STUDIES ON SUSTAINABLE CONCRETE USING METAL CASTING INDUSTRIAL WASTE

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ABSTRACT: Some of the environmental issues associated with the metal casting industry are emission of harmful and poisonous gases, dust and particles and generation of waste pollutants. The government and metal casting industry associations have setup several norms and guidelines to help the industry fight pollution by controlling emissions and proper disposal of pollutants. To reduce the pollution that is caused by the foundry we used the waste gray cast iron and ductile cast iron as admixture in concrete. In this study, gray cast iron and ductile cast iron turnings are used as admixture in concrete and compared it with conventional concrete. The main idea of the present work is to examine the effect of adding industrial waste in the form of Cast iron (CI) from the casting industry in the concrete mix. This work examines the possibility of using gray cast iron and ductile cast iron turnings as a partial replacement to sand for new concrete(M30). Gray cast iron and ductile cast iron turnings are partially added as 0%, 10%, 15%, 20%, 25%, 30% and tested for its compressive, Split Tensile and flexural strength at to 7 days, 28 days, and were compared with those of conventional concrete. From the results obtained, it reveals that increased CI turnings proportions result in increased compressive strength flexural strength and split tensile strength of the concrete against the controlled specimen of concrete mix. However beyond 25% replacement of sand with CI turnings the is no change in strengths.

KEYWORDS: Cast iron turnings, Compressive Strength, Flexural Strength, Split tensile Strength.

I. INTRODUCTION

Rapid urbanization in developing countries such as India is creating a shortage of adequate housing in cities. Using artificial aggregates for quality concrete is a natural step to mitigating this problem. The world wide consumption of materials in concrete production is very high, and several developing countries have encountered difficulties in meeting the supply of materials in order to satisfy the increasing needs of infrastructural development in recent years.

Industrialization is one of the key factors for any developing economy like India. However, industrialization on the other hand has lead to serious problems leading to environmental pollution. Therefore, the industrial waste seems to be a by-product of the growth. The major generators of industrial solid wastes are the thermal power plants producing coal ash, the integrated Iron and Steel mills producing blast furnace slag and steel melting slag, nonferrous industries like aluminium, zinc and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer, allied industries producing gypsum, marble and stone cutting industry, textile industry generating solid sludge etc. In recent years, the Iron and Steel industry has played a vital role in the development of the country's economy as India has turned out to be the 5th largest producer of crude steel in the world with the total finished steel (alloy + non-alloy) production for sale of 47.30 million tonne (MT) during April – December 2016.

India is expected to be the 2nd largest producer by the year 2015-16. With such pace of development, the industry is also adding up to the industrial solid waste (ferrous + non-ferrous) every year. Taking a case of the Bhilai Steel Plant (BSP), management of the solid waste (ferrous + non-ferrous) has been a serious matter of concern because the actual generation is more than the computed norms. At the base capacity of the plant (5.0 million tonne), the plant should generate 2.0 million tonne solid waste but on an average of the production of (2004-2007), BSP has generated about 2.7 million tonne of solid waste per annum.

Out of this 24.8% was sold, 14.2% was recycled and rest 60% was dumped in the dump yards. This 60% of the dumped solid waste is totally useless and only adds to the land pollution and is one of the major environmental concerns. Also, the total Steel and blast Furnace solid waste generation, the source of which is the conversion process of pig iron to steel and manufacture of iron, was around 35.0 million tonne per annum, which was 3rd largest quantity of waste after Fly Ash (70.0 million tonne per annum) and Lime stone wastes (50.0 million tonne per annum). (National Waste Management Council – Ministry of Environment and Forests-1990/1999). Iron and Steel scrap is one of the essential requirements for manufacture of steel and iron in mini-steel industry.

CAST IRON POWDER

Iron scrap is available in the country in the form of pressed bundles, a mixture of used steel components (called as a commercial scrap), turnings and borings and heavy melting scrap. These are generated by industries of all sectors like automobiles, railways and engineering workshops. One of the constituents of this commercial scrap is the turnings of CI castings that are rejected from a foundry due to defects. The production rate of the rejected castings is variable since it depends on the casting technique implemented, material used for casting, demand of the consumer, efficiency of the machinery and workmanship. The rejected castings are sold for turning to the turning industry.

