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Effect of Partial Replacement of Sand by Mild Steel Filings in Concrete

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ABSTRACT:
Metals waste materials create serious environmental problems, mainly owing to the inconsistency of the waste streams. Mild steel filings are very small pieces of steel that look like a steel fiber. They are very often used in science demonstrations to show the direction of a magnetic field. The purpose of this project is to evaluate the possibility of using mild steel filings as one of the components of concrete mix. Five different percentage of mild steel filing were added to concrete mix to measure the variation which may be obtained in compression and tensile strength of concrete after 7 & 28 days. A number of standard cubes and cylinders were casted and tested in this study using 0% (control), 10%,15%, 20% and 25% of mild steel filing in concrete mix. Concrete cubes of size 150mm x150mm x 150mm and cylinders will be prepared and tested for compressive strength and tensile strength respectively after 7 and 28 days. A result data obtained has been analyzed and compared with a control specimen. Result data clearly shows percentage increase in 7 and 28 days compressive strength and flexural strength.

Keywords: *Mild steel filings, compressive strength test, split cylinder test.*

1. INTRODUCTION

The management of steel filings and turn outs poses a major problem for all third world countries. Also, with the increasing number of lathe machines, the industrial development which several countries are currently knowing, and the small percentage of recycled steel filings (rethreaded or used for other purposes) due to the absence of an adequate plan for eliminating this waste, these countries know surely a major environmental problem. The absence of statistics on this subject does not enable us today estimate suitably the mass of waste steel filings thrown in nature or burned in public dumpsters. But if we compare these countries with the European Union countries which took this problem in charge, through legislation, recycling companies, re-search, we can say that many countries are postponing the solution to this problem, and that the mass of steel filings can only be considerable.

One of the recommended solutions to solve this environmental problem is to incorporate steel filings as aggregates in the cement concretes. On this subject, several studies concerning the use of steel filings as aggregates were carried out. These research works showed that the benefits of associating steel filings-concrete with high deformability and on the durability of these composites.

Moreover, the benefit which we can gain from using the cement concretes for the roadways makes us think about multiplying the studies on the cement composites that incorporate steel filings aggregates since the rigidity of the cement concretes can make it possible either to decrease the granular layer necessary to the asphalt road- way or to allow the use of less resistant concretes. This is the case with the use of concretes having a considerable part of steel filings.

Even though there are many sustainable destinies for waste steel filings, the construction industry has shown little understanding of the potential of this waste. However, a number of promising possibilities have been emerging that have some weight in the market: asphalt, kindergarten and sports area pavements, impact barriers on roads, and breakwaters. These applications prove how interesting it is to pursue new research fields that could show how waste steel filings can be reused competitively in the sector.

With a great ecological concern and in saving traditional aggregates, we have replaced a part of the conventional aggregates by steel filing aggregates resulted from different lathe machines and workshops.

2. Material and Methods

The material used in the project is cement, sand, coarse aggregates, mild steel filings. The cement, sand and coarse aggregates are easily available in the market while the mild steel filings are available at workshops and lathe machine workshops. For this Project the mild steel filings were collected from a workshop of IUST Awantipora. The steel filings used were in the size range of 2 to 5cm.

2.1 Materials used

Materials obtained for making concrete (cement, sand and aggregate) were tested for their respective properties according to the respective IS codes.

i) Cement

Ordinary Portland Cement (OPC) 53 Grade (Max cement) has been used for this project. The summary of various tests conducted on cement as per IS: 4031. The data reported is average value of three test trials: -

Table 2.1: - Physical Properties of cement

Synod.	Characteristics	Obtained Values	Standard Values
1.	Standard Consistency	28%	27-33%
2.	Initial Setting Time	.55hrs	Not less than 30 minutes
3.	Final Setting Time	5.57hrs	Not more than 10 hours

i) Fine Aggregates

Fine aggregate are materials passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Good quality river sand passing through 4.75 mm IS sieve with specific gravity of 2.6, was used as fine aggregate.

ii) Coarse Aggregates

Coarse aggregate form the main matrix of the concrete, whereas fine aggregate form the filler matrix between the coarse aggregate. Crushed natural rock stone aggregate available from local sources were used. 10-20 mm of coarse aggregates were used.

iii) Mild steel filings:

Mild steel of standard quality is used to convert into filings of thickness 1-2mm and size 2 to 5cm. The modulus of elasticity of mild steel is 200000Mpa.

