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Investigating the durability of self-compacted Concrete for Underwater and Tunnel structures

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Abstract

Concrete is one of the versatile construction materials which are used worldwide. Self-Compacting Concrete is a type of concrete which is capable of flowing into the form work uniformly, without segregation and bleeding, better finishes, easier placement, thinner concrete sections, no vibration, safer working environment without any application of vibration. Self-compacting concrete (SCC), which flows under its own weight and doesn't require any external vibration for compaction, has revolutionized concrete placement. The research was carried out to find weather Red mud and foundry sand can be used for construction purpose fulfilling the requirement of Self-compacted concrete, foundry sand and Red mud being waste products where therefore used for ecofriendly construction purpose, such concrete have relatively low yield value to ensure high flow ability, a moderate viscosity to resists segregation and bleeding and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. In this research the cement was replaced by red mud in the ratio of 10% to 50% and sand was replaced by foundry sand in the ratio of 10% to 50%, water cement ratio of 0.48 was maintained. Nominal mix design was chosen for the research purpose, compressive strength test and Splitting tensile strength test were performed, it was found that on replacing both foundry sand and red mud by 20% the result showed maximum increase in compressive strength and split tensile i.e. 17.84% and 23.04% Respectively after 90 days of curing, the results were satisfactory when compared to conventional concrete.

Keywords: Compressive Strength, Durability, Foundry Sand, Red Mud, Tensile Strength.

1. Introduction

Self-compacting concrete represents one of the most significant advances in concrete technology for decades. This concrete is able to flow and to fill the most restricted places of the framework without vibration. An idea of self-compacting concrete, a material that flows, that is placed into framework and compacted under influence of self-weight only, without vibration and additional processing emerged. As the durability of concrete structures became an important issue in japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. The concept of self-compacting concrete was purposed in 1986 by Professor Hajime Okamura (1997) and the prototype of self-compacting concrete.To increase the strength parameters of Self-compacted concrete various approach are being made by bisecting concrete proportion and replacing the concrete constituents in different proportion. By replacing cement by 30%, 35% and 40% fly ash and 15% red mud after neutralization the concrete with 35% fly ash and 15% RM neutralized give optimum compressive strength (Shendure*et al*; 2015). a study on self-compacting concrete (SCC) using red mud as partial replacement for cementations material along with iron tailings as partial replacement for sand. Cementations material in the mixture was replaced with red mud at 1%, 2%, 3% and 4%. For each red mud replacement level, 10% of fine aggregate (regular sand) was replaced with iron tailings and strength of specimens were accounted for 28 days, The tensile strength achieved for 2% Red Mud with 10% iron tailings is more compared to other mixes and is Increased by 1.5%.The maximum flexural strength was achieved at 2% red mud with 10% iron tailings. The flexural strength increased by 6.42 % at for this mix.(Kiran*et al*.; 2014). Early self-compacting concretes relied on very high contents of cement paste and, once super plasticizers became available, were added in concrete mixes. The mixes required specialized and well controlled placing methods in order to avoid segregation, and high contents of cement paste made them prone to shrinkage. A research evaluated the feasibility of incorporating red mud as a partial replacement for Portland cement into a controlled low-strength material (CLSM) made by industrial by-products (e.g., ponded ash and fly ash). Red mud was substituted for Portland cement in amounts of 5, 10, 15, 20, 25, and 30 % by weight (Tan Manh Do and Young-sang Kim ;2016). Bricks made of red mud can be used as light weight construction materials (Garg et al.;2015). The introduction of modern self-leveling concrete or self-compacting concrete is associated with the drive towards better quality concrete pursued in japan around 1983, where the lack of uniform and complete compaction had been identified as the primary factor responsible for the poor performance of concrete structures.

