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Experimental study on strength properties of concrete replacing cement by marble dust and sand by iron ore tailings

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Abstract
The present experimental study is carried out to find the behaviour of iron ore tailings (IOT) and marble dust by partially replacing fine aggregate (natural sand) at 10%,20%,30%,40% and ordinary Portland cement (OPC) at 5% 10%,15%,20% respectively for M40 grade concrete as per IS 10262-2009. The sample of IOT material for the present project is brought from Bellary district Karnataka. The test was carried on fresh and hardened concrete. It is found that as the percentage of IOT increase workability reduces. So admixture superplasticizer "CONPLAST-SP340" was used to maintain workability. The optimum replacement was found at 10% IOT and 5% marble dust based on strength properties.

Keywords
Iron ore tailings (IOT), Marble dust, Superplasticizer.

1.Introduction
According to a recent report by the World Health Organization (WHO), among world's 20 polluted cities, India is 14 based on particulate matter 2.5 levels in 2016 (published on May 1, 2018). It gives a clear indication of global warming because of not adopting the technology, which may lead to environmental problems in coming days.

It is a big challenge to the government to develop the country without harming the environment by using all the safety measure to protect the globe.

For every developing country, construction industry plays a very important role. In construction industries demand of steel and materials of concrete like aggregate, sand and cement is day by day increasing rapidly along with which is affecting the environment due to using of natural resources.

To avoid the use of natural resources to protect the environment many studies and researchers are going on to replace the natural resources by waste generated by industries like iron ore tailings (IOT) is replacing to natural sand and marble dust to cement. IOT is generated due to heavy demand for steel in the world and after the extraction of valuable ore. It is disposed of in open land which leads to land pollution. The waste produced is more than 10-12 million tons per year [1]. As it has very fine material property left over after the extraction of slurry, researchers suggest that instead of dumping IOT used as a substitute to fine aggregate.

Marble dust also has lots of demand for decorative purpose in building construction. From the quarry to finishing process more than 20-30% of waste generated which is very fine particle. If it deposes in open place it causes air pollution which is hazardous material to health as well to the agricultural land which reduces the fertilization of crop [2]. For its fineness property purpose, it is to be found by many recent past year scientists are trying to use in the building construction by replacing partially by cement to marble dust.

1.2Scope of the project
Utilization of waste products in construction industries as partially or fully replacement in concrete and other building materials. Recent past years Iron ore tailings the large production in Indian steel industries due to heavy demand of construction. To reduce the environmental issues replacement of fine aggregate and cement as IOT and marble dust respectively plays an important role and it acts as an alternative method too.

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1.3Objectives

The paper objectives are as follows:

1) Studying the properties and behavior of IOT and marble dust with conventional concrete.
2) Natural sand is replaced by IOT and cement by marble dust.
3) Studying the workability of concrete after replacing IOT & marble dust for fine aggregate and cement respectively
4) Determining the mechanical strength properties of concrete after replacement.

1.4Literature review

Kumar et al. [1] found that increase in percentage of the IOT decreases the workability, hence superplasticizer is necessary. Compressive strength concrete is more at 40% replacement of the IOT than the reference mix (NC).In case of the flexural reference, mix is maximum than the replacement.

Gopi [2] stated that compaction factor and strength increased up to 15% replacement of cement by marble dust and slump decreased as a percentage increased. Marble dust recognized as low costing material and keeps the environment safe. Test were carried out for partially replacement cement by marble dust to 0%, 5%, 10%, 15%, 20% and 25% for M30 grade concrete .

Ugama et al. [3] suggested that due to fine particles and more surface area, IOT reduces the workability. 20% of IOT replacement has got a closer compressive strength to the replacement of sand (RS). At the age of 28days curing for IOT replacement 43.67N/mm2 and RS is 45.02N/mm2 which values are close. Therefore 20% IOT replacement is limited and splits tensile strength gave good values than the RS.

Navale et al. [4] instructed to use admixture superplasticizer for workability and found that there is no effect on the compressive strength by substituting the natural sand. Got maximum compressive strength up to 40% of IOT replacement.