Table 2.2: - Properties of Mild Steel Filings

Thickness mm	Modulus of lasticity	Density g/cc
0.1-0.2	2.1×10^5	7.8

The above specifications have been specified by principal manufacturer of filings.

iv) Water

Tap water conforming to IS Code was used for mixing as well as curing of concrete specimens. The pH of water was checked by using pH paper and the pH was 6.4.

3. Preparation of samples:

All samples were prepared in the Concrete Laboratory at IUST during the months of March-June, 2015. The samples for compression testing were cubes of size (15cm x15cm x15cm), the Beams of size (50cm x 10cm x 10cm) were used for flexure testing and the cylinders of size (10cm x 20cm) were used for split tensile strength testing.

3.1 Mixing:

The cement: sand: aggregate ratio of 1:1:2 was taken and the calculations of each constituent were done by weight analysis. For replacements, the sand replacement %age was taken as in Table: 3.3. The water/cement ratio was kept as 0.45 for all samples.

The proportioned mix was blended together by hand, and then water was added to it in small quantities. The mixture was mixed continuously by hand using trowels till the appropriate concrete workability is reached.

CONCRETE MIX DESIGN (GRADE M20)

i) Characteristic compressive strength
Required in the period of 28 days - 20Mpa

Max. Size of aggregate - 20 mm (angular)

Degree of workability - 0.90

Type of exposure – mild

ii) Test data for materials
Specific gravity of cement - 3.10

Specific gravity of C.A - 2.65

Specific gravity of F.A - 2.65

Target mean strength of concrete
The Target mean strength for

Specified Characteristic cube strength = 20 + (1.65 x 4) =26.6 MPa

Adopt W/C ratio of 0.45

For change in W/C ratio, compacting factor, for sand belonging to

zone II following adjustment is required.

Table. 3.1 Change in W/C Ratio

Change in condition	Present adjustment required	
	Water content	Sand in total aggregate
For decrease in W/C ratio	0	-3.0
For increase in compaction factor	+3	0
For sand	0	-1.5
Total	3	-4.5

Table 3.2: Mix proportion.

Sno.	Mix Id	Cement kg/m^3	Sand kg/m^3	Steel Filings kg/m^3	Coarse Agg. kg/m^3	% replacement	W/C ratio
01	**PC**	**600**	**600**	**0**	**1200**	**0**	**0.45**
02	**SF5**	**600**	**570**	**30**	**1309**	**05**	**0.45**
03	**SF10**	**600**	**540**	**60**	**1309**	**10**	**0.45**
04	**SF15**	**600**	**510**	**90**	**1309**	**15**	**0.45**
05	**SF20**	**600**	**480**	**120**	**1309**	**20**	**0.45**
06	**SF25**	**600**	**450**	**150**	**1309**	**25**	**0.45**

Where;

SF5 represents sample with 5% steel filings

Similarly, SF10, SF15, SF20, SF25 represent their respective samples

PC represents plain concrete.

4. Result and Interpretation
The results show the variation in Compressive strengths, Flexural strengths, split tensile strength of various mixes in which the fine aggregates are replaced by various percentages of steel filings. (Refer Table 4.1). The results also show the variation in Compressive strength.

4.1 Standard Consistency Test:
i) For standard cement:

Table 4.1:Standard consistency result.

Sample	Consistency (%)	Mean
PC	27	28
PC	29	
PC	28	

4.2 Initial & Final setting time tests:

i) For standard cement.

Table 4.2: Setting time results.