On an average, a small automobile industry in Autonagar, Vijayawada generates 300 tonnes of turnings per annum. These turnings can be reused for the casting but the problem in doing so is that re-melting CI will not yield the same products. In order to obtain CI on re-melting, certain elements are required to be added to them like Carbon, Vanadium, Manganese, Silicon, Sulphur, Chromium etc. whose quantities depend upon the microstructure and strength required. Such addition makes the process costly and also such operations require skilled labour. The collection and processing of scrap in an organized manner is undertaken by a few units in the country. In the local market, scrap is supplied by dealers who in turn arrange to have scrap collected manually or through sub-dealers. Gray iron, or grey cast iron, is a type of cast iron that has a graphitic microstructure. It is named after the gray colour of the fracture it forms, which is due to the presence of graphite.

STRUCTURE OF CAST IRON

A typical chemical composition to obtain a graphitic microstructure is 2.5 to 4.0% carbon and 1 to 3% silicon by weight. Graphite may occupy 6 to 10% of the volume of grey iron. Silicon is important to making grey iron as opposed to white cast iron, because silicon is a graphite stabilizing element in cast iron, which means it helps the alloy produce graphite instead of iron carbides; at 3% silicon almost no carbon is held in chemical form as iron carbide. Another factor affecting graphitization is the solidification rate; the slower the rate, the greater the time for the carbon to diffuse and accumulate into graphite.

Table 1. Chemical composition of cast iron

Carbon	3.2 to 3.60%
Silicon	2.2 to 2.8%
Manganese	0.1 to 0.2%
Magnesium	0.03 to 0.04%
Phosphorus	0.005 to 0.04%
Sulphur	0.005 to 0.02%
Copper	<0.40%
Iron	balance

CAST IRON POWDER AS AN ADMIIXTURE

In India, most of the structures are made with concrete, as it is easily available, can be manufactured on site without any requirement of any skilled labour and also is economical, durable and has no negative impact on the environment. Thus, concrete has become an important part of the human life and existence. Concrete has found its applications in nearly all major constructions like dams, canals, towers, houses, roadways, railway sweepers etc. sludge as a source of water in concrete production has insignificant effect on compression strength, while it has a sharp effect on the slump values. The successful utilization of Cast iron would turn these waste materials that causes disposal problem into a valuable resource. The utilization will also reduce the strain on supply of iron, which will also reduce the cost of concrete.

Figure 1. Cast Iron waste used for our work

Figure 2. Sieved Cast Iron powder used for our work

OBJECTIVE OF THE PRESENT WORK:

The basic objective of this work is to study the suitability of metal casting waste as replacement to fine aggregate in concrete.

II. METHOLODOGY

Experimental work is carried out on strength properties of M30 concrete with casting waste of metal industry in varying proportions replacing the fine aggregate. The CI turnings used in the experiments were procured from an automobile industry at Autonagar, Vijayawada which is a major mechanical hub of Andhra Pradesh state. Particle analysis was performed using sieve analysis as per IS 383:1976 and other materials used are fine aggregate, coarse aggregate, cement, sand and water. To carry out the presented study, concrete cubes with varying proportions of CI turnings replacing the sand were casted. CI turnings were added at an interval of 0%, 10%, 15%, 20%, 25% and 30% since the fly-ash addition is allowed maximum up to 30% of the cement as per IS standards. So, the present addition was also done according to it. Compressive and flexural strength was selected for study of the effect of the proposed addition. Before initiating the concrete mix design calculation, batch preparation and testing.

MIX DESIGN CALCULATIONS

The M30 mix design for the proposed concrete mix was calculated according to IS 10262:2009. Quantities of cement, coarse aggregate and water were kept constant while the proportion of sand was gradually decreased with increasing proportion of CI turnings. CI turnings were added at an interval of 0%, 10%, 15%, 20%, 25% and 30% of sand. The details of mix design are shown in Table 2. Material proportioning based on mix design as shown in Table 3.

Table 2. Mix design for M30 concrete mix

Material by weight			**Mix proportion**
% addition	**Sand [kg]**	**CI [kg]**	**C:W:Fa:Ca:CI:A**
0	**15.08**	**0**	1: 0.4: 1.508: 3.052: 0.000: 0.05
10	**13.58**	**1.5**	1: 0.4: 1.358: 3.052: 0.150: 0.05
15	**12.82**	**2.26**	1: 0.4: 1.282: 3.052: 0.226: 0.05
20	**12.07**	**3.02**	1: 0.4: 1.207: 3.052: 0.302: 0.05
25	**11.31**	**3.76**	1: 0.4: 1.131: 3.052: 0.376: 0.05
30	**10.56**	**4.52**	1: 0.4: 1.056: 3.052: 0.452: 0.05

C- Cement, W-Water, F_a - Fine Aggregate, C_a – Coarse Aggregate, CI- Cast Iron, A- Admixtures

Table 3. Material proportioning based on mix design.