1.2 Need of Self- compacted concrete

The properties, such as, fluidity and high resistance to segregation enables the placement of concrete without vibrations and with reduced labor, noise and much less wear and tear of equipment. Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period. Self-compacting concrete is growing rapidly, especially in the precast market where its advantages are rapidly understood and utilized. Super plasticizer enhances deformability and with the reduction of water/powder segregation resistance is increased. High deformability and high segregation resistance is obtained by limiting the amount of coarse aggregate. However, the high dosage of super-plasticizer used for reduction of the liquid limit and for better workability, the high powder content as 'lubricant' for the coarse aggregates, as well as the use of viscosity-agents to increase the viscosity of the concrete have to be taken into account.

1.3 Objectives of the study

Even though extensive work is reported on SCC, not much work is reported on the behavior of SCC with red mud and foundry sand as admixtures. Keeping this in view, the present experimental investigation is taken up to study the behavior of replacement of cement with the red mud and replacement of sand with the foundry sand in different proportion of concrete mixes. The main aim is to obtain specific experimental data, to understand fresh and hardened properties of self-compacting concrete with red mud and foundry sand. Further it is also aimed to study durability aspects of admixtures. Broadly the main aim of the present investigation of SCC with red mud and foundry sand are:

1. To study fresh properties of SCC in addition with red mud and foundry sand.
2. To study the compressive strength and split tensile strength of SCC.

2. Materials and Methodology

2.1 Materials; Materials used are shows in table 1

Table 1 materials used

No.	Materials Used
1	Cement OPC grade 43
2	Coarse Aggregate
3	Fine Aggregate
4	Foundry Sand
5	Red mud
6	Water

2.2 Methodology

The selection of mix materials and their required proportion was done through a process called mix design. There are number of methods for determining concrete mix design. The methods used in India are in compliance with the BIS (Bureau of Indian Standards). The objective of concrete mix design is to find the proportion in which concrete ingredients-cement, water, fine aggregate and coarse aggregate should be combined in order to provide the specified strength, workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2000. The specification of a concrete mix must therefore define the materials and strength, workability and durability to be attained. IS: 10262-1982 gives the guidelines for concrete mix designs. In this study, six batches of mixes were determined. The mixes was taken with (1:1.52:2.8, w/c=0.48) .The cement was replaced by red mud in the ratio of 10% to 50% and sand was replaced by foundry sand in the ratio of 10% to 50%. The properties such as compressive strength, Tensile strength..Sequential concreting process was followed as mentioned bellow:

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2.3 Batching:

Accurate batching of the materials was done using an electronic weight balance to cast 9 cubes in a mould of 150mm×150mm×150mm using bacteria and 3 cubes using conventional practice.

2.4 Casting of Specimens:

The mix types chosen were 1:1.52:2.8, w/c=0.48. The concrete mix was prepared using 10 mm & 20 mm coarse aggregates. Mix with equal amount of natural coarse aggregate i.e. equal weights of both red mud and foundry sand (10% - 50% each) were prepared and used to cast the specimens.

In all the above mixes workability was measured by slump test, compaction factor test and flow table test. The test specimens were 150mm x 150mm cubes for compressive strength. The specimens were cast according to IS: 516-1959. The specimens were tested at the age of 7, 28 and 90 days. The test procedures were followed as per relevant Indian standard specifications. The batching was done by weight.

Table 3.7 Size of Molds

S. No.	Moulds	Size (mm x mm)	No. of Specimen Casted
1.	Cube	150x150x150	63

2.5 Mixing and Compaction:

The component materials were weighted on the weighting machine. The mixing was done manually. Cement, aggregates, red mud, foundry sand and admixtures were thoroughly mixed in dry condition to get the homogeneous mix. Water was then added slowly to get a uniform mix. The mixing time was in the range of 4-5 minutes for all the mixes. Cast iron moulds were used for casting specimens. The specimens were cast according to IS: 516-1959. The compaction was done by vibrating the moulds for about 2 minutes using the table vibrator. Excess material was struck off using a rod. Top surface was given smooth finish using suitable floats and trowel. The concrete specimens were removed from the moulds after 24 hours. Specimens were kept in clean and fresh water for curing in water tanks and cured till testing. The cubes were tested at the age of 7, 28 and 90 days.

