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Development of High Strength Concrete Using Ferrochrome Slag Aggregate As Replacement to Coarse Aggregate

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ABSTRACT: *Ferrochrome slag is one of the alternative materials which can be used as coarse aggregate in concrete. Ferrochrome slag is a major solid discarded bi-product got during the manufacturing of ferrochrome alloy. The Ferrochrome slag generated is a stable, dense, crystalline product having tremendous mechanical and engineering properties suitable for utilization as aggregate material in concrete. In the current study, Replacement of ferrochrome slag with conventional coarse aggregate in concrete for high strength (M50 Grade) concrete for every incremental of 25% replacement upto 100% is done. The fresh properties of concrete are determined by means of Slump cone test, Vee-Bee consistometer test and Compaction factor test. The hardened property of concrete is determined by casting cubes for compressive strength, cylinders for split tensile strength and prisms for flexural strength for 7days, 14days and 28days curing. The results obtained are compared with conventional coarse aggregate (0% replacement) concrete.*

Keywords: *Ferrochrome Slag, Coarse Aggregate, Compressive Strength, Split Tensile Strength, Flexural Strength*

I. INTRODUCTION

Concrete is a versatile material widely used as principle element for structures and for other applications. The demand on concrete is increasing day by day due to the growing population, housing, transportation and other amenities. As a result the demand for concrete making materials also increases leading to the scarcity of naturally available fine and coarse aggregate required for concrete making. Additionally, the speedy development of industrialization contributed to different types of waste bi-products which is environmentally dangerous and creates problem in disposal. Hence, utilization of suitable waste bi-products in construction industries has become an inevitable option in recent days by fulfilling the demands of concrete as well as reduction in impact on environment. The use of industrial waste as aggregates in concrete provides good platform to utilize the waste as alternatives to naturally available aggregates in concrete as aggregates are the main constituents of concrete making about 75% of its total volume. Ferrochrome slag is one of the alternative materials which can be used as both coarse and fine aggregate for replacement of river sand and crushed rock ballast in concrete by altering the physical form.

Ferrochrome slag a waste bi-product generated during the manufacturing of ferrochrome alloy. Ferrochrome alloy is manufactured in a submerged electric arc furnace by physiochemical process at the temperature of 1700^{o}C. Individually the molten liquids of the ferrochromium and slag flow out into dippers. Due to the different specific gravities of metal and slag, separation of the two liquids takes place. The liquefied ferrochrome slag gradually cools down in air forming a stable, dense, crystalline product having tremendous mechanical properties. The main constituents of ferrochrome slag are Sio_2, Al_2O_3 and Mgo with minor traces of ferrous/ferric oxides and Cao.

The use of Ferrochrome slag is limited when associated to its generation. They are used in civil engineering works and motorway constructions to some extent. The use of ferrochrome slag can reduces the procurement of natural aggregates and reduces the impact on environment. Although the waste slag has excellent properties, its usage has been limited due to its potentiality of discharging dangerous chromium compounds to the environment.In the present study, Ferrochrome Slag is assessed for its suitability to partially and fully replace the conventional coarse aggregate in M50 Grade concrete.

II. EXPERIMENTAL PROGRAMME

2.1 Material Properties

2.1.1 Cement

Cement used in this experimental programme is Ordinary Portland cement (OPC) of 43-grade Jay-pee cement. The cement for the whole experiment is brought in a single batch and stored properly. The cement properties are determined from experimental investigations and presented in Table 1. The cement is confirming to the IS: 8112-1989.

Table 1: Typical Properties of Cement

Property	***Results Obtained***	***Tolerance Limits as per IS: 8112-1989***
Specific Gravity	3.01	3.15
Fineness	2.5%	Not more than 10%
Standard Consistency	30%	Not more than 35%
Setting time (Initial)	120 minutes	30 minutes minimum
Setting time (Final)	300 minutes	600 minutes maximum
Strength at Compression 3days 7days 28days	 32.5N/mm^2 43.0N/mm^2 52.0N/mm^2	 23N/mm^2 minimum 33N/mm^2 minimum 43N/mm^2 minimum

2.1.2 Fine aggregate

The Fine aggregate used is naturally available River sand. The properties of Fine aggregate are determined from experimental investigations and presented in Table 2. The Fine aggregate is confirming to IS: 383-1970.

Table 2: Typical Properties of Fine aggregate

Property	***Results Obtained***
Specific gravity	2.76
Fineness Module	2.87
Water absorption (%)	2
Grading as per IS: 383-1970	Zone – II

2.1.3 Coarse aggregate

2.1.3.1 Conventional Coarse aggregate

Rock Ballast (Machine crushed) as Coarse aggregate is obtained from a local quarry. The properties of conventional coarse aggregate are determined and presented in Table 3. The Coarse aggregate is confirming to IS: 383-1970.

