International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

National Conference on Recent Advances in Civil Engineering Infrastructure(rACEi-2021)

Experimental study of concrete with partial replacement of fine aggregate by using iron scale

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Received 05 Aug 2021, Accepted 10 Aug 2021, Available online 15 Aug 2021, **Special Issue-9 (Aug 2021)**

Abstract

This experimental investigation involves the comparative study of the properties of concrete subjected to partial replacement of fine aggregate by using iron scale with conventional concrete. The study involves six different mixes consisting of different replacement levels S2(10%), S3(20%) , S4(30%), S5(40%), S6(50%) & S7(60%) of iron scale replacement of fine aggregate (M Sand) of which compared with conventional concrete(S1). This study investigates for fresh concrete properties such as slump cone test and hardened concrete properties such as compressive strength test for cubes, splitting tensile test for cylinders and flexural strength test for beams. These properties are compared with conventional concrete with an aim of finding the optimum partial replacement level of fine aggregate with iron scale.

Keywords: *M-Sand, Iron scale, fresh and hardened concrete properties.*

1. Introduction

Concrete, the single most widely used building material around the world, is a heterogeneous composite that consists of combination of readily available basic building materials including cement, water, coarse aggregate, fine aggregate, and in some cases, admixtures, fibers or other additives, according to the need. The main objective of the present study is to find out a suitable, effective and alternative material for partial replacement of fine aggregate, to find out possible utilization of waste materials in construction industry that in turn considerably minimize the usage of fine aggregate and reduce construction cost, to explore possibilities of improving mechanical properties of concrete using Iron scale instead of fine aggregate partially, to evaluate the effect of using iron scale in concrete and to investigate the strength of replaced concrete with that of conventional concrete.

This project is mainly undertaken to study the behavior and performance of concrete using waste material such as Iron scale. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal.

2.Literature review

Gaurav desai et.al, (2015) The properties involve of compressive strength, split tensile strength and flexure strengths of M20 conventional concrete by replacing the 0%, 10%, 20% and 30% of steel slag was added, tests were conducted on concrete cubes, cylinders and beams to study compressive strength, split tensile strength, and flexural strengths. The results are compared with the normal conventional concrete. The strength properties of concrete are determined with the various replacement level of steel slag with fine aggregate. The use of steel slag aggregates in concrete by replacing natural aggregates is a most promising concept. Steel slag aggregates are already being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance.

Anupam singhal.et.al (2015) Effect of sand replacement by mill scale on the properties of concrete work aims to evaluate the use of mill scale in Portland cement concrete, as a replacement for natural fine aggregates. The water/cement ratio used was 0.5 for all mix proportions. The compressive strength at different proportions did not give a general trend and two peaks were obtained at 60% replacement and 100% replacement. Maximum tensile strength was observed at 60%replacement of standard sand. A mix design was also done for M35 grade of concrete by the IS method. OPC of 43 grade was selected and sand replacement was done with mill scale varying from 0% to 80% with a suitable water cement ratio of 0.40. The compressive strength was measured after 28 days of completion of curing. Maximum strength was obtained for 40% sand replacement. Moreover, concrete with mill scale has demanded greater water content to maintain the workability.

Anil singh et.al (2016) Study of partial replacement of fine aggregate by iron slag study shows the possibilities of using iron slag as partial replacement of fine aggregate (sand) by iron slag. Iron slag was used to replace 25% to 30% of sand by weight at increment of 5% for both cube and cylinder. The strength of concrete increases rapidly with increase the iron slag content and the optimum value of compressive strength is obtained at 30% replacement. After 30% replacement the strength decreases. Similarly in the case of split tensile strength, the strength increases with the increase in iron slag content and the optimum value of split tensile strength is obtained at 30%. The uniform load conditions for compressive strength and split tensile strength are 4KN and 2KN respectively. In this study, the compressive strength of the iron slag concrete was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete.