Fig 1. Mixing

2.6 Curing:

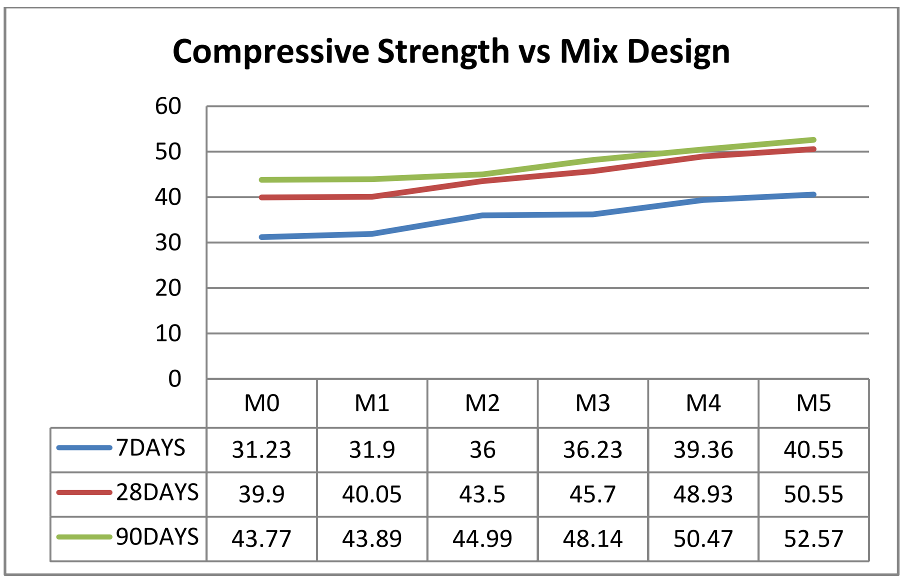
The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. From the time addition of water to the dry ingredients. After this period the specimen should be marked and removed from the moulds and immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to the test. The water or solution in which the specimen s are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.

3. Tests and Results

3.1 Compressive Strength Test:

3.2 Compressive strength vs. Mix Design of replaced foundry sand for 7, 28 and 90 days

Compressive strength of foundry sand was found higher than ordinary cement. 50 % replacement of sand by sand by foundry sand sample has compressive strength 40.55 MPa for 7 days curing , 50.12 MPa for 28 curing and 52.37 MPa for 90 curing samples whereas compressive strength of ordinary Portland concrete is 31.98 MPa,39.83 MPa and 43.44 MPa for 7, 28 and 90 days curing sample respectively. The maximum value of compressive strength was achieved by the sample of 50% (foundry sand) +50 % (natural sand) samples.



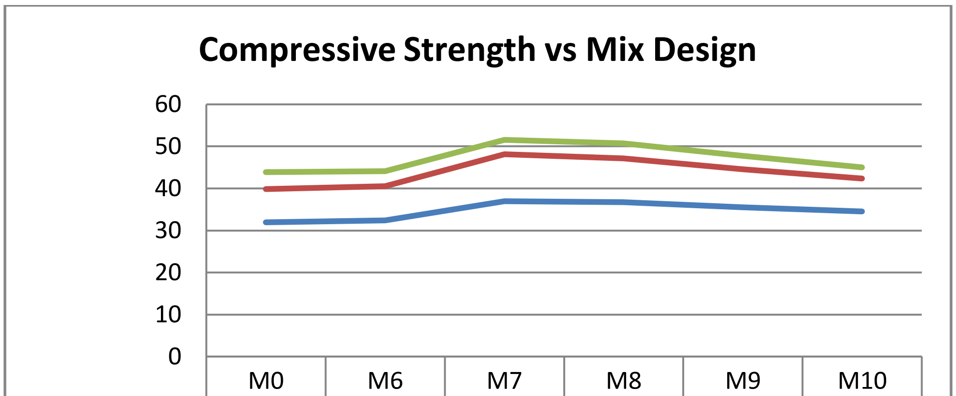
	M0	M1	M2	M3	M4	M5
7DAYS	31.23	31.9	36	36.23	39.36	40.55
28DAYS	39.9	40.05	43.5	45.7	48.93	50.55
90DAYS	43.77	43.89	44.99	48.14	50.47	52.57