Table 3: Typical Properties of Coarse aggregate

Property	***Results Obtained***
Maximum nominal size(mm)	20.0
Specific gravity	2.811
Bulk density(kg/m^3)	1700
Water absorption (%)	2
Fineness Modulus	6.22
Impact Value (%)	24.67
Crushing Value (%)	29.97

2.1.3.2 Ferrochrome slag aggregate

Ferrochrome slag aggregate used in this study, is a waste material collected from a dump yard at M/S. NINITA ENTERPRISES, Rasulgarh, Bhubaneswar in Odisha. . The Ferrochrome slag aggregate properties are determined and tabulated in Table 4. The Ferrochrome slag aggregate is confirming to IS: 383-1970.

Table 4: Typical Properties of Ferrochrome slag aggregate

Property	***Results Obtained***
Maximum Nominal size(mm)	20.0
Specific gravity	3.0
Bulk density(kg/m^3)	1783
Water absorption (%)	2.0
Fineness Modulus	5.0
Impact value (%)	6.71
Crushing value (%)	11.750

2.1.4 Metakaolin

Metakaolin is used as a cement additive in concrete due to its pozzolanic nature. Metakaolin increases the workability and strength of concrete. Metakaolin used in this study is procured from ASTRA chemicals, Chennai.

2.1.5 Super plasticizer

Super plasticizers are used when there is use of fly ash, slag or silica fume in concrete replacements. Super plasticizer used in this study is Conplast SP430 procured from Fosroc Chemicals (INDIA) Limited, Bengaluru. Conplast SP430 confirming to IS: 9103-1999.

2.2 Mix Design and Mix Proportion

The grade of concrete adopted for experimental investigations is M50. The mix design is carried out according to guidelines of concrete mix-proportioning IS: 10262-2009. The mix is designed to have a minimum slump of 25-50mm.

It is observed that the cement content required for mix proportioning exceeds the design stipulations hence Metakaolin is replaced to 10% with weight of cement. 10% replacement is optimum value obtained based on trial mixes. It is observed that workability decrease with increase in replacement of conventional coarse aggregate with ferrochrome slag aggregate. Therefore, to achieve the required slump super plasticizer that is Conplast SP430 to 2% is used. The maximum size of coarse aggregate and ferrochrome slag aggregate is 16mm. A proportion of 1:1.32:1.29 with a Water/Cement ratio of 0.33 is obtained.

2.3 Preparation of Specimens

In the present investigation, to evaluate various properties of concrete mixes, tests are conducted to examine the performance of concrete mixes in both fresh and hardened state. The fresh property of concrete is evaluated by its workability. The test apparatus required for the whole experiments should be cleaned and freed from old concrete set before beginning the experiment. The hardened properties of concrete using ferrochrome slag aggregate are studied by casting cubes, cylinders and prisms.Fresh concrete being in slurry form requires good moulds to shape it to required form. So the moulds ought to be inflexible and solid to hold the heaviness of wet concrete without protruding any place. The moulds are screwed tightly to avoid leakages. A thin layer of lubricant is coated on the internal surface of the moulds.

The entire mixing of concrete is done through a mechanical mixer. The entire mix is done according to IS: 1791 and IS: 12119. The whole concrete is mixed for five minutes.

Vibration compaction is a method where the mould is filled in three equal layers and vibrated on a table vibrator at each layer over a period of 30 – 45 seconds per layer to complete compaction. After the compaction of specimens is complete, top surface should be finished off with a neat trowel. The casted specimens are removed from moulds after 24 hours and details of specimen with date are to be marked on the top surface for identification.

The casted specimens are carefully demoulded from the moulds after a period of 24 hours and submerged in a water tank which is free from organic and inorganic impurities for curing. The specimens are removed after a curing period of 7days, 14days and 28days for testing. The specimens should be allowed to dry in shade before testing.

2.4 Tests on Concrete

This Section describes the experiments programmed to establish Fresh and hardened properties of the Normal concrete as well as Concrete added with different percentages of ferrochrome slag aggregates.

2.4.1 Tests on fresh concrete

The fresh properties of concrete are determined by its measure of its workability. In this study, the Slump Cone Test, the Compaction Factor Test and Vee Bee Consistometer Test are engaged to measure workability.

2.4.2 Test on Hardened Concrete

The Testing of Hardened concrete plays a vital role in governing and checking the quality of cement concrete works and helps to determine the performance of the concrete with respect to strength and durability. In this study, for each batch of concrete, three cubes of 150mm x 150mmx 150mm sizes are tested for Compressive Strength. Three cylinders of 100mm diameter x 200mm height size are tested for Split Tensile Strength and three prisms of 500mm x 100mm x 100mm size are tested for Flexural Strength.

