PARTIAL REPLACEMENT OF CEMENT IN MORTAR BY USING RED MUD AND RICE HUSK ASH

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Abstract—In the modern world of high competition and environmental awareness, it has become necessary to find an alternative materials that can be widely used. With a similar views in mind, in the present study, the red mud and rice husk ash are used in partial qunatitites with the cement in mortar. With the ambit of the mechanical strength of the cement, the compressive, tensile and flexure behavior of the mortar specimens are studied and presented. The parent objective of the present study is to suggest possible percentage of use of red mud and rice husk ash along with cement which will help to reduce the cement consumption in construction industry.

Index Terms- Cement, Red Mud, Rice Husk Ash, Mortar.

1 INTRODUCTION

In the world of rapid development and growing industrialization there has been significant awareness regarding the hazardous waste being produced. To dispose of these waste byproducts various new methodology are developed and used and the best of all is recycling. Mussels et al. (1993) presented a review to assess the feasibility of bioremediation of bauxite residue by making estimates of the possible substrate and inoculums required to achieve neutrality.

World consumption of cement is forecast to continue to increasing from last 15 years and there will be massive growth of cement demand in upcoming years. So it will be economically beneficial if reduction in the amount of cement by providing some alternate material from industrial waste which is hazardous to the environment.

In the present experimental study two industrial waste materials that is residual waste called as red mud which is from aluminum industry and other is rice husk ash from the paddy have been considered for cement replacement in mortar.

Bauxite is the world's primary source of aluminium. India ranks 5th in the world to have bauxite reserves. Red mud is the residue from the Bayer's process of alumina extraction from bauxite digestion with caustic soda leading to production of alumina (Al_2O_3). The composition of the Red Mud depends upon the type of bauxite and the processing used. For every ton of alumina extracted, around 1.2-1.4 tons of red mud is produced. Across the world, the amount of red mud produced is around 70 million tons while India alone produces 2 million tons. Red Mud, as a soild waste, is disposed in mud lakes in the forms of stack in ponds as dry mud or directly discharged into the water bodies through pipelines. The chemical analysis showed that red mud contains silica, aluminum, iron, calcium and several of other minor constituents. Due to its high alkalinity, ranging form pH 10–13, and its metal content it can lead to dust pollution and environmentaly pollution.

Rice husk is the protective covering part on the rice grains during its growth. These porous silica skeletons are removed during the refining of the rice which majorly constitute of silica (20%) and cellulose (40%). The rice husk ash contains 92-95% silica. With such high silica content it is economical to extract silica from the ash. Rice husk ash is obtained at 1000°C containing around 85%-90% amorphous silica, exhibiting excellent chemical properties. Also, it is highly porous and light weight in nature and high external surface area. In a major rice producing country like India, for every 1000 Kg of paddy milled, about 220 Kgs (22%) of rice husk is produced, which generated about 55 Kgs of RHA which is quite big quantity and displosal of this waste is again lead to environmental problems.

Due to chemical and physical properties of red mud and rice husk ash, it is reported in the literature that both waste materials can be used in construction and other industries.

Krishna et al. (2004) gave a report on bioremediation of red mud by using fungus (Aspergillustubingensis). Rout et al. (2012) has discussed the use of red mud as an alternative embankment material based on experimental results and finite element analysis. The geotechnical properties such as specific gravity, classification, compaction characteristics, triaxial shear strength and dispersion properties of red mud have been discussed. Dursun et al. (2006) used the red mud for phosphate removal from waste water. Bhaskar et al. (2014), Sawant et al. (2013) and Chen and Luan (2010) had taken efforts to use of processed red mud in the concrete construction.

In present experimental studies, both the waste materials are used as a paritial replacement for cement in mortar. Experimental methodology and discussion on the results have been presented in the following sections.

2 MATERIALS AND METHODOLOGY

In the present exprimental studies, Ordinary Portland cement (OPC) [Grade 53] confirming to I.S. 12269-1989 is used for mortar preparation. The specific gravity and fineness of used cement are found to be 3.15 and 2%, respectively during cement basic testing. Chemical composition of OPC used here is presented in Table 1.

Table 1: Chemical Composition of OPC

Compounds	In %
Al_2O_3	6.125
Fe_2O_3	3.620
SiO_2	23.694
CaO	61.992
Na_2O	1.042
K_2O	0.270

Aggregates used in experimental work is conformed to the IS650 (1991) [Grade I sand having particle size less than 2mm and greater than 1 mm, Grade II sand having particle size less than l mm and greater than 0.5mm and Grade III sand having particle size less than 0.5mm and greater than 0.09mm].