Fig. 2 Compressive strength vs. Mix Design of replaced foundry sand for 7, 28 and 90 days

W/C=0.48

3.3 Compressive strength vs. Mix Design of replaced red mud for 7, 28 and 90 days:

Compressive strength of cement replaced by red mud with different proportions at 7, 28 and 90 days curing samples, the compressive strength of 100% ordinary cement is 31.98 MPa for 7 days curing, 39.83 MPa for 28 curing and 43.44 MPa for 90 curing samples where as higher compressive strength was achieved by replacing cement by 20% red mud and compressive strength was increased 16.13%, 20.88% and 17.84% after 7, 28 and days curing samples. The compressive strength of the samples is 37.14 MPa, 48.15MPa and 51.19 MPa for 7, 28 and 90 days curing sample respectively. The maximum value of compressive strength was achieved by the sample of 80% (Ordinary Portland cement) +20 % (red mud) samples.

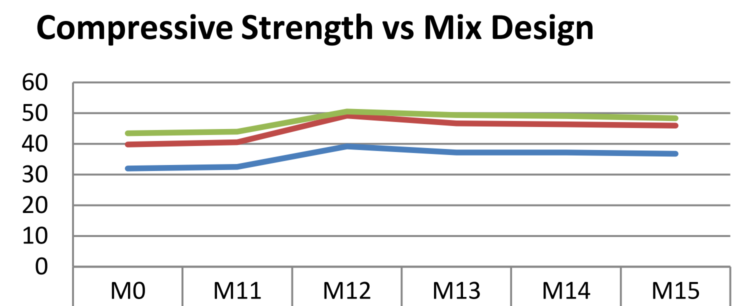


	M0	M6	M7	M8	M9	M10
7DAYS	31.99	32.48	36.98	36.78	35.57	34.59
28DAYS	39.83	40.48	48.15	47.16	44.56	42.34
90DAYS	43.88	44.07	51.54	50.73	47.71	44.98

Fig.3 Compressive strength vs. Mix Design of replaced red mud for 7, 28 and 90 days W/C=0.48

3.4 Compressive strength vs. Mix Design of replaced red mud and foundry sand for 7, 28and 90 days:

Compressive strength of red mud is higher than ordinary cement. 20 % replacement of cement by red mud and 20 % sand by foundry sand sample has Compressive strength 39.15 MPa for 7 days curing, 49.17 MPa for 28 days and 50.46 MPa for 90 days curing, curing samples whereas Compressive strength of natural sand and cement is 31.98 MPa, 39.83 MPa and 43.44MPa for 7,28 and 90 days curing sample respectively



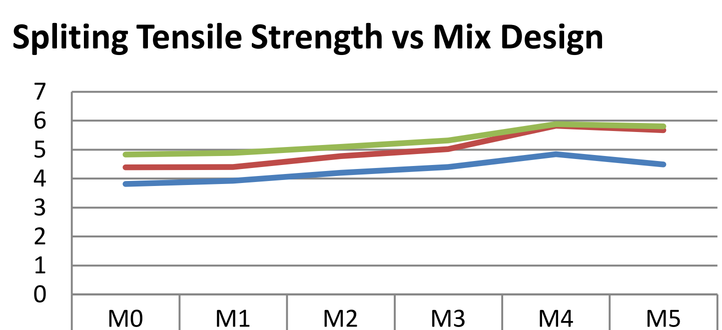
	M0	M11	M12	M13	M14	M15
7DAYS	32	32.48	39.17	37.23	37.17	36.79
28DAYS	39.76	40.5	49.12	46.67	46.29	45.93
90DAYS	43.44	43.96	50.46	49.37	49.03	48.31