Initial setting time (hrs.).	Final setting time (hrs.).	Mean of initial setting time.	Mean of final setting time.
0.52	5.72	0.55	5.57
0.55	5.41		
0.59	5.58		

4.3 Abrasion and Crushing Tests for Coarse Aggregates:

Table 4.3: Result of abrasion test.

Tests	Natural Aggregates.	Mean of natural agg.
Abrasion value (%).	2.0	1.87
	1.9	
	1.7	
Crushing value (%).	7.1	6.46
	6.5	
	5.8	

4.4 Water Absorption Tests for Coarse and Fine Aggregates:

Table 4.4: Water absorption results.

	Water Absorption value (%).		Mean
Coarse Aggregates.	Gravel.	0.73	0.66
		0.65	
		0.61	
		0.17	
		0.15	
Fine Aggregates.	River Sand.	0.29	0.31
		0.34	
		0.31	

4.5 Workability test results for percent steel filings in concrete:

Table 4.5:Workability results.

Sample	Slump(mm)	%age reduction of slump
PC	70	_
SF-5	68	4
SF-10	64	12
SF-15	63	14
SF-20	60	14.28
SF-25	58	17.14

4.6 Compression test:

A. 7 days Compressive strength concrete with 5, 10, 15, 20 and 25% replacements of fine agg. by steel filings.

Table 4.6: 7 days compressive strength of cubes.

Sample	Stress(N/mm^2)
PC	15.2
SF-5	16.02
SF-10	16.3
SF-15	17.3
SF-20	19.9
SF-25	19.6

B. 28 days Compressive strength concrete with 5, 10, 15, 20 and 25 % replacements of fine agg. by steel filings.

Table 4.7: 28 days compressive strength of cubes.

Sample	Stress(N/mm^2)
PC	24.80
SF-5	25.96
SF-10	33.31
SF-15	32.12
SF-20	31.10
SF-25	30.20

4.7 Flexure test:

The flexural strength of specimen is expressed as the modulus of rupture Fb which if 'a' equal the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of specimen, in cm is calculated as follows:

$$\text{fb} = \frac{\text{f x l}}{bd^2}$$

Table 4.8:28 days flexural strength.

Samples	Stress(N/mm^2)
PC	3.56
SF-5	3.91
SF-10	4.69
SF-15	4.82
SF-20	4.77
SF-25	4.52

4.8 Split tensile strength test:

When load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to horizontal stress of magnitude;

$$Stress = \frac{2\text{p}}{\pi LD} \quad (\text{N/mm}^2)$$

Table 4.9:28 days split tensile strength.

Sample	Stress(N/mm^2)
PC	3.1
SF-5	3.39
SF-10	3.37
SF-15	3.56
SF-20	3.54
SF-25	3.50

Discussion

Following variation are studied:

a) Fresh concrete:

Workability: While carrying our project work, it was visualized that workability of concrete decreased with increase in percentage replacement of fine aggregate by steel filing content.

Table 4.10:Percent reduction of slump.

Sample	%age reduction of slump
PC	________
SF-5	4
SF-10	12
SF-15	14
SF-20	14.28
SF-25	17.14