Mohamed Alwaeli(2011) Recycling of scale and steel chips waste as a partial replacement of sand in concrete study is focusing on the use of selected waste of iron and steel industry (steel chips and scale) as a partial replacement for sand in the production of concrete. In this research study, concretes were made with steel chips scale (ScC) and (SchC) as substitution for raw sand. Sand was replaced by these wastes in different proportions (25%, 50%, 75%, and 100%) by weight of sand.The compressive strength of concrete containing steel chips is better than conventional concrete, while in the case of concrete mixed with scale in excess of 25%, the strength become deteriorated.

P. Velumani (2020) Steel mill scale waste and granite powder waste in concrete production said to the study is fine aggregate is one of the large scale consuming materials in the construction industry. In general, river sand has been used as a fine aggregate for making concrete, mortar, etc. In this investigation, M20 grade concrete with the replacement of sand by steel mill scale waste and granite powder waste from 10% to 100% with the increments of 10%.This paper presents a detailed experimental study on compressive strength, bulk density, and water absorption of the M20 grade concrete containing steel mill scale and granite powder. Based on the outcomes of the experimental investigations it was concluded that the replacement of the two industrial wastes steel mill scale and granite waste powder for sand as fine aggregate, both wastes showed a remarkable compressive strength up to their 100% replacement and optimized at 30% to achieve the maximum strength. An increase in the percentage of replacement of steel mill scale increased concrete's density and increase in water absorption. Whereas, the increase in the percentage of replacement of granite powder resulted in a decrease in water absorption and almost a minimum decrease in the density of the concrete.

3.Material Properties

3.1.Cement

Cement is the essential binding material for the production of concrete. For using cement in important and major works it is incumbent on the part of the user to test the cement to confirm the requirements of the Indian Standard specifications with respect to its physical and chemical properties. In this investigation Portland Pozzolona Cement confirming to IS1489-1991 (Part 1)) shown in fig 1 and table 1 for properties of cement.

Fig 1 Portland Pozzolona Cement

Table1 Properties of cement

S.No	Properties	Values
1	Normal consistency	32%
2	Initial setting	95 mins
3	Final setting time	270min
4	Specific gravity	2.9

3.2 Fine aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge. Usually manufactured sand is used as a fine aggregate at place where natural sand is not available crushed stone (m sand) is used as a fine aggregate. The sand used for the experimental works was locally procured and conformed to grading zone II. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS383-1970 and results are provided in Table. The sand was first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then was washed to remove the dust. According to IS 383: 1970 the fine aggregate is being classified in to four different zone that is zone-I, zone-II, zone-III, and zone-IV.M Sand is shown in fig 2 and the properties of fine aggregate is table 2.

Fig 2 M Sand

Table2 Properties of fine aggregate

S.No	Properties	Values
1	Fineness modulus	2.655
2	Specific gravity	2.58
3	Zone	II

3.3. Iron scale

Iron scale is an industrial waste material. It is a by-product of outer layer of the pipe while bending of pipe line. It consisting essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminium, manganese, calcium. The material is obtained from the BHEL, Thirumayam where it is non-useable waste as shown in the fig 3 and the properties of iron scale is table 3 and 4.

Fig 3 Iron scale

Table 3 Properties of iron scale

S.No	Properties	Values
1	Fineness modulus	2.68
2	Specific gravity	3.79
3	Zone	II

Table 4 Different proportion of iron scale properties

S. No	properties	10% IS	20% IS	30% IS	40% IS	50% IS	60% IS
1	Fineness modulus	2.97	2.94	2.73	2.7	2.62	2.45
2	Specific gravity	2.69	2.67	2.68	2.75	3.08	3.21
3	Zone	II	II	II	II	II	II

3.4. Coarse aggregate

The materials which are retained on a 4.75mm sieve are called coarse aggregate. Coarse aggregate forms the main matrix of the concrete. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used in the present study is shown in fig 4 and the properties of coarse aggregate is table 5.

Fig 4 Coarse aggregate

Table 5 Properties of coarse aggregate

S.No	Properties	Values
1	Fineness modulus	7.584
2	Specific gravity	2.94

3.5.Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Potable water is generally considered satisfactory. In the present investigation, potable water was used for both mixing and curing purposes.

4. Mix Proportion and Experimental Programme

4.1. Mix Proportion

The concrete mix is designed as per IS 10262-2019 and IS 456-2000 for the conventional concrete.