Fig.4 Compressive strength vs. Mix Design of replaced red mud and foundry sand for 7, 28and 90 days

4. Splitting Tensile strength

4.1 Variation of splitting tensile Strength for replaced foundry sand of 7 days:

Splitting tensile Strength of foundry sand is higher than ordinary cement. 50 % replacement of sand by sand by foundry sand sample has Splitting tensile Strength 4.47 MPa for 7 days curing , 5.67 MPa for 28 days curing and 5.82 MPa for 90 days curing samples whereas Splitting tensile Strength of ordinary Portland concrete is 3.81 MPa, 4.38 MPa and 4.82 MPa for 7, 28 and 90 days curing sample respectively. The maximum value of Splitting tensile Strength was achieved by the sample of 50% (foundry sand) +50 % (natural sand) samples.



	M0	M1	M2	M3	M4	M5
7DAYS	3.82	3.93	4.2	4.4	4.84	4.49
28DAYS	4.39	4.4	4.78	5.02	5.83	5.68
90DAYS	4.83	4.89	5.09	5.32	5.88	5.8

Fig.5 splitting tensile Strength vs. Mix Design of replaced foundry sand for 7, 28 and 90 days

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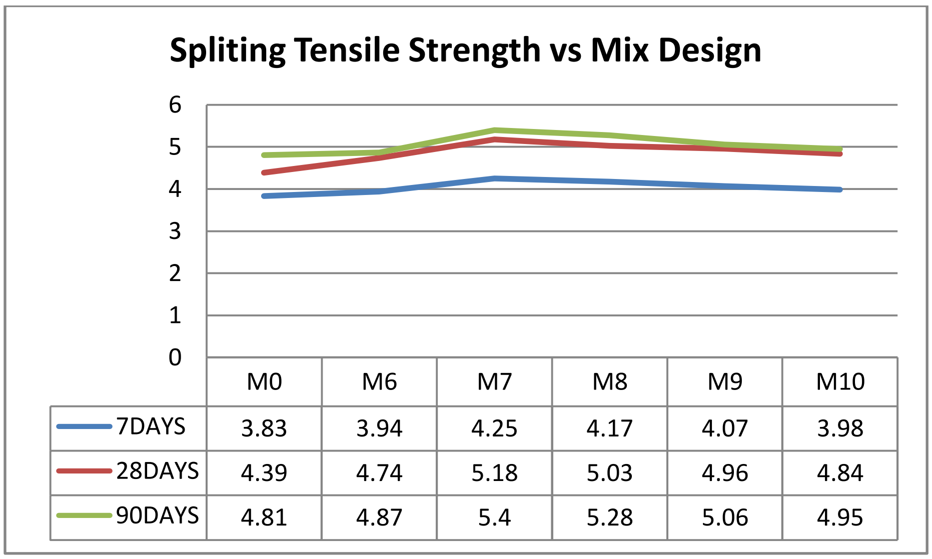
4.2 Splitting tensile Strength vs. Mix Design of cement replaced by red mud for 7, 28 and 90 days:

Splitting tensile Strengthof cement replaced by red mud is higher than ordinary cement. 20 % replacement of cement by red mud sample has Splitting tensile Strength4.2 MPa for 7 days curing , 5.16 MPa for 28 days curing and 5.39 MPa for 90 days curing samples whereas Splitting tensile Strengthof ordinary Portland concrete is 3.81 MPa, 4.38 MPa and 4.82 MPa for 7, 28 and 90 days curing sample respectively. The maximum value of splitting tensile Strengthwas achieved by the sample of 20% (red mud) +80 % (cement) samples.

