International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 7, July - 2014

Effect of Replacing Sand by Iron Ore Tailings on the Compressive Strength of Concrete and Flexural Strength of Reinforced Concrete Beams

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***Abstract*— In this experimental work, the effect of replacing sand partially or completely in cement concrete by iron ore tailing, which is a waste from the iron ore industry and which has disposal problem leading to environmental pollution, is investigated. Cement concrete cubes and reinforced concrete beams are tested for compressive strength and flexural strength respectively by varying percentages of sand replacement by iron ore tailing. It is found that the cube compressive strength of cement concrete and flexural strength of reinforced cement concrete beams are in no way impaired by sand replacement. On the other hand, there is an enhancement in the strength for all percentages of sand replacement. The increase in strength is, however, not very substantial.**

Keywords—sand; iron ore tailing; compressive strength; flexural strength; reinforced concrete beam

I. INTRODUCTION

The increasing demand for heavy construction material like steel and iron has resulted in the establishment of many iron ore mining companies. Iron ore tailing is a waste generated from the iron ore industry (vide Figure 1). It is a very fine aggregate residue resulting from the extraction of iron from iron ore. The residue left after extraction is in the form of slurry. Usually the ore tailing is disposed of in the vicinity of plant as waste material over several hectares of valuable land leading to water and land pollution. Large quantities of iron ore tailing are generated in India every year leading to environmental pollution and disposal problem. Problems involved in the disposal of iron ore tailing are lack of space, cost etc.

Many researchers have made studies on the use of iron ore tailing in concrete. A few are mentioned here. Huang et al. [1] have used iron ore tailings in powder form to partially replace cement to enhance the environmental sustainability of ECC (engineered cementitious composites). Mechanical properties and material greenness of ECC containing various proportions of IOTs (iron ore tailings) were investigated. The replacement of cement with IOTs resulted in 10–32% reduction in energy consumption and 29–63% reduction in carbon dioxide emissions in green ECC compared with typical ECC. Rui Ying Bai et al. [2] have assessed the alkali silica reaction (ASR) of iron ore tailings sand using rapid mortar bar method (GB/T 14684-2001). The replacement of cement by 30% fly ash (FA), 50% ground granulated blast-furnace slag (GGBFS), 10% metakaolin (MK) and replacement of sand by 15% ground iron ore tailings (GIOT) led to the ASR-expansion to below 0.10%. Compared with replacement of cement, replacement of sand led to better performance. Furthermore, the fine particles less than 75μm in iron ore tailings sand are beneficial to the reduction of expansion induced by ASR. Sujing Zhao et al. [3] have explored the possibility of using iron ore tailings to replace natural aggregate to prepare UHPC (ultra high performance concrete) under two different curing regimes. It was found that 100% replacement of natural aggregate by the tailings significantly decreased the workability and compressive strength of the material. However, when the replacement level was no more than 40%, for 90 days standard cured specimens, the mechanical behavior of the tailings mixes was comparable to that of the control mix, and for specimens that were steam cured for 2 days, the compressive strengths of the tailings mixes decreased by less than 11% while the flexural strengths increased by up to 8% compared to the control mix.

Cement concrete is a processed construction material of widespread use in the field of civil engineering. The availability of natural sand for construction purpose is gradually depleting. To overcome this difficulty and reduce the environmental pollution arising from disposal of iron ore tailing, the possibility of replacing partially or completely the sand by iron ore tailing is considered here. In the present work the sand in cement concrete is successively replaced by 10%, 20%, 30%, 40%, 60%, 80% and 100% by iron ore tailing to determine the effect on compressive strength of cement concrete and flexural strength of reinforced cement concrete beams. The iron tailing used in the present investigation is taken from the Kuduremukh Iron Ore Company Ltd. (KIOCL), Kuduremukh and has the physical properties given in Table 1.

Table 1: Physical properties of iron tailing used

Physical Property	Value
Particle shape	Spherical
Density	14.5 kN/ m³
Specific gravity	3.10
Colour	Dark tan (brown)
Optimum dry density (ODD)	1.71 gm/cc
Optimum moisture content (OMC)	21 %

Figure 1: Iron ore tailing

Concrete cubes and reinforced concrete beams were cast with different percentages of sand replacement by iron ore tailing and tested to determine the cube compressive strength and flexural strength. The mix proportions for M20 concrete were designed [4] and used for both cubes and beams.

II. EXPERIMENTAL WORK

A. Compressive test on concrete cubes

The sand in the concrete was replaced successively by different percentages of iron ore tailings. Concrete cubes of size 150 mm*150 mm*150 mm were cast by replacing 0%, 10%, 20%, 30%, 40%, 60%, 80% and 100% of sand by iron ore tailing in concrete. The cubes were cured for 28 days. The quantities of the ingredients used in the present work are given in Table 2.