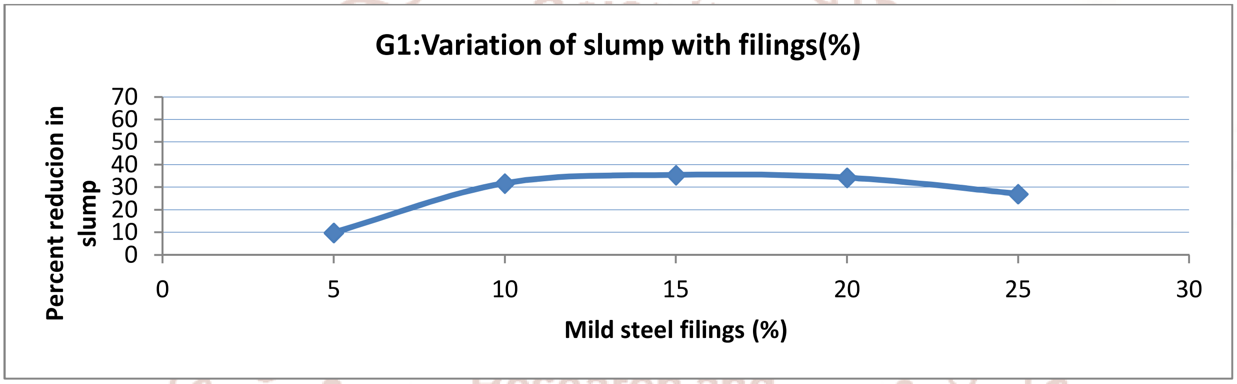

Fig 4.1 Variation of Slump with Filings (%)

Reason for low workability:

Low workability of mild steel filed concrete is due to hinderance of movement of concrete particles by mild steel filings and due to friction between aggregates and filings. The reason for the reduction of slump with %age increase of filings may be due to the ball effect of filings which hinder the movement of aggregates.

b) Hardened concrete:

Compressive strength: There is increase in compressive strength of concrete on replacement of fine aggregate by mild steel filings. 7 days compressive strength of SF-20 is found to be highest among all the replaced mixes. While, 28 days compressive strength is found to be highest for SF-10.

Table 4.11: Percent increase in 7 days compressive strength.

Sample	Percent increase in 7day compressive strength
SF-5	5.39
SF-10	7.14
SF-15	13.8
SF-20	30.92
SF-25	28.94

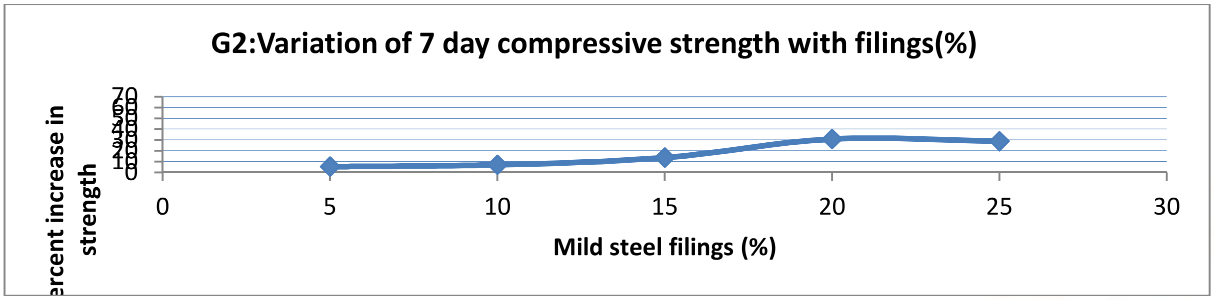

Fig 4.5 Variation of 7 Days Compressive Strength with Filings (%)

Table 4.12:Percent

Sample	Percent increase in 28-day compressive strength
SF-5	4.68
SF-10	34
SF-15	29.5
SF-20	25.4
SF-25	21.78