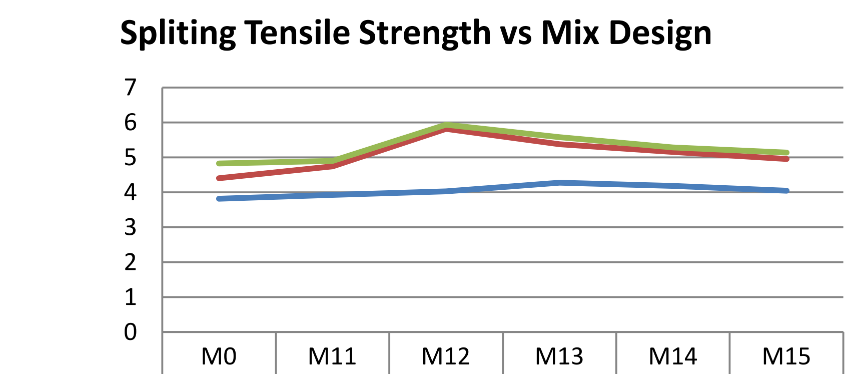


	M0	M6	M7	M8	M9	M10
7DAYS	3.83	3.94	4.25	4.17	4.07	3.98
28DAYS	4.39	4.74	5.18	5.03	4.96	4.84
90DAYS	4.81	4.87	5.4	5.28	5.06	4.95

Fig.6 splitting tensile Strength vs. Mix Design of cement replaced by red mud for 7, 28 and 90 days

4.4 Splitting tensile Strength vs. Mix Design of replaced red mud and foundry sand for 7,28 and 90 days:

Splitting tensile strength of red mud is higher than ordinary cement. 20 % replacement of cement by red mud and 20 % sand by foundry sand sample has splitting tensile strength 4.3 MPa for 7 days curing, 5.81 MPa for 28 days and 5.93 MPa for 90 days curing samples whereas splitting tensile strength of natural sand and cement is 3.81 MPa, 4.38 MPa and 4.82 MPa for 7, 28 and 90 days curing sample respectively.



	M0	M11	M12	M13	M14	M15
7DAYS	3.82	3.93	4.03	4.28	4.19	4.05
28DAYS	4.4	4.74	5.82	5.38	5.16	4.95
90DAYS	4.83	4.9	5.94	5.58	5.29	5.14

Splitting tensile Strength vs. Mix Design of replaced red mud and foundry sand for 7,28 and 90 days

5. Interpretation

1. Compressive strength of self-compacting concrete of 20 % replacement of cement by red mud is more than ordinary cement specimens. The compressive strength increases 16.13 % for 7 days curing and 20.88 % for 28 days curing and 17.84% for 90 days curing sample.

2. The splitting tensile strength of red mud (20%) is higher than ordinary cement. 20 % replacement of cement by red mud and 20 % sand by foundry sand sample has splitting tensile strength increased 12.85% for 7 days curing , 32.64% for 28 days and 23.03% for 90 days curing.

6. Scope of the Future Study

The strength characteristics of red mud and foundry sand concrete can be further studied by taking into account the following parameters:

1. Instead of using deformed steel bars mild steel bars can also be used.
2. Using rusted (deformed or mild steel) bars in place of non-rusted steel bars.
3. Using fiber concrete in place of plain concrete.
4. Using different diameter of bars such as 12mm, 16mm etc. for calculating bond strength using pull-out test.
5. Using different grades of cement i.e. 33 and 53 grade.
6. With different type and grading of sand.
7. Varying the mix proportion and water cement ratio. .
8. Use of retarding and water reducing admixtures.

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Conclusion

- Research on the usage of waste materials is very important because material waste is gradually increasing with the increase in population and increase in urban development. Red mud and foundry sand is easy to obtain and decrease the cost. Red mud and foundry sand can be therefore used in the high concrete structural concrete.
- Economical and environmental pressures justify consideration of this alternative material source i.e. red mud, foundry sand in places where there availability it decrease the cement and sand cost.
- It can be said that it is a creative and environment friendly solution to used mud and waste foundry sand.

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