# EFFECT OF RED MUD AND IRON ORE TAILINGS ON THE STRENGTH OF SELF-COMPACTING CONCRETE

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**Abstract**

The current trend all over the world is to utilize the treated and untreated industrial by-products as a raw material in concrete, which gives an eco-friendly edge to the concrete preparation process. This practice not only helps in reuse of the waste material but also creates a cleaner and greener environment.This study aims to focus on strength aspects of Self-compacting concrete (SCC) which has been prepared by partially replacing cementitiousmaterial by red mud (RM) and in the same mix, partially replacing sand by Iron Ore Tailings(IOT). Cementitious material in the SCC mixture was replaced with RM at 1%, 2%, 3% and 4%. For each RM replacement level, 10%, 20%, 30%, 40% of fine aggregate (regular sand) was replaced with IOT.

**Keywords:** Self- compacting concrete, Iron Ore Tailings, Red Mud

## Introduction

Self-compacting concrete (SCC) is an innovative concrete which can be placed and compacted under its own weight with little or no vibration effect and at the same time cohesive enough to be handled without segregation or bleeding.Adoption of SCC offers substantial benefits in enhancing construction productivity, reducing overall cost, and improving work environment. Cost reduction in the building is the primary objective in developing countries like India. To achieve this objective, intensive efforts are being made in effective utilization of industrial by-products particularly from mining and mineral industries.

Ullas et al., (2010) did experimental study on masonry units made of Iron ore tailings in compressed earth block (CEB). In that they used optimum mix proportions of soil, sand, cement and the sand fraction is replaced by IOT at 25%, 50% and 100%. They checked block characteristics like wet compressive strength, water absorption, initial rate of absorption, linear elongation and they found that considerable amount of sand can be replaced by IOT without compromising desirable characteristics of CEB.Sujing et al., (2013) studied the possibility of using Iron ore tailings to replace natural aggregate to prepare ultra - high performance concrete (UHPC). It was found that the 100% replacement of natural aggregate by Iron ore tailings significantly replaced the workability and compressive strength of material. However when the replacement level was not more than 40%, for 90 days standard cured specimens, the mechanical behavior of the tailings was comparable to that of control mix and for specimens that were steam cured for 2 days, the compressive strengths of the tailing mixes decreased by 11% while the flexural strength increased by up to 8% compared to the control mix. Xiaoyan Huang et al., (2013) used an attempt to use Iron ore tailings to develop greener engineered cementious composites (ECCs). He found that, with cement content 117.2 - 350.2 kg/m$^3$, exhibit a tensile ductility of 2.3 - 3.3%, tensile strength of 5.1 - 6 MPa and compressive strength of 46 - 57 MPa at 28 days.MangalpadyAruna (2012) mentioned in his paper that the composition of tailings is directly dependent on the composition of the ore and the process of mineral extraction used on the ore. He studied the suitability and reliability of Iron ore tailings in manufacture of Paving Blocks. He prepared five reference mixes using cement, jelly dust and baby jelly with different mix ratios and by using sand and Iron ore tailings as fine aggregates. The results of his study showed that compressive strength of tailing based mix was higher than the respective reference mix.MohanKushwaha et al. (2013), have reported that the use of red mud as an admixture up to 2% will improve the compressive strength and if over 2% of red mud is added then the strength starts decreasing.

In this paper self-compacting concrete is prepared by partially replacing cementitious material by red mud (RM) and in the same mix partially replacing sand by iron ore tailings. Cementitious material in the mixture was replaced with red mud at 1%, 2%, 3% and 4%. For each red mud replacement level, 10%, 20%, 30%, 40% of fine aggregate (regular sand) was replaced with Iron Ore Tailings.

## Materials

### Cement

Ordinary Portland cement (43 grade) was used in this study. The cement was tested according to IS: 8112-1989. The specific gravity was found to be 3.1.

### Fly Ash

The fly ash used in this study was obtained from Raichur Thermal Power Plant Station (RTPS). As the fly ash produced by Raichur Thermal Power Plant Station (RTPS) contain less carbon content and are extremely finer than any other source. This enable to study the SCC mixes containing fly ash incorporation. The specific gravity was found to be 2.23.