TABLE 2: QUANTITIES OF INGREDIENTS USED

% of iron ore tailings	Quantity of cement (kgf)	Quantity of sand (kgf)	Quantity of iron ore tailings (kgf)	Quantity of coarse aggregate (kgf)	Water (kgf)
0	4.425	6.06	0	13.053	2.212
10	4.425	5.454	0.606	13.053	2.212
20	4.425	4.848	1.212	13.053	2.212
30	4.425	4.242	1.818	13.053	2.212
40	4.425	3.636	2.424	13.053	2.212
60	4.425	2.424	3.636	13.053	2.212
80	4.425	1.212	4.848	13.053	2.212
100	4.425	0	6.06	13.053	2.212

The compressive strength test on cubes was conducted in a compression testing machine in accordance with the specifications of Bureau of Indian Standards [5]. The compressive strengths obtained from the tests are presented in Table 3. Each value of the compressive strength in Table 3 is an average of three experimental determinations.

TABLE 3: COMPRESSIVE STRENGTH OF CUBES FOR VARIOUS PERCENTAGES OF SAND REPLACEMENT

% of iron ore tailing	Cube compressive strength (N/mm²)
0	33.33
10	35.56
20	36.96
30	37.33
40	38.30
60	36.44
80	35.11
100	34.22

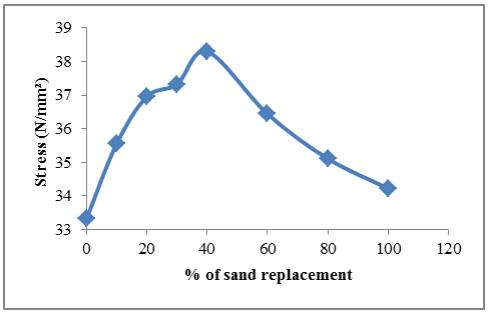

Figure 2: Cube compressive strength versus percentage of sand replacement

B. Flexural test on reinforced concrete beams

Reinforced cement concrete beams of length 1000 mm and cross-section 100 mm*100 mm with 2 bars of 8mm diameter at bottom, 2 hanger bars of 6mm diameter at the top and two-legged stirrups of 6mm diameter at 300mm c/c throughout were cast. The fabricated reinforcement cage was kept in the beam mould of size 1000 mm*100 mm*100 mm with adequate cover on all the sides. M20 concrete and Fe 415 steel were used. The beams were cast by replacing 0%, 10%, 20%, 30%, 40%, 60%, 80% and 100% of sand successively by iron ore tailing and then cured for 28 days. The quantities of ingredients used for the reinforced concrete beams are given in Table 4.

TABLE 4: QUANTITIES OF INGREDIENTS USED IN BEAMS

% of iron ore tailings	Quantity of cement (kgf)	Quantity of sand (kgf)	Quantity of iron ore tailings (kgf)	Quantity of coarse aggregate (kgf)	Water (kgf)
0	13.110	17.961	0	38.676	6.555
10	13.110	16.165	1.796	38.676	6.555
20	13.110	14.369	3.592	38.676	6.555
30	13.110	12.573	5.388	38.676	6.555
40	13.110	10.777	7.184	38.676	6.555
60	13.110	7.184	10.777	38.676	6.555
80	13.110	3.592	14.369	38.676	6.555
100	13.110	0	17.961	38.676	6.555

The beam specimens were tested under two point loading in Universal Testing Machine. The midspan deflections were measured using dial gauge.

Figure 3: Two point load test on beams

TABLE 5: FLEXURAL STRENGTH AND MIDSPAN DEFLECTION OF TEST BEAMS FOR DIFFERENT % OF SAND REPLACEMENT

% of sand replacement by iron ore tailing	Ultimate load (kN)	Midspan deflection at ultimate load (mm)
0	**10.625**	8.113
10	11.875	7.177
20	11.875	9.713
30	11.25	10.587
40	12.5	10.660
60	11.875	6.050
80	12.5	7.467
100	12.5	8.787

It is observed that the flexural strength of reinforced concrete beams is no way affected by replacing sand with iron ore tailing. On the other hand, the flexural strength increases whenever the sand is replaced by iron filings for all percentages of replacement. The increase in strength is not very substantial. The central deflection is found to be maximum for about 40 % of sand replacement. The central deflection for beams with sand replaced partially by iron filings is more than that of the beam with no replacement in the range of 20 to 40 percent replacement.

III. CONCLUSIONS

The following conclusions are made based on the above experimental work.

- The compressive strength of cement concrete is in no way affected by replacing sand by iron ore tailing. On the other hand there is an increase in the compressive strength due to sand replacement by iron ore tailing. The maximum increase in compressive strength occurs for about 40 percent of sand replacement.
- The flexural strength of reinforced concrete beams is in no way impaired by replacement of sand by iron ore tailing. On the other hand, there is enhancement of flexural strength for all percentages of sand replacement. The increase in flexural strength is not very substantial. The central deflection is found to be maximum for about 40 % of sand replacement. The central deflection for beams with sand replaced partially by iron filing is more than that of the beam with no replacement in the range of about 20 to 40 percent replacement.
- The sand in cement concrete may be replaced by iron ore tailing in concrete production without compromising on the strength and it greatly reduces the water and land pollution that would otherwise occur due to disposal of the iron ore tailing on land.

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ACKNOWLEDGEMENT

The authors express their thanks to the Principal and Management of Nagarjuna College of Engineering and Technology, Bangalore for their encouragement and support. The authors also express their thanks to the civil engineering undergraduate students Ms. Swetha K C, Ms Kavitha V C, and Mr. Akash A of Nagarjuna College of Engineering, Bangalore.