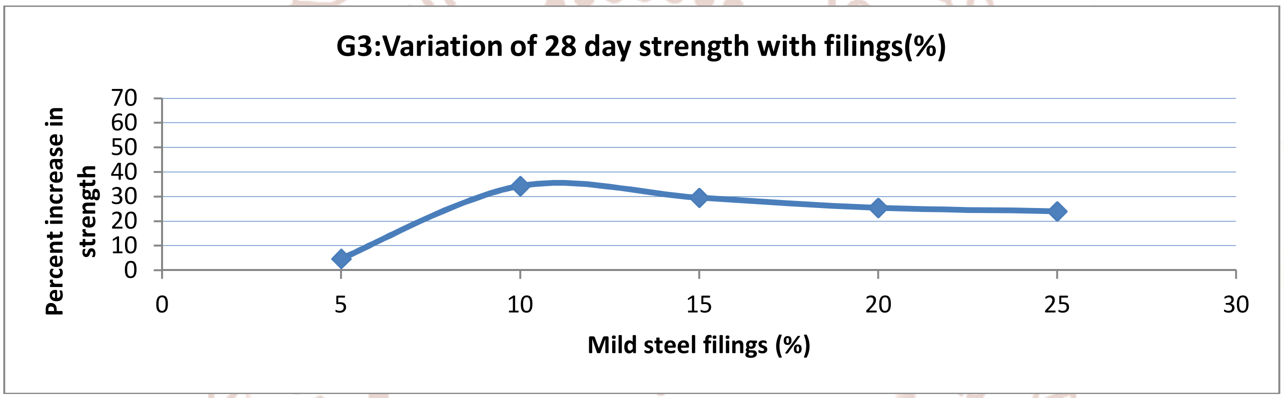

Fig 4.3 Variation of 28 Days Strength with Filings (%)

Reason for high compressive strength:

Increases of compressive strength of mild steel filing concrete than plain concrete is due to proper bonding between concrete and steel filings. High compressive strength of steel filled concrete is also due to high adhesion between concrete and filings and cement matrix. It is also contributed due to high strength of steel particles than concrete matrix around them.

Compressive strength comparison:

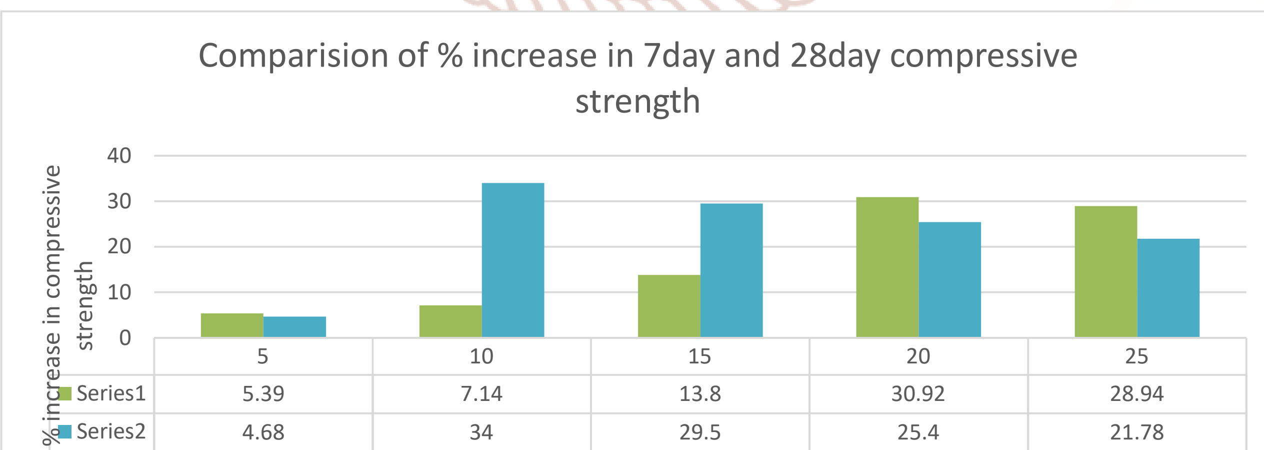

Fig 5.4 Comparison of % Increase on 7 Days and 28 Days Compressive Strength

Flexure strength:

Flexure strength steel filing concrete shows varying trend. 28 days flexure strength of SF-15 is found to be highest among all replacement mixes as well as plain concrete. There is an overall increase in flexural strength of concrete by replacement of fine aggregates with steel filings.

Table 4.13: Percent increase28 days flexural strength.