### Red Mud (RM)

Red mud is a waste material generated by the Bayer process widely used to produce alumina from bauxite. In the Bayer process, the insoluble product generated after bauxite digestion with sodium hydroxide at elevated temperature and pressure to produce alumina is known as red mud or bauxite residue. The waste product derives its color and name from its iron oxide content. The red mud used in this study was obtained from Hindalco Industries Limited, Belgaum, and Karnataka. The red mud used in this study was sieved through 600µ sieve. The specific gravity was found to be 2.807.

### Fine aggregate

Natural river sand with maximum size of 4.75mm was used in this study. The specific gravity was found to be 2.64.

### Iron Ore Tailings

Iron ore tailings are the materials left over after the beneficiation process of separating the valuable fraction from the worthless fraction of an iron ore. The various processes of beneficiation are crushing, screening, grinding, washing, jigging, cycloning, using magnetic separator etc. Even though left over iron ore tailing contains 20-30% of iron, further extraction from it will be costly. The composition of tailings is directly dependent on the composition of the ore and the process of mineral extraction used on the ore. Its specific gravity is found to be 3.24.

### Coarse aggregate

SCC can be made from most normal concreting aggregates. Coarse aggregates differ in nature and shape depending on their extraction and production. SCC has been produced successfully with coarse aggregates up to 40 mm, however these trials are made keeping maximum aggregate size of

12 mm. The coarse aggregates, obtained from a local source, had a specific gravity of 2.65. The size fraction of the coarse aggregate used is extremely important for determining the optimum amount of paste content to obtain all the necessary characteristics of a flowing concrete. The fine and coarse aggregates were tested according to IS: 383-1970.

**Admixture**

Admixtures are essential in determining flow characteristics and workability retention. Ideally, they should also modify the viscosity to increase cohesion. Newly developed types of super plasticizer, known as Poly-Carboxylate Ethers (PCE), are particularly relevant to SCC. They reconcile the apparently conflicting requirements of flow and cohesion, avoiding potential problems and unwanted retardation and excessive air entrainment, particularly at higher workability if the mix design is correct. The admixture used in the current program was Algihyperplast N supplied by ALGI. ALGIHYPERPLAST-N is powerful Naphthalene based super plasticizer recommended of site mixed concrete or for concrete which requires high early strength or where concrete is placed within half an hour of mixing.

**Mix Proportioning**

In this study 17 concrete mix proportions were made (Table1 and Table 2). The first mix was a controlled mix (without red mud and IOT) and the remaining 16 mixtures contained red mud and IOT. The controlled SCC mix was designed for M25 grade. EFNARC guidelines were followed to design the SCC mix. Cementitious material in the mixture was replaced with red mud at 1%, 2%, 3% and 4%. For each red mud replacement level, 10%, 20%, 30% and 40% of fine aggregate (regular sand) was replaced with Iron Ore Tailings (IOT).

Table-1 SCC mix designation

| Mix Designation | Description |
|---|---|
| NSCC | SCC without red mud and iron ore tailings |
| 1RM10IOT | 1% red mud + 10% iron ore tailings |
| 2RM10IOT | 2% red mud + 10% iron ore tailings |
| 3RM10IOT | 3% red mud + 10% iron ore tailings |
| 4RM10IOT | 4% red mud + 10% iron ore tailings |
| 1RM20IOT | 1% red mud + 20% iron ore tailings |
| 2RM20IOT | 2% red mud + 20% iron ore tailings |
| 3RM20IOT | 3% red mud + 20% iron ore tailings |
| 4RM20IOT | 4% red mud + 20% iron ore tailings |
| 1RM30IOT | 1% red mud + 30% iron ore tailings |
| 2RM30IOT | 2% red mud + 30% iron ore tailings |
| 3RM30IOT | 3% red mud + 30% iron ore tailings |
| 4RM30IOT | 4% red mud + 30% iron ore tailings |
| 1RM40IOT | 1% red mud + 40% iron ore tailings |
| 2RM40IOT | 2% red mud + 40% iron ore tailings |
| 3RM40IOT | 3% red mud + 40% iron ore tailings |
| 4RM40IOT | 4% red mud + 40% iron ore tailings |