Grade designation = M30
Type of cement = PPC (IS 1489-1991 Part 1)
Maximum nominal

size of aggregate = 20mm
Minimum cement content = 300kg/m³
Maximum water
cement ratio = 0.5
Workability = 100mm
Exposure condition = Moderate
Degree of supervision = Good
Type of aggregate = Crushed angular aggregate

Table 6 Mix proportions per 1m³ for various concrete mixes

S.No	Mix	C (kg)	M Sand (kg)	Iron scale (kg)	CA (kg)	W (kg)
1	S1	448	607	0	1185	197
2	S2	448	546.3	60.7	1185	197
3	S3	448	485.6	121.4	1185	197
4	S4	448	424.9	182.1	1185	197
5	S5	448	364.2	242.8	1185	197
6	S6	448	303.5	303.5	1185	197
7	S7	448	242.8	364.2	1185	197

4.2. Experimental Programme

Laboratory drum mixer was used for the preparation and mixing of all concrete mixtures. A drum mixer is a mechanical device, which uses a revolving drum to combine cement, coarse aggregate, fine aggregate such as M Sand and Iron scale and water to form a homogenous mass. Workability of all concrete mixtures was checked immediately after the finishing of mixing operation. All the concrete specimens were casted in steel moulds. All the moulds were cleaned and oiled properly before the mixing of concrete ingredients. They were properly tightened to correct dimensions before casting operations. Care was taken to ensure that there must not be any gap left so as to prevent the leakage of slurry. Concrete specimens were compacted in three layers using hand compaction. After the casting operations, concrete specimens were left in the casting room for approximately 24 hours, after which they were de-moulded and placed in the curing tank.
Size of cube mould = 150mm x 150mm x 150mm
Size of cylinder mould = 150mm x 300mm
Size of beam mould = 1700mm x 150mm x 100mm

5. Result and Discussion

In this chapter the test results on fresh concrete and hardened concrete such as slump test, compressive strength, Split tensile strength and flexural strength obtained from the experimental study are discussed below.

5.1.Slump cone test

The targeted slump have been analyses as per the IS code IS 1199–1959. The results of the slump test showed that at 0% replacement level, the concrete mix gave a true slump value of73 mm. The slump decreases, as the percentage replacement level increases, from 0% to 60% of iron scale. It shows that manufactured sand is generally finer than that of iron scale. Table 7 shows the variation of slump value of concrete using iron scale. From the graph it is observed that in concrete, percentage of iron scale increases,it decreases the workability.

Table 7 Values of slump cone test

S.No	Mix designation	% of Iron scale	Slump value	Workability
1	S1	0	73	Medium
2	S2	10	68	Medium
3	S3	20	62	Medium
4	S4	30	57	Medium
5	S5	40	48	Low
6	S6	50	42	Low
7	S7	60	37	Low

5.2. Compressive strength test

The Compressive tests are carried out on CTM after curing with water for 28 days. Fig 5 shows the compressive strength variations. The compressive strength goes on increasing for 10%, 20%, and 30% but goes on decreasing for 40%, 50% and 60% compare to conventional concrete. The result shows that 30% replacement is desirable and economical replacement of iron scale as compare to fine aggregate. Also 10%, 20% and 30% replacement increases the strength as compare to conventional concrete.

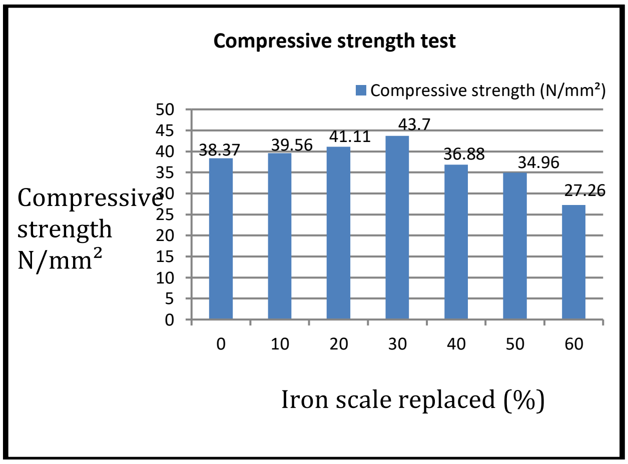

Fig 5 Compressive strength of concrete cubes

5.3. Split tensile strength test

The Split tensile tests are carried out on CTM after curing with water for 28 days. Fig 6 shows the split tensile strength variations.. The split tensile strength goes on increasing for 10%, 20%, 30% and 40% but goes on decreasing for 50% and 60% compare to conventional concrete.