Sample	Percent increase in flexural strength
SF-5	9.83
SF-10	31.7
SF-15	35.4
SF-20	34.2
SF-25	27.00

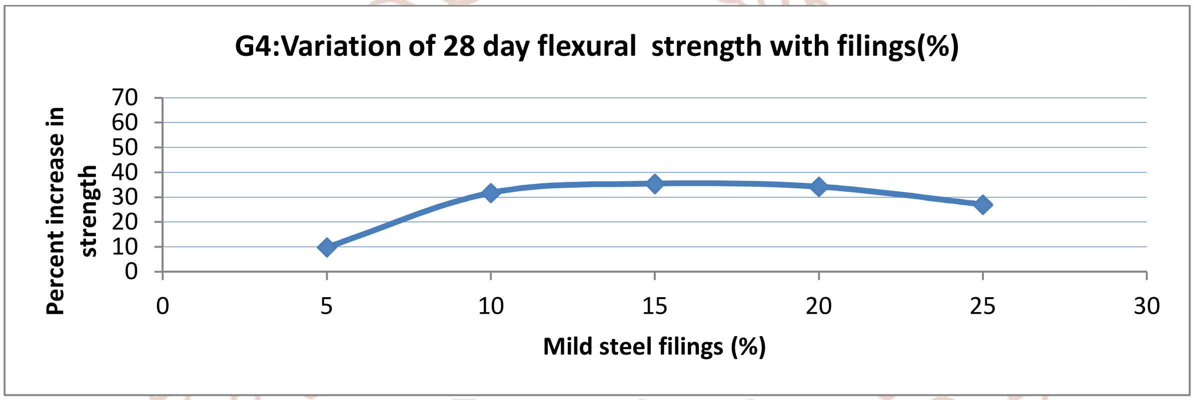

Fig 5.5 Variation of 28 Days Flexural Strength with Filings (%)

Reason:

The reason for the increase in the flexural strength is due to the bridging of crack by the steel filing. It enables the composite concrete to take more load in flexure. The improve may also be due the proper bond between mild steel turn-outs and concrete.

Split tensile strength:

Split tensile strength of steel filings concrete also increases. However, maximum tensile strength was found at 15% replacement of fine aggregate by steel filings.

Table 4.14: Percent increase28 days split tensile strength.

Sample	Percent increase in flexural strength
SF-5	9.35
SF-10	10.00
SF-15	14.83
SF-20	14.19
SF-25	12.9

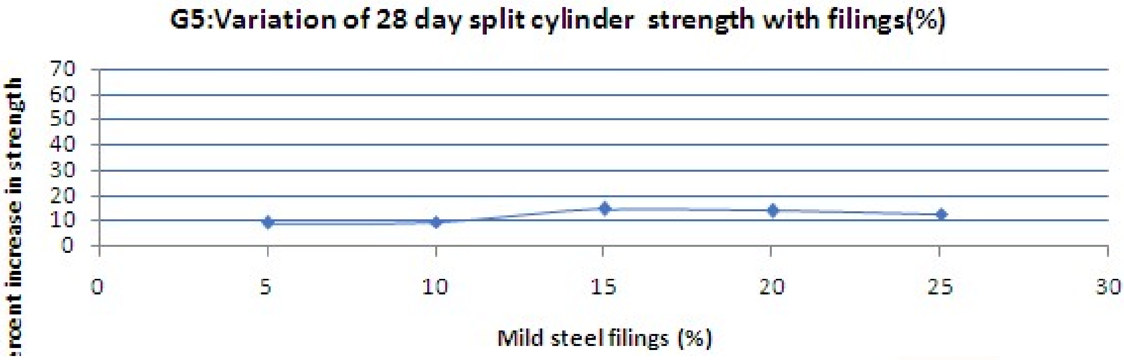

Fig 4.6 Variation of 28 Days Split Cylinder Strength with Filings (%)

5. Conclusion and Recommendations

The purpose of this study was to determine if waste materials such as mild steel filings or steel turn-outs enhances the characteristic properties of concrete. The data presented in this project shows that there is great potential for the utilization of waste steel turn-outs obtained by various lathe machines and steel workshops. By rehabilitating these scraps extracted from the steel lathe shops, improved the tensile properties of concrete in the order of 30 to 35 %. This is very much encouraging as the use of such scraps is affordable by the common man.