| Trail. No | Cement (kg/m$^3$) | Fly ash (kg/m$^3$) | RM (kg/m$^3$) | IOT (kg/m$^3$) | Water (kg/m$^3$) | W/C | FA (kg/m$^3$) | CA (kg/m$^3$) | SP (l/m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| NSCC | 367.5 | 332.5 | 0 | 0 | 212.8 | 0.304 | 632.35 | 689.05 | 3.59 |
| IRM10IOT | 365.66 | 330.83 | 7 | 63.23 | 212.8 | 0.304 | 569.11 | 702.89 | 3.59 |
| 2RM10IOT | 363.82 | 329.17 | 14 | 63.23 | 212.8 | 0.304 | 569.11 | 703.14 | 3.59 |
| 3RM10IOT | 361.98 | 327.51 | 21 | 63.23 | 212.8 | 0.304 | 569.11 | 703.37 | 3.59 |
| 4RM10IOT | 360.15 | 325.85 | 28 | 63.23 | 212.8 | 0.304 | 569.11 | 703.61 | 3.59 |
| 1RM20IOT | 365.66 | 330.83 | 7 | 126.47 | 212.8 | 0.304 | 505.88 | 714.63 | 3.59 |
| 2RM20IOT | 363.82 | 329.17 | 14 | 126.47 | 212.8 | 0.304 | 505.88 | 714.89 | 3.59 |
| 3RM20IOT | 361.98 | 327.51 | 21 | 126.47 | 212.8 | 0.304 | 505.88 | 715.14 | 3.59 |
| 4RM20IOT | 360.15 | 325.85 | 28 | 126.47 | 212.8 | 0.304 | 505.88 | 715.41 | 3.59 |
| 1RM30IOT | 365.66 | 330.83 | 7 | 189.70 | 212.8 | 0.304 | 442.64 | 726.25 | 3.59 |
| 2RM30IOT | 363.82 | 329.17 | 14 | 189.70 | 212.8 | 0.304 | 442.64 | 726.65 | 3.59 |
| 3RM30IOT | 361.98 | 327.51 | 21 | 189.70 | 212.8 | 0.304 | 442.64 | 726.90 | 3.59 |
| 4RM30IOT | 360.15 | 325.85 | 28 | 189.70 | 212.8 | 0.304 | 442.64 | 727.14 | 3.59 |
| 1RM40IOT | 365.66 | 330.83 | 7 | 252.94 | 212.8 | 0.304 | 379.41 | 738.14 | 3.59 |
| 2RM40IOT | 363.82 | 329.17 | 14 | 252.94 | 212.8 | 0.304 | 379.41 | 738.39 | 3.59 |
| 3RM40IOT | 361.98 | 327.51 | 21 | 252.94 | 212.8 | 0.304 | 379.41 | 738.65 | 3.59 |
| 4RM40IOT | 360.15 | 325.85 | 28 | 252.94 | 212.8 | 0.304 | 379.41 | 738.88 | 3.59 |

Table – 2: Concrete mixture proportions

**Preparation and casting of specimens**

150 × 150 × 150 mm cubes were casted for compressive strength. For split tensile strength 150 × 300 mm cylinders were casted. For the flexural strength beams of 100 × 100 × 500 mm were casted. After casting, all the test specimens were kept at room temperature for 24 hours and then demoulded. These were then placed in the water curing tank**.**

**Properties of fresh concrete**

The properties of fresh concrete such as slump, passing ability, filling ability and segregation resistance were determined according to EFNARC specifications. The tests carried out to determine these properties were slump flow test, L – box test and V – funnel test. The results were found to be within the EFNARC permissible limits (Table3).