WP et al. [5] suggested that the compressive strength does not affect by replacing the natural sand by IOT, at 40% of partial replacement of IOT shows maximum and central deflection at compressive and flexural strength respectively. He stated that sand can be replaced by IOT to produce the concrete [5].
Kumar and Dhaka [6] suggested that the marble powder may be used as partial replacement of cement in a concrete. It enhances a property of concrete. It cost less compare to cement as marble dust is easily available in marble company. And also it helps to reduce the land pollution.

Singh et al. [7] suggested that in cement production units marble dust may be used up 10% as it does not influence to the setting time. Used material marble dust ratio enhances the specific gravity and reduces the area of the surface. In this study found that compressive strength is more as compared to the ordinary Portland cement (OPC).

Kumar and Kuma [8] suggested that up to 10% cement replaced with marble dust has given good results to test and up to 15% replacement split tensile and flexural strength increased thereafter reduced.

Alsadey [9] suggested that the adding limited superplasticizer as per the design increases the workability. It is concluded that superplasticizer helps to enhance the strength of concrete. If the superplasticizer dosage more than the required it will harm to the concrete.

Muhit [10] suggested from the results of the study, it is decided that by addition of superplasticizer the workability of concrete can be enhanced. By using the proper dosage of chemical admixture slump loss can be reduced to a great extent. In superplasticizer, the concrete effect is too high. Up to a specific limit (1.0%) with the increment of superplasticizer dosage, the compressive strength is improved and it is compared with a control specimen which fabricated without any SP. The effective range of dosage is 0.6-1.0%.

2.Experimental investigation

2.1Materials

2.1.1Cement

OPC was used for the project conforms to the Indian standards IS 12269-1987 grade 53 (UtraTech). Following test has been carried out in the project as per IS: 4031-1998 [11]. *Table 1* shows the physical properties of cement tested in the laboratory.

Table 1 Physical properties of cement tested in the laboratory

S. No	Characteristics	Results
1	Fineness	3.4%
2	Initial setting time	185 min
3	Soundness	1 mm
4	Final setting time	270min
5	Norman Consistency	32%
6	Specific gravity	3.09
7	Final setting time	270 min

2.1.2Coarse aggregates (CA)

20mm and 10mm aggregates are used obtained from local crushers. The test was carried as per the IS: 2386.

Three trials were conducted for selecting the proportion of 20mm and 10mm coarse aggregate fraction. The Proportion for 50:50 and 60:40 of 20mm and 10mm coarse aggregate fraction did not give proper gradation. The proportion for 40:60 of 20mm and 10mm fraction of coarse aggregates was well graded. Hence this proportion is selected for present studies [12]. *Table 2* shows the physical properties of coarse aggregates.

Table 2 Physical properties of coarse aggregates

S. No	Characteristics	Value
1	Aggregate	Angular
2	Free surface moisture	-
3	Specific gravity	2.2
4	Bulk density	
5	a)Lose condition	1.53g/cm^3
	b)Compacted condition	1.748 g/cm^3
6	Abrasion value	22.86
7	Impact value	13.73
8	%Water absorption	0.67

2.1.3Fine aggregates

Natural sand has been used in our work. Test carried as per IS: 383-1970 [13].Test and results are in below *Table 3*

Table 3 Physical Properties of fine aggregates

S. No	Characteristics	Value
1	Zone	II
2	Fineness modulus	3.87
3	Water absorption	2.0
4	Specific gravity	2.61
5	Silt content	Nil

2.1.4 Water

Portable water as ingredients in the concrete for casting and curing, water added as per the mix design. Water should use as per the standards IS: 456-2000 [14].

2.1.5 Iron Ore Tailings (IOT)

Waste material left after the extraction of valuable material from iron ore is known as tailings. The material was brought from Kej mineral, Bannehatti village, Torangal, Bellary district.

Table 4 shows the physical properties of IOT.

Table 4 Physical properties of IOT

S. No	Characteristics	Value
1	Colour	Reddish brown
2	Specific gravity	2.66
3	Fineness modulus	3.78
4	Optimum moisture content	8.84%
5	%Water absorption	15.87
6	Maximum dry density	2.508 g/cc

2.1.6 Marble dust

The material is which generates more than 20%-30% waste from the quarry to till finishing work in building construction for decorative purpose. The material used locally available granite and marble works industry [2]. *Table 5* shows the physical properties of marble dust.