The higher strength concretes were used for the commercial applications only as it cost high. But, due to its advantageous properties of using fewer materials which is the reserve in nature and revenue returns in the form of utilizable spaces within the buildings, it is adopted by the common man too. The post cracking behavior of turn steel fibre reinforced concrete is well comparable with the results of concrete enhanced by conventional commercially available steel fibres. The scraps which were discarded unattended has shown its way of rehabilitation by enhancing the properties of concrete at absolute zero additional cost thus proving a new step of sustainable development. Thus, it may be considered that the waste steel turn-outs form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as fine aggregate.

In this project, the performance of concrete made by adding steel turn-outs was studied. The following conclusions were drawn:

1) Fresh concrete properties such as compaction factor value and Slump decreased with the higher replacement levels of turn-outs of steel.
2) Increase in steel filing content enhanced the compressive strength of the concrete significantly and showed optimum value at 10% of steel filings.
3) There is a great potential for steel turn-outs to be used in the concrete, thus saves area from becoming as landfill and is thus eco-friendly with environment.
4) The combined action of aggregates and steel filings enhance thermal conductivity that helps to the transport of heat. If we analyze such properties in relation to density in the hardened state, we can note an increase of the thermal conductivity with the density increasing, the increase of density corresponds to a more compact structure, so to a reduction of its porosity.
5) In reference to the test concerning the resistance of steel filing concrete to Sulphate and Chloride attack, it is found that it shows improved resistance to these attacks. The reason is evident as by adding steel filings dense matrix is formed i.e. less porous and also crack propagation is restricted which prevents the aggression of these deleterious chemicals.
6) During the tests it was noted that as the percentage amount of steel filings increased, the amount of energy required for casting specimens increased substantially, because of the reduction of workability in the concrete.
7) It was also observed that the incorporation of the steel filings has little effect on pre-cracking but greatly improve its post-cracking.
8) Steel filings substantially improve the toughness and ductility of the composite concrete.

9) The purpose of this study was to determine if a waste material like steel turn-outs enhance the characteristic properties of concrete. The data presented in this project shows that there is great potential for the utilization of steel turn-outs as aggregates. It is considered that these steel scarps would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for more expensive material such as rock aggregate.

10) There is little increase in the unit weight of the composite concrete.

Thus, we can conclude that there is decrease in workability and little increase in unit weight to the inclusion of steel filings aggregates do limit its use in some structural applications, but it has lot of desirable characteristics such as higher compressive and flexural strength, higher impact and toughness resistance, enhanced ductility and better thermal conductivity etc. These properties can be advantageous to some construction applications.

Recommendation:

Workability:
The workability of concrete due to partial replacement of fine aggregate by steel filings decreases the workability with respect to standard. Though, workability decreases to small extent due to addition of filing yet it need to be addressed. It can be improved by use of plasticizers and super plasticizers along with filings. Use of plasticizer may allow more reduction of W/C ratio hence more durability and strength.

Compressive strength:
There is increase in compressive strength of concrete on % replacement of fine aggregate by steel filings. The compressive strength SF-10 is found to be highest among all the replaced mixes, which is 34% more than plain concrete. So, we recommend SF-10 to be the best option as compared to other replacement mixes**.**

Split Tensile strength.
Split tensile strength of steel filings concrete also increases by partial replacement of sand by filings. However, maximum tensile strength was found to be in case of 15% replacement of fine aggregate by steel filings.

Flexural strength:
The 28 days flexure strength of SF-15 is found to be highest among all replacement mixes. For other percentages it is also found that flexural strength has increased than the plain cement concrete.

Ductility:
On performing flexural tests, we came to know that due to incorporation of steel filings in concrete, it gained ductility. So, it can be used as a foundation material in earthquake areas due to ductility and dampness as well.

Connection Material:
During the test it was observed the steel filing in concrete prevent sapling of concrete as compared to the plain concrete, hence this concrete in future can prove better material for connections than plain concrete.

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