Table-3: Properties of SCC mix proportions

| Mix | V-funnel (seconds) | Slump flow (mm) | L-box (mm) |
|---|---|---|---|
| NSCC | 9.5 | 750 | 0.82 |
| 1RM10IOT | 9.3 | 758 | 0.82 |
| 2RM10IOT | 9.3 | 762 | 0.83 |
| 3RM10IOT | 9.2 | 764 | 0.84 |
| 4RM10IOT | 9.2 | 770 | 0.84 |
| 1RM20IOT | 8.1 | 772 | 0.86 |
| 2RM20IOT | 8.2 | 772 | 0.86 |
| 3RM20IOT | 8.3 | 778 | 0.86 |
| 4RM20IOT | 8.3 | 782 | 0.88 |
| 1RM30IOT | 8.1 | 783 | 0.89 |
| 2RM30IOT | 8.0 | 784 | 0.91 |
| 3RM30IOT | 7.8 | 786 | 0.91 |
| 4RM30IOT | 7.6 | 787 | 0.92 |
| 1RM40IOT | 7.5 | 791 | 0.94 |
| 2RM40IOT | 7.5 | 793 | 0.95 |
| 3RM40IOT | 7.4 | 793 | 0.96 |
| 4RM40IOT | 7.4 | 797 | 0.96 |

**Properties of hardened concrete**

The compressive strength tests on the cubes were performed at ages 7 and 28 days. The split tensile tests on cylinders and the flexural strength tests on beams were performed at 28 days. All tests were performed in accordance with the provisions of IS: 516-1959.

**Results and discussion**

**Compressive Strength**

The concrete mixtures were made with the controlled mix as well as with RM and IOT to check the compressive strength for 7 and 28 days of curing (Fig. 1 and Fig.2).Every mix which had been replaced withRM and IOT achieved higher strengths than the normal SCC mix.At 28-days, the control mixture NSCC (0% RM, 0% IOT) achieved a compressive strength of 32.8 MPa. The mix with 2% RM along with 30% IOT achieved the highest strengths. The mixes which had 2% RM had relatively higher strengths compared to other mixes at 28 days.

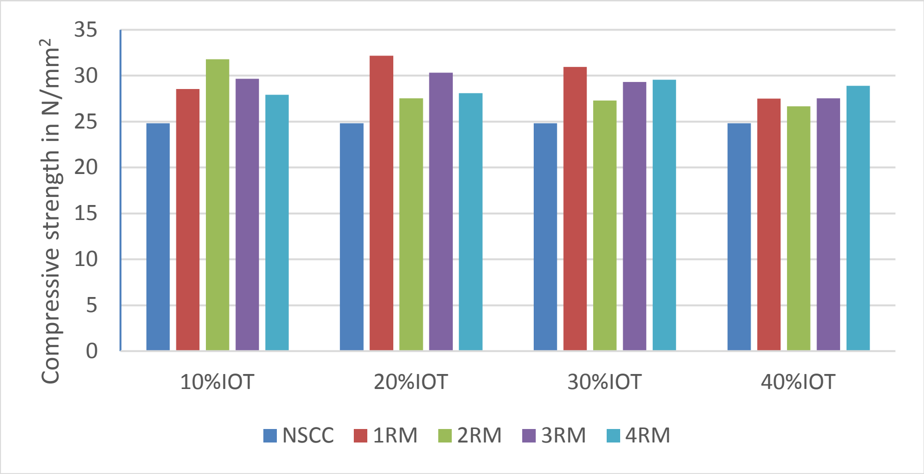


**Fig 1**.7 Dayscompressive strength of SCC mix proportions


**Fig 2**. 28 Days compressive strength of SCC mix proportions

**Split Tensile strength**

At 28-days, the control mixture NSCC achieved a split-tensile strength of 3.45 MPa (Fig. 3). The mix with 2% RM with 30% IOT achieved the highest strength of 3.885 MPa.Here the increase in strength was 12.46% compared to the normal SCC mix.The mixes which had 2% RM had relatively higher split tensile strengths compared to other mixes.