The result shows that 30% replacement is desirable and economical replacement of iron scale as compare to fine aggregate.

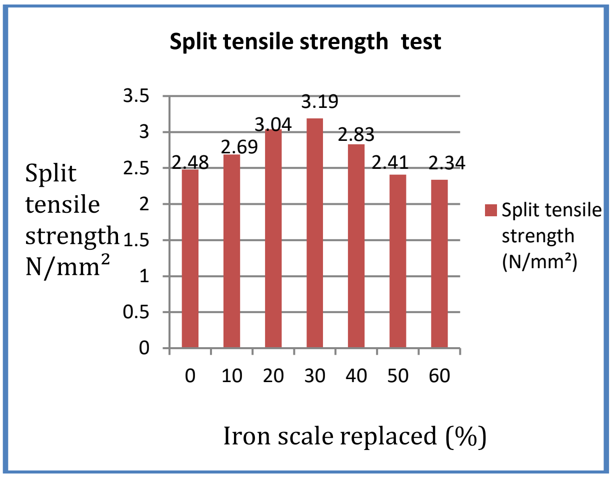

Fig 6 Split tensile strength of cylinders

5.4. Flexural behaviour of concrete beams

The concrete beams of suitable size 1700x150x100mm were cast. Two points loading was employed for determination of flexural strength under two point loading at the age of 28 days with simply supported end condition, centered over bearing blocks adjusted for an effective span of 1500 mm. Load was transferred to the specimens by two point loading at a distance of 100 mm from each support. The load was applied without shock and it was increased at a uniform rate till the ultimate failure of the beam took place. LVDT are kept at L/2 and L/3 distance from the support .The deflection at mid span and one third span was recorded for each increment of load by using LVDT. The specimens were tested in UTM of capacity of 500 KN. The flexural behavior of S1,S2S1,S2,S3,S4,S5,S6 and S7 was determined for beam was and the average results are reported.

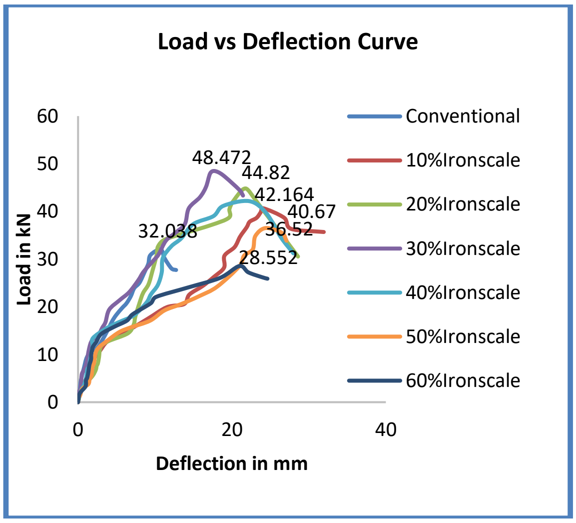

Fig 7 Load vs Deflection curve

Conclusions

1) The workability of concrete decreases with increase in percentage of iron scale.
2) Compressive strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate
3) replacement level had maximum compressive strength at all other proportions. The value of compressive strength is 43.7 N/mm².
4) Splitting tensile strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate replacement level had maximum splitting tensile strength at all other proportions. The value of splitting tensile strength is 3.19 N/mm².
5) Flexural strength of concrete was increased with inclusion of iron scale as partial replacement of manufactured sand. Concrete mix with 30% fine aggregate replacement level had maximum flexural strength at all other proportions. The value of ultimate load is 48.472 kN and corresponding mid span deflection of the beam specimen is 17.754mm.

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