The red mud used in the experimental work is collected from HINADLCO, Belgaum, Karnataka and are used for partial replacement of cement in mortar. The percentage replacement of cement by red mud adopted in first phase of study are 5%, 10%, 15% and 20% of cement quantity. The chemical composition is obtained from the XRF analysis and depicted in Table 2. The moisture content accounted is 11.9% and the noted value of pH is 11.3 on the pH scale. The particle diameter of red mud ranged between 0.8 μm to 50 μm with an average value of 14.8 μm. From the fineness modulus test conducted on the red mud specimen, it is found to be 40% finer for 90 μm sieve. The level of radioactivity is observed to be extremely low. The setting time of cement and red mud gel is shown in Table 3.

Table 2: Chemical Composition of Red Mud

Compounds	In %
Al2O3	22.522
SiO2	19.497
Fe2O3	34.752
TiO2	3.58
Na2O	10.684
CaO	0.503

Table 3: Setting Time of Red Mud-Cement Gel

Cement (%)	Red Mud (%)	Initial Setting Time (minutes)	Final Setting Time (minutes)
100	0	104	232
95	5	99	220
90	10	96	213
85	15	105	237
80	20	109	260

The rice husk ash is super pozzolanic in nature which helps reduce the high cost of the concrete structure when replacing against the expensive binding material. The percentage replacement of cement by rice husk ash adopted in second phase of study are 5%, 10%, 15% and 20% of cement quantity. The chemical composition is obtained from the XRF analysis and tabulated in Table 4. The specific gravity of rice husk ash is observed to be 2.3. Also, bulk density of rice husk ash noted as 20 kg/m^3 with an average surface area of 36.47 m^2/g. The setting time of cement and rice husk ash gel is shown in Table 5.

Cement aggregate ratio 1:3 is used for mortar preparation. Standard consistency test confirming IS4031: Part 6 (1988) have been performed on cement paste to fix the appropriate water-cement (W/C) ratio and based on the test, W/C ratio 0.33 is used for control specimens (pure cement mortar spcimens). Similarly, standard consistency test have been performed on cement-red mud paste and cement-rice husk ash paste to fix the water-cementenious ratios. Based on test, W/C ratios used are 0.34, 0.36, 0.38 and 0.39 for 5%, 10%, 15% and 20% red mud replacement against cement and 0.33, 0.37, 0.39 and 0.41 for 5%, 10%, 15% and 20% rice husk ash replacement against cement.

Table 4: Chemical Composition of Rice Husk Ash

Compounds	In %
Silicon Oxide	72.850
Aluminum oxide	16.125
Iron Oxide	1.881
Calcium Oxide	1.089
Magnesium Oxide	0.5
Sodium Oxide	0.322
Potassium Oxide	1.263
Ignition Loss	3.56

Table 5: Setting Time of Rice Husk Ash-Cement Gel

Cement (%)	Rice Husk Ash (%)	Initial Setting Time (minutes)	Final Setting Time (minutes)
100	0	122	183
95	5	133	220
90	10	143	231
85	15	150	240
80	20	156	257

Cubes of size 70.7 mm X 70.7 mm X 70.7 mm have been prepared compression test and for flexural test, small beams of 300 mm length and 25 mm in width and depth have been prepared. Briquette moulds are used for samples preparation for tensile test. All specimens are cured for 3, 7 and 28 days. Compression testing have been done using 30T universal testing machine (UTM) under the gradual application of load at the controlled strain rate.

3 RESULTS AND DISCUSSION

The mechiancal properties includes compressive strength, tensile strength and flexural strength have been studied for all prepared samples and compared with the control specimens

at 3 days, 7 days and 28 days. All results in preceddding tables are reported is averge value of minimum three samples.

The comparison of compressive strength of cement-red mud mortar specimens for 3, 7 and 28 days with cement mortar control specimens have been presented in Table 6. The compressive strength of control specimen on 28 days from casting is 36.72 MPa. The cement-red mud mortar specimens showed compressive strength on 28 days from casting are 36.10 MPa, 34.33 MPa, 30.33 MPa and 25.25 MPa for 5%, 10%, 15% and 20% cement replacement with red mud, respectively. It is observed that as red mud percentage goes on increase, compressive strength of mortar cubes reduced due to probably less content of calcium oxide (CaO) and silica (SiO_2) in red mud as compared to OPC cement which are responsible for strength gain. However, in the literature, it is mentioned that rate of strength gain is slow in early days when red mud is used along with cement. Further, the comparison of tensile and flexure strength of cement-red mud mortar specimens for 3, 7 and 28 days with cement mortar control specimens have been depicted in Table 7 and Table 8, repectively. The tensile and flexural strength of control specimen on 28 days is 3.0 MPa and 7.15 MPa, respectively. It is observed that as red mud percentage goes on increase, both tensile and flexural strength of cement-red mud mortar cubes increase. From this phase of experimental studies, it is suggested that 10% red mud can be used along with cement for mortar with littile compromising in the compressive strength. However, durability and use of red mud in cement concrete research need to be highlighted.