Table 5 Physical properties of marble dust

S. No	Characteristics	Results
1	Specific gravity	2.74
2	Colour	White

2.1.7 Superplasticizer

Superplasticizer is also called as “High Range Water Reducers” because without increasing the water workability can be achieved. In this experimental studies, Fosroc Conplast SP430 DIS used. Dosage decided by slump cone test by various trials.

2.2Mix proportion

Mix proportion for M-40 grade concrete is after correction of water [15]. *Table 6* shows the mix proportion.

Table 6 Mix proportion

Cement	Fine aggregates	Coarse aggregates	Water
1	1.43	2.628	0.496
437.7 kg	625.6 kg	1150.33 kg	217.52 kg

2.3Mixing and casting

Cubes has to be casted after cleaning and oiling to determine the compressive strength of IOT 10%,20%,30% & 40% and marble dust 5%,10%,15% & 20 respectively with addition of superplasticizer admixture.

2.4Batching

It is the process of measuring the ingredients for concrete. Batching can be done by two methods.

1. Volumetric/volume batching 2. Weigh batching Present experimental studies have been carried out by weigh batching method. Weigh batching is found that very convenient method for concrete mixing. Weigh batching may be differing from one project to another project as per the requirement/magnitude of the project. Ingredients to measure by as per standard procedure with accuracy of 0.5 grams.

2.5 Mixing

Mixing is a part of the concrete and it plays a vital role for homogeneous mix and gives good strength and durability of the concrete. Mixing has two methods:
1. Hand mixing
2. Machine mixing

The present study hand mixing adopted.

Hand mixing

Hand mixing is carried out in the small-scale construction project. It is done on the impervious plate, Concrete ingredients like cement, sand, aggregates, and water to weigh/measured as per the mix design and mix it by using the shovel manually till the homogeneous color achieved.

Natural sand is partially replaced by 10%, 20%, 30% & 40% and cement by marble dust 5%, 10%, 15% and 20% with water and also superplasticizer admixture added as per the design mix.

2.6 Placing of concrete

After mixing all the ingredients properly and placed the concrete in molds as per the IS code norms. Molds were cleaned and oiled than filled in three layers by 25 tamping using the 16 mm diameter and 600mm length tamping rod for good compressive strength result.

2.7 Curing

The method adopted in this project is water curing by immersion. The concrete specimens were placed in the curing tank at the ambient temperature for curing. The concrete cubes are immersed in a water pond for 3days, 7days and 28 days.

2.8 Fresh concrete tests

2.8.1 Slump test and compaction factor

Both tests are carried out to find workability of concrete. The test is conducted where the maximum size of the aggregate should not be more than 40mm, the test can be carried out at the lab and also a site.

2.9 Tests on hardened concrete

2.9.1 Compressive strength test

This test conducted to know characteristics of concrete, it depends on many factors like w/c ratio, concrete ingredients, mixing, placing and curing. The casted cube to be tested on the compressive strength machine or universal testing machine (UTM), the tests are carried out after the curing period like 3days, 7days, 28 days [16]. *Figure 1* shows the flexural-testing of specimen.

Figure 1 Flexural-testing of specimen

2.9.2 Split-tensile strength test

A cylinder size 150mm (dia.) × 300mm (ht.) were prepared and tested under UTM [17]. *Figure 2* shows the split-tensile strength of specimen.

It can be calculated by using the Formula given below:

$$\sigma = \frac{2P}{\pi DL}$$

Where, σ is the Split Tensile Strength $\frac{N}{mm2}$

P=Load (N)
L=Height (mm)
D=Dia. (mm)