% addition	Cement(Kg)	Sand(Kg)	20mm aggregate (Kg)	10mm aggregate (Kg)	Water(Kg)	CI(Kg)	Admixture (Kg)
0 %	10	15.08	19.84	10.68	4	0	0.5
10 %	10	13.58	19.84	10.68	4	1.5	0.5
15 %	10	12.82	19.84	10.68	4	2.26	0.5
20 %	10	12.07	19.84	10.68	4	3.02	0.5
25 %	10	11.31	19.84	10.68	4	3.76	0.5
30 %	10	10.56	19.84	10.68	4	4.52	0.5

III. EXPERIMENTAL WORK

PREPARATION OF CONCRETE SAMPLES

Concrete cubes of size 150×150×150mm, cylinders of size 300x 150 and beams of size 700x150x150mm were casted in standard moulds at three intervals (around 50 mm each). At each interval, concrete was compacted giving 25 blows by a compaction rod. At the end of the third interval, cubes and beams were vibrated for 1-2 minutes on a vibrating machine and then the top surface of the cube was finished using a trowel. After that, the moulds were left for drying for 24 hours. At the end of 24 hours, the cubes and beams were removed from the moulds and were submerged in water tanks for curing for 28 days.

TESTING OF SPECIMENS

Cube compressive strength test:

Compression test on the cubes is conducted on the 2000 kN AIMIL - make digital compression testing machine. The pressure gauge of the machine indicating the load has a least count of 1 kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen and the ultimate load is noted. The cube compressive strength of the concrete mix is then computed. This test has been carried out on cube specimens at 7 days and 28 days age.

Split tensile strength test:

This test is conducted on 1000 kN AIMIL make digital compression testing machine. The cylinders prepared for testing are 150 mm in diameter and 300 mm long. After noting the weight of the cylinder, diametrical lines are drawn on the two ends, such that they are in the same axial plane. Then the cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and the load is recorded. From this load, the splitting tensile strength is calculated for each specimen. In the present work, this test has been conducted on cylinder specimens after 7 days and 28 days.

Flexural strength test:

The test is conducted on a loading frame. The beam element is simply supported on two rollers of 4.5 cm diameter over a span of 450 mm. The element is checked for its alignment longitudinally and adjusted if necessary. Required packing is provided using rubber material. Care was taken to ensure that the two loading points were at the same level. The loading was applied on the specimen through hydraulic jacks and was measured using a 500 kN pre-calibrated proving ring. The load is transmitted to the beam element through the I-section and two 16mm diameter rods spaced at a distance of 300mm. For each increment of loading, the deflections at the centre of span are recorded using dial gauges. Continuous observations were made and the cracks were identified with the help of magnifying glass. Well before the ultimate stage, the deflectometers were removed and the process of load application was continued. As the load increased, the cracks are widened and extended to top and finally the specimen collapsed in flexure.

IV. RESULTS AND DISCUSSIONS

The test results for compressive strength of concrete cubes split tensile strength of cylinders and flexural strength of concrete beams were presented in tabular forms and graphs. The results of compressive strength, Flexural strength and split tensile strength are given in tables 4,5,6,7,8 and 9. The graphical representations of variations of strength with percentage increases of CI were shown in figures 3,4 5,6,7 and 8.

Table 4. Compressive Strength with replacement of Cast iron turning for 7 days, MPa

S.No	% Cast Iron Turnings	Compressive Strength at 7 days MPa
1	0 %	28
2	5 %	28
3	10 %	30
4	15 %	31
5	20 %	35
6	25 %	36
7	30 %	36

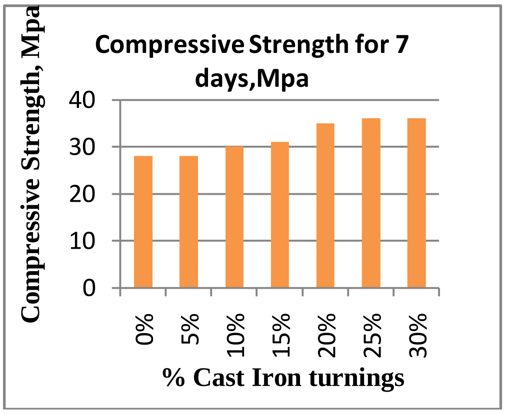

Figure 3. Compressive strength for 7 days

A graph is plotted between percentage cast iron turnings on x-axis and compressive strengthat 7 days on y-axis. Initially the compressive strength at 0% replacement of cast iron turnings is 28 Mpa and finally reached to 36 Mpa, after 30% replacement of sand with cast iron turnings for 7 days. From the graph it is understood that ther is no rise in compressive strength after 25% replacement with cast iron turnings.