Table 6: Compressive Strength (MPa) for Cememnt-Red Mud Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Comp. Strength (MPa)
Control Specimen	3	796	21.92
	7	802	27.40
	28	806	36.72
5 % Red Mud + Cement	3	810	19.45
	7	802	25.83
	28	788	36.10
10 % Red Mud + Cement	3	793	22.65
	7	795	24.96
	28	798	34.33
15 % Red Mud + Cement	3	801	24.06
	7	803	23.30
	28	802	30.33
20 % Red Mud + Cement	3	794	19.72
	7	793	20.54
	28	800	25.25

Table 7: Tensile Strength (MPa) for Cememnt-Red Mud Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Tensile Strength (MPa)
Control Specimen	3	160	1.65
	7	160	2.60
	28	162	3.00
5 % Red Mud + Cement	3	158	1.83
	7	160	2.81
	28	156	3.19
10 % Red Mud + Cement	3	160	1.93
	7	162	2.83
	28	161	3.43
15 % Red Mud + Cement	3	158	2.19
	7	159	2.66
	28	160	3.51
20 % Red Mud + Cement	3	160	2.24
	7	156	3.03
	28	157	3.66

Table 8: Flexural Strength (MPa) for Cememnt-Red Mud Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Flexural Strength (MPa)
Control Specimen	3	420	4.12
	7	434	6.01
	28	426	7.15
5 % Red Mud + Cement	3	428	4.79
	7	412	6.29
	28	420	7.43
10 % Red Mud + Cement	3	422	4.84
	7	424	6.50
	28	425	7.69
15 % Red Mud + Cement	3	433	5.18
	7	426	6.64
	28	422	7.73
20 % Red Mud + Cement	3	419	5.50
	7	420	6.89
	28	423	8.03

The comparison of compressive strength of cement-rice husk ash mortar specimens for 3, 7 and 28 days with cement mortar control specimens have been presented in Table 9. The compressive strength of control specimen on 28 days from casting is 36.72 MPa. The cement-rice husk ash mortar specimens showed compressive strength on 28 days from casting are 35.50 MPa, 35.33 MPa, 35.22 MPa and 35.58 MPa for 5%, 10%, 15% and 20% cement replacement with rice husk ash, respectively. It is also observed here that as rice husk ash percentage goes on increase, compressive strength of mortar cubes reduced. However, rate of decrease in compressive strength compared to cement-red mud mortar specimen is less. The comparison of tensile and flexure strength of cement-rice husk ash mortar specimens for 3, 7 and 28 days with cement mortar control specimens have been depicted in Table 10 and Table 11, repectively. It is observed that use of rice husk ash with cement in mortar reduced both tensile and flexural strength.

Table 9: Compressive Strength (MPa) for Cememnt-Rice Husk Ash Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Comp. Strength (MPa)
Control Specimen	3	796	21.92
	7	802	27.40
	28	806	36.72
5 % Red Mud + Cement	3	810	21.96
	7	802	23.12
	28	788	35.50
10 % Red Mud + Cement	3	793	23.30
	7	795	26.61
	28	798	35.33
15 % Red Mud + Cement	3	801	19.79
	7	803	27.14
	28	804	35.20
20 % Red Mud + Cement	3	794	18.5
	7	793	27.12
	28	801	35.58

Table 10: Tensile Strength (MPa) for Cememnt- Rice Husk Ash Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Tensile Strength (MPa)
Control Specimen	3	160	1.65
	7	160	2.60
	28	162	3.00
5 % Red Mud + Cement	3	155	1.52
	7	157	2.40
	28	160	2.94
10 % Red Mud + Cement	3	159	1.47
	7	160	2.30
	28	156	2.85
15 % Red Mud + Cement	3	156	1.33
	7	162	2.32
	28	158	2.55
20 % Red Mud + Cement	3	162	1.18
	7	157	2.17
	28	158	2.43

Table 11: Flexural Strength (MPa) for Cememnt-Rice Huck Ash Mortar Specimens

Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. Flexural Strength (MPa)
Control Specimen	3	420	4.12
	7	434	6.01
	28	426	7.15
5 % Red Mud + Cement	3	410	3.98
	7	420	5.86
	28	423	6.64
10 % Red Mud + Cement	3	422	3.67
	7	423	5.72
	28	426	6.41
15 % Red Mud + Cement	3	425	3.22
	7	422	5.39
	28	418	6.2
20 % Red Mud + Cement	3	426	3.12
	7	423	5.18
	28	428	5.79

3 CONCLUDING REMARKS

In the present experimental studies, effort has been put to check the feasibility of use of red mud and rice husk ash in cement mortar. It is observed that 10% replacement of the red mud for cement is possible from compressive, tensile and flexural strength point of view with a littile compromising in compressive strength. However, from compressive strength point of view, rice husk ash is best alternative materials for replacement of cement in moratar and can be used upto 10% to 15 %. Morever, tensile and flexural strength reduced to some extent even for 5% rice husk quantity. Further, research is required to address the issues like, corrosion, durability of cement product along with red mud and rice husk ash.