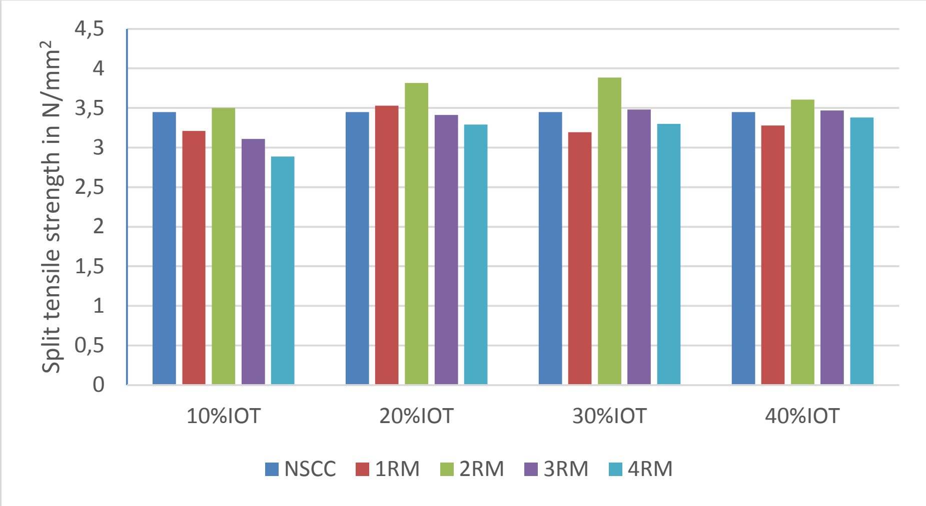


**Fig 3.** 28 daysSplit tensile strength of SCC mix proportions

## Flexural Strength

At 28-days, the control mixture NSCC achieved a flexural strength of 6.23 MPa (Fig. 4). The flexural strength achieved for all the mix is more than the control mix and all these values are more than IS specified values. As in the case of compressive and split tensile strengths, the mix with 2% RM with 30% IOT tailings achieved the highest flexural strength of 7.88 MPa.The flexural strength increased by 26.48% for this mix.The mixes which had 2% RM had relatively higher strengths compared to other mixes.

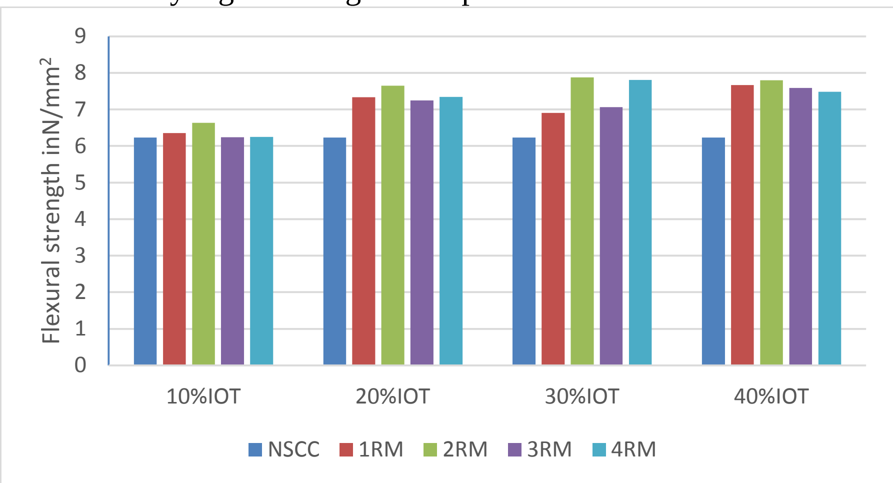


**Fig 4**. 28 days Flexural strength of SCC mix proportions

## Conclusion

The following conclusions were drawn from the experimental results of this study

i) The compressive strength achieved for all the mix is more than the control mix
ii) The maximum compressive strength and split tensile strength was achieved at 2% RM with 30% IOT.
iii) The flexural strength achieved for all the mix are more than the control mix and all these values are more than IS specified values. The maximum flexural strength was achieved at 2% RM with 30% IOT.
iv) The optimum strength for every test was achieved at 2% RM for every IOT replacement level.

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