period.
- Better split tensile strength was achieved with the addition of Red mud and Copper slag as waste material in concrete. The strength has increased up to 22.44% when compared to that of the conventional concrete specimen after 28-days curing period.

- Considering all the above points it is interesting to say that the optimum utilization of Red Mud in mortar was found to be 15 % as a partial replacement of cement by RM.
- This study proves that the mechanical properties of the concrete are increased by addition of 15%RM+40%CS as an additive to concrete.

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