Table 5. Compressive Strength with replacement of Cast iron turning for 28 days, MPa

S.No	% Cast Iron Turnings	Compressive Strength at 28 days, MPa
1	0 %	38
2	5 %	40
3	10 %	42
4	15 %	48
5	20 %	48
6	25 %	49
7	30 %	49

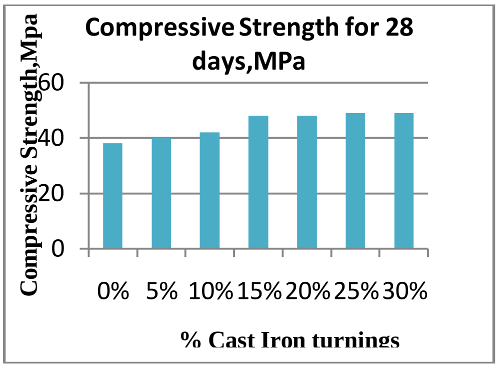

Figure 4. Compressive strength for 28 days

A graph is plotted between percentage cast iron turnings on x-axis and compressive strengthat 28 days on y-axis. Initially the compressive strength at 0% replacement of cast iron turnings is 38 Mpa for 28days and finally reached to 49 Mpa, after 30% replacement of cast iron turnings for 28 days. From the graph it is understood that ther is no rise in compressive strength after 25% replacement with cast iron turnings.

Table 6. Flexural Strength with replacement of Cast iron turning for 7 days, MPa

S.No	% Cast Iron Turnings	Flexural Strength at 7 days, MPa
1	0 %	3.29
2	5 %	3.29
3	10 %	3.41
4	15 %	3.46
5	20 %	3.68
6	25 %	3.73
7	30 %	3.73

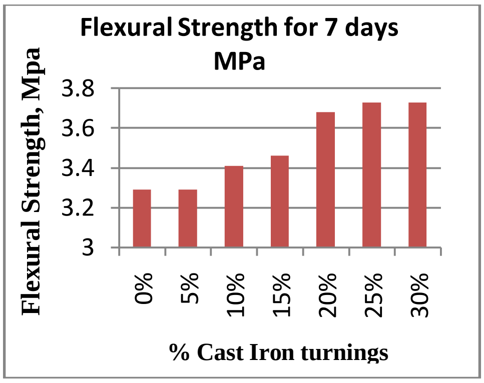

Figure 5. Flexural strength for 7 days

A graph is plotted between percentage cast iron turnings on x-axis and flexural strength at 7 days on y-axis. Initially the flexural strength at 0% replacement of cast iron turnings is 3.29Mpa for 7days and finally reached to 3.73Mpa, after 30% replacement of cast iron turnings for 7 days. From the graph it is understood that ther is no rise in flexural strength after 25% replacement with cast iron turnings.

Table 7. Flexural Strength with replacement of Cast iron turning for 28 days, MPa

S.No	% Cast Iron Turnings	Flexural Strength at 28 days , MPa
1	0 %	4.46
2	5 %	4.58
3	10 %	4.69
4	15 %	5.02
5	20 %	5.02
6	25 %	5.07
7	30 %	5.07

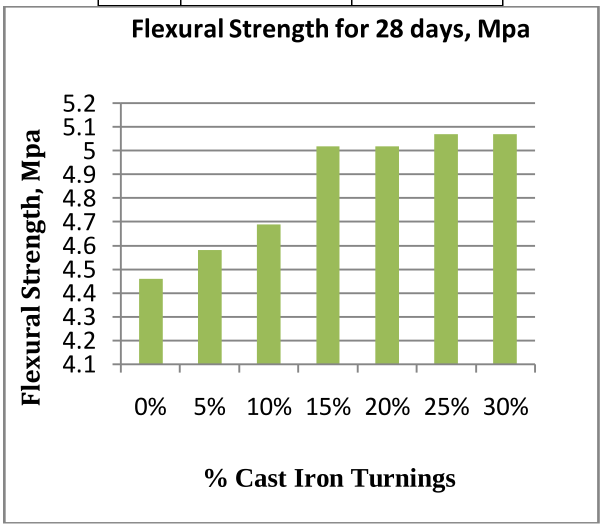

Figure 6. Flexural strength for 28 days

A graph is plotted between percentage cast iron turnings on x-axis and flexural strength at 28 days on y-axis. Initially the flexural strength at 0% replacement of cast iron turnings is 4.46Mpa for 28days and finally reached to 5.07Mpa, after 30% replacement of cast iron turnings for 28 days. From the graph it is understood that ther is no rise in flexural strength after 25% replacement with cast iron turnings.