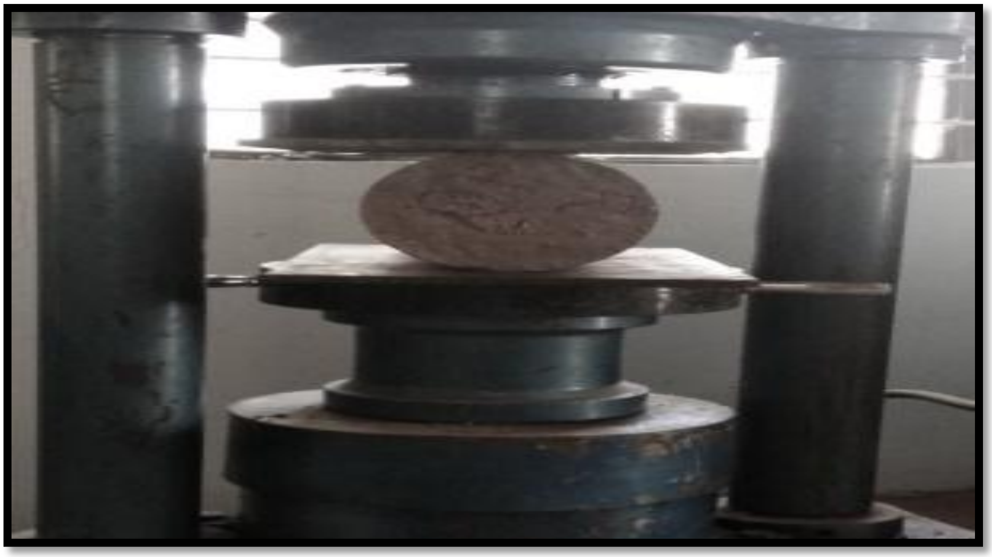

Figure 2 Split-tensile strength of specimen

2.9.3 Flexural-strength test

Test for different mix and different curing period 7days and 28 days carried on the prism/ beam of size 100×100×500mm casted and cured. The test results are calculated using the below formula. *Figure 3* shows the flexural-testing of specimen.

$$Fcr = \frac{P \times L}{B \times D^2}$$

Where: F_{cr} = flexural-strength $(\frac{N}{mm2})$
P=Load (N)
L=Length (mm)
B=width (mm)
D=depth (mm)

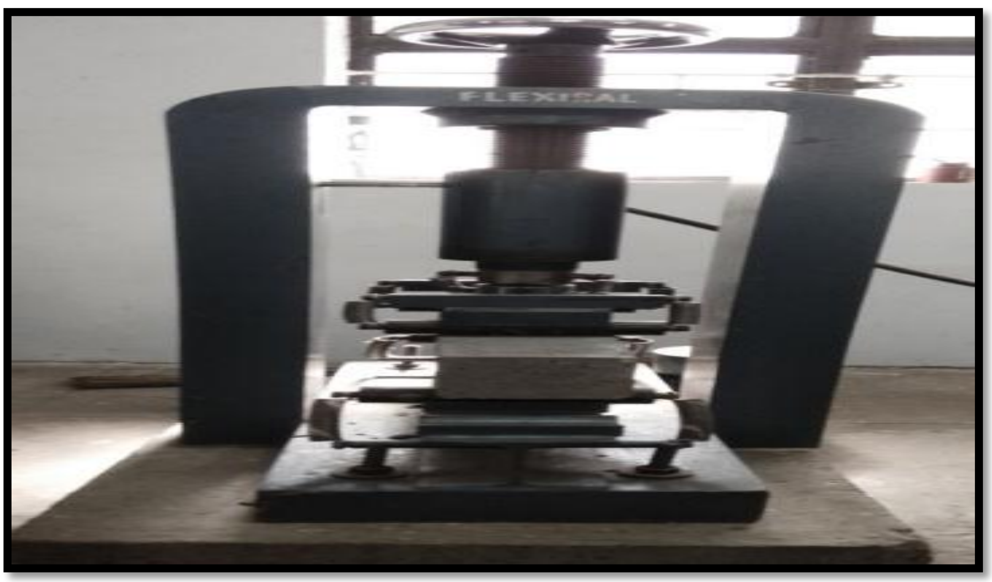

Figure 3 Flexural-testing of specimen

3.Results and discussion

Results of fresh concrete slump test and compaction factor test are carried to find the workability of concrete. The dosage of superplasticizer for all replacement levels are fixed based on slump test. *Table 7* shows the slump cone result without superplasticizer.