III. RESULTS AND DISCUSSION

3.1 Results

The test results of various tests performed on fresh and hardened properties of conventional concrete and concrete with replacement of Ferrochrome slag as aggregates are presented in Tables 5, 6, 7 and 8.

Table 5: Test results of Workability

43 Grade - Ordinary Portland Cement					
M50 Grade					
SL NO	*% of Replacement*	*W / C Ratio*	*Slump (mm)*	*Compaction Factor*	*Vee Bee Time (Sec)*
1	0	0.33	-	0.95	9
2	25		-	0.98	9
3	50		-	0.99	9
4	75		-	0.99	8
5	100		-	1.0	8

Table 6: Compressive strength of concrete cubes for various percentages of Ferrochrome Slag Aggregate

SL NO	*Percentage of Replacement*	*Compressive Strength (N/mm^2)*		
		7Days	*14Days*	*28Days*
1	0	31.97	35.65	50.27
2	25	44.39	45.61	52.49
3	50	52.87	56.96	57.47
4	75	54.51	60.30	70.24
5	100	36.79	43.74	55.98

Table 7: Split tensile strength of concrete cylinders for various percentages of Ferrochrome Slag Aggregate

SL NO	*Percentage of Replacement*	*Split Tensile Strength (N/mm^2)*		
		7Days	*14Days*	*28Days*
1	0	2.65	2.94	3.53
2	25	3.27	3.29	4.03
3	50	3.72	4.49	4.58
4	75	4.45	4.59	5.26
5	100	3.90	4.08	4.64

Table 8: Flexural strength of concrete Prism for various percentages of Ferrochrome Slag Aggregate

SL NO	*Percentage of Replacement*	*Curing Period (days)*	*Flexural Strength (N/mm^2)*
1	0	28	3.65
2	25		3.76
3	50		4.31
4	75		6.24
5	100		4.55

3.2 Discussion

Suitability of material

The specific gravity of ferrochrome slag (3.0) is greater than conventional coarse aggregate (2.81). This indicates that the quality of ferrochrome slag is good and concrete produced using this material will have high density. The Fineness modulus of ferrochrome slag (5.0) is less than that of conventional coarse aggregate (6.22). Hence indicates that ferrochrome slag affect the workability and strength of concrete. Impact value and crushing value of ferrochrome slag are more in comparison with that of Conventional Coarse aggregate indicating that material is of good quality and suitable for concrete making. Hence, Ferrochrome slag can be considered for use as conventional coarse aggregate in concrete.

Fresh Properties of Concrete

From the slump cone test, Collapse slump is observed in each replacement of ferrochrome slag aggregate in concrete indicating the concrete is highly workable mix. This is due to the addition of super plasticizers to the concrete. From the compaction factor test it is observed that M50 grade concrete is High workable. In Vee bee consitometer test, the time taken for re-moulding from frustum of cone to cylinder shape under vibration is termed as Vee bee time or degree. Vee bee time recorded is very less. This may be due to the use of super plasticizers in concrete.

Hardened Properties of Concrete

From the experimental values presented in Table 6 and 7, corresponding to curing period of 7days, 14 days and 28 days it can be observed that compressive strength and Split Tensile Strength of M50 Grade concrete increased with increase of ferrochrome slag aggregates up to 75% replacement and decreases slightly at 100% replacement. However the values obtained for 100% replacement are higher than the values of conventional concrete.

Based on the experimental values in Table 8, corresponding to curing period of 28days it can be observed that Flexural strength of M50 Grade concrete increased with increase of ferrochrome slag in concrete upto 75% replacement and decreases slightly at 100% replacement of ferrochrome slag aggregate. However the values of Flexural strength obtained for 100% replacement are higher than the values of conventional concrete.

Hence, based on the results of various tests performed on fresh and hardened properties, it is concluded that ferrochrome slag is suitable for use as alternative to conventional coarse aggregate in M50 Grade concrete.

IV. CONCLUSIONS

Based on the experimental investigation conducted on conventional coarse aggregate concrete and ferrochrome slag aggregate replaced concrete for M50 Grade, the following conclusions are drawn.

1. The basic properties like Specific gravity, impact strength and crushing strength of ferrochrome slag aggregates are higher than conventional coarse aggregate.
2. Workability of M50 grade concrete increased with increase of ferrochrome slag. This may be due to the use of Super Plasticizers.
3. The replacement of conventional coarse aggregate with ferrochrome slag aggregate in concrete upto 75% has resulted in increased strength in compression, split tensile and flexure by conventional curing.
4. Ferrochrome slag can be considered as alternative to conventional coarse aggregate in M50 grade concrete mix due to its higher strengths achieved.
5. The usage of ferrochrome slag as coarse aggregate in concrete reduces the usage of conventional coarse aggregate resulting in reduction of Environmental pollution.

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