Table 8. Split tensile Strength with replacement of Cast iron turning for 7 days, MPa

S.No	% Cast Iron Turnings	Split tensile Strength at 7 days, MPa
1	0 %	2.3
2	5 %	2.3
3	10 %	2.7
4	15 %	2.8
5	20 %	3.0
6	25 %	3.6
7	30 %	3.6

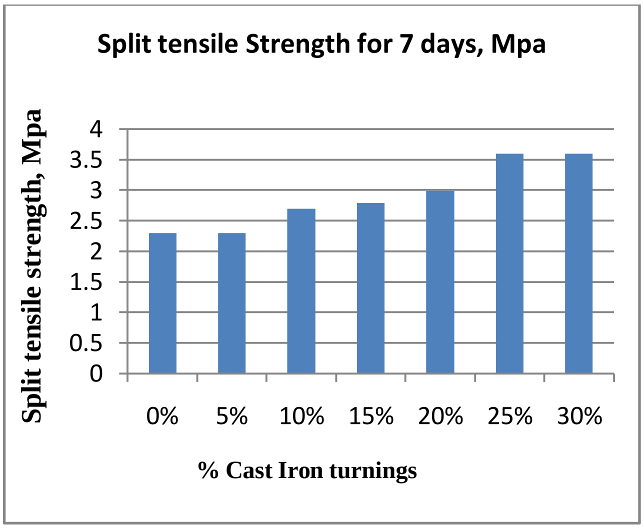

Figure 7. Split tensile strength for 7 days

A graph is plotted between percentage cast iron turnings on x-axis and Split tensile Strength at 7 days on y-axis. Initially the Split tensile Strength at 0% replacement of cast iron turnings is 2.3 MPa for 7days and finally reached to 3.6 MPa, after 30% replacement of cast iron turnings for 7 days. From the graph it is understood that ther is no rise in flexural strength after 25% replacement with cast iron turnings.

Table 9. Split tensile Strength with replacement of Cast iron turning for 28 days, MPa

S.No	% Cast Iron Turnings	Split tensile Strength at 28 days, MPa
1	0 %	3.1
2	5 %	3.3
3	10 %	3.4
4	15 %	3.8
5	20 %	3.8
6	25 %	3.9
7	30 %	3.9

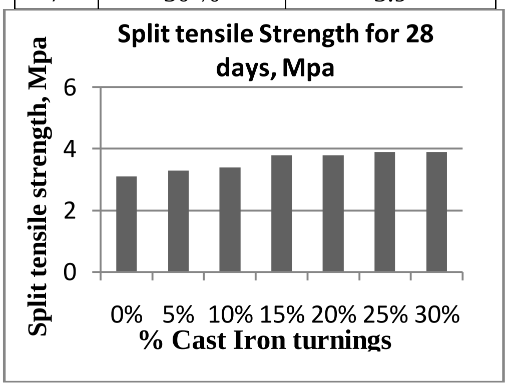

Figure 8. Split tensile strength for 28 days

A graph is plotted between percentage cast iron turnings on x-axis and Split tensile Strength at 28 days on y-axis. Initially the Split tensile Strength at 0% replacement of cast iron turnings is 3.1 MPa for 28days and finally reached to 3.9 MPa, after 30% replacement of cast iron turnings for 28days. From the graph it is understood that ther is no rise in flexural strength after 25% replacement with cast iron turnings.

V. CONCLUSIONS

The following conclusions are derived from the present experimental work:

- The above discussed results show that the addition of CI turnings in the concrete mix has a positive impact on the compressive strength, split tensile and flexural strength of the concrete mix.
- Compressive strength increases with an increase in percentage of CI turnings up to 25% replacement of cement and beyond 25% there is no change in strength.
- Flexural strength also increases with increase in percentage of CI turnings up to 25% replacement and of cement beyond 25% there is no change in flexural strength.
- Split tensile strength increases with an increase in percentage of CI turnings up to 25% replacement of cement and beyond 25% there is no change in flexural strength.
- Considering the strength criteria, the replacement of cement by CI turnings is feasible. Therefore we can conclude CI turnings can be used as a partial replacement to fine aggregate.

Future Scope:

The presented work displays the effect of GCI and DCI turnings on the compressive strength of the concrete mix. Such industrial scrap can be combined with other wastes like Fly-ash, Marble powder, demolition waste etc. to examine the combined effect on concrete characteristics thus, reducing the required quantity of cement, sand and aggregate in the mix.

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