Table 7 Slump cone result without superplasticizer

S. No	Mix Type	Slump value in mm
1	C.C	100
2	MX1 (10%IOT, 5%MD)	95
3	MX2 (20%IOT,10%MD)	25
4	MX3 (30%IOT,15%MD)	0
5	MX4 (40%IOT,20%MD)	0

MD: Marble dust

Table 8 shows the slump cone result with Superplasticizer. *Table 9* shows the replacement level increases and the slump value decreases.

Table 8 Slump cone result with Superplasticizer

S. No	Mix type	The dosage of SP (%)	Slump value in mm
1	MX1 (10%IOT, 5%MD)	0.15	105
2	MX2 (20% IOT,10% MD)	0.5	90
3	MX3 (30%IOT,15%MD)	1.0	85
4	MX4 (40%IOT,20%MD)	1.5	55

MD: Marble dust

Table 9 Compaction factor result with Superplasticizer

S. No	Mix type	Compaction factor
1	Conventional	0.9
2	MX1 (10% IOT, 5% MD)	0.93
3	MX2 (20% IOT,10% MD)	0.9
4	MX3 (30% IOT,15% MD)	0.92
5	MX4 (40% IOT,20% MD	0.9

MD: Marble dust

3.1 Results on hardened properties

Table 10 shows that the compressive strength was maximum for conventional concrete (51.7 N/mm^2) considering all the mixes. Among all the replacement levels, mix1 (10% IOT and 5% marble dust) had more compressive strength (49.03 N/mm^2).

Table 10 Results of compression test

S. No	Mix type	Compressive strength (N/mm^2) 3days	7days	28days
1	C.C	18.81	32.14	51.7
2	Mix-1	13.62	22.21	49.03
3	Mix-2	15.4	25.03	42.36
4	Mix-3	13.18	21.32	32.88
5	Mix-4	13.03	21.18	28.43

Table 11 shows that the split tensile strength was maximum for conventional concrete (3.69 N/mm^2) considering all the mixes. Among all the replacement levels, mix1 (10% IOT and 5% marble dust) had more compressive strength (3.82 N/mm^2).

Table 12 shows that the flexural strength was maximum for conventional concrete (7.1 N/mm^2) considering all the mixes. Among all the replacement levels, mix1 (10% IOT and 5% marble dust) had more compressive strength (6.83 N/mm^2).

Table 13 shows that, as the replacement rate level increases the water absorption rate increases in concrete mix.

Table 11 Results of split tensile strength

S. No	Mix Type	Split tensile strength (N/mm^2) 7days	28days
1	C.C	2.63	3.69
2	Mix-1	2.54	3.82
3	Mix-2	2.12	3.67
4	Mix-3	2.12	3.62
5	Mix-4	1.79	3.1

Table 12 Test results of flexural-strength

S. No	Mix type	Split tensile strength (N/mm^2) 7days	28days
1	C.C	5.1	7.1
2	Mix-1	4.33	6.83
3	Mix-2	4.16	6.16
4	Mix-3	3.66	5.8
5	Mix-4	3.16	5.16

Table 13 Durability test results

S. No	Mix type	Dry weight in grams (W1)	Wet weight in grams (W2)	% Water absorption
1	C.C	8440.14	8468	0.33
2	Mix-1	8481.83	8520.5	0.45
3	Mix-2	8564.1	8609.5	0.53
4	Mix-3	8579	8642	0.74
5	Mix-4	8666.9	8745	0.9

4.Conclusion and future work

Without superplasticizer, as the replacement % increases the workability reduces. Superplasticizer at different dosage for all replacement increased workability. Compressive strength and split tensile strength for 5% marble dust and 10% IOT was more than normal concrete.

Flexural strength for normal concrete was more than all the replacement percentages. The optimum mix should be limited to 5% marble dust and 10% IOT in the concrete mix. Water absorption increases as the % of replacement increases in a durability test.

In place of cement, replacement uses some other binding material and studies the properties of concrete. Different durability tests like chloride penetration test, carbonation test can be conducted on all replacement tests. Future study can be made by changing water-cement ratio and using different admixtures.

Acknowledgment

None.

Conflicts of interest

The authors have no conflicts of interest to declare.

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