USING OF FERRO-CHROME SLAG AS A COARSE AGGREGATE AND STONE DUST AS A FINE AGGREGATE

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Abstract – *The objective of the studies has been to know the properties of concrete by replacing coarse aggregate by Ferrochrome slag and fine aggregate by Stone Dust. Ferro-chrome slag is a waste material obtained from the production of Ferro-chrome, an essential component in stainless steel. It has been observed that Ferro-chrome slag waste is a suitable material for highway pavement work. This research work was conducted to know the performance of Ferro-chrome slag waste as a coarse aggregate in concrete which can substitute fully natural granite aggregates and to investigate the performance of stone dust as an fine aggregate. The fresh properties of concrete are determined by means of Vee-Bee consistometer test and Compaction factor test. The hardened property of concrete is determined by casting cubes for compressive strength and cylinders for split tensile strength for 7days and 28days curing. The results obtained are compared with conventional coarse aggregate concrete*.

Key Words: Coarse Aggregate, Compressive Strength, Split Tensile Strength, Ferrochrome Slag, Flexural Strength

1. INTRODUCTION

1.1 General

Concrete is a very important material and widely used in construction industry .It offers stability and design flexibility for the residential marketplace and environmental advantages through every stage of manufacturing and use .Locally, the characteristic compressive strength is usually measured based on 150 x150mm cubes according to BS approach. Concrete is a construction material composed of cement (commonly Portland cement) as well as other cementation material such as fly ash and slag cement, aggregate, water and chemical widely used in construction industry. Now a days there are many filter materials used in construction industries. In cement-based products, such as concrete and mortars, a balance between the particle sizes of the component must be kept in order to obtain the required material properties, such as workability and strength. Sometimes the aggregates lack the necessary amount of fines, hence fine particles, i.e. filler material, have to be added. The stone cutting plants are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the stone waste quickly and use in the construction industry The advantages of utilization of by products or aggregates obtained as waste materials are pronounced in the aspects of reduction in environmental load and waste management cost, reduction of production cost as well as improving the quality of concrete. Considering the above facts in view, the effect of partial replacement of fine aggregate with stone dust on concrete strength under compression and tension was investigated. Use of by products such as slag, dust or sludge from the metallurgical industries as filler materials in concrete may help to conserve natural resources and at the same time be an economically positive option. However, to be able to successfully use the available they must be suitable for the planned purpose, i.e. they must be compatible with cement. In this paper the experimental studies of Ferrochrome-slag and Stone dust will be discussed.

1.2 Ferro-Chrome Slag

Ferro-chrome (Fe-Cr) slag is a waste material obtained from the production of Ferro-chrome, an essential component in stainless steel. It has been observed that Ferro-chrome slag waste is a suitable material for highway pavement work. This research work was conducted to investigate the performance of Ferro-chrome slag waste. As an artificial coarse aggregate in concrete which can substitute fully natural granite aggregates

1.2 Chemical composition of Ferro-Chrome Slag.

Ferrochromium is a master alloy of iron and chromium. In high carbon ferrochromium, metallic Cr content is 60–65% with varying amounts of Fe and C. Ferrochromium is produced pyrometallurgically by Carbothermic reduction of chromite ore ($FeO{\cdot}Cr_2O_3$). The main raw material in the production of ferrochrome is chromite, which is basically chrome and iron oxides containing mineral. Chromite is used as lumpy ores, which must be generally agglomerated to make them usable to charge for the furnace. Fines in the smelting furnace cause unbalanced operation and thus decrease productivity. Different types of carbon

are used to reduce metal oxides in the furnace. The most important of them is metallurgical coke. Quartzite, bauxite, dolomite, corundum, lime and olivine are used as fluxing materials to get the right composition of slag.
A careful quality control of raw materials ensures maximum output and uniform quality in the smelting process. The main components of the slag are SiO_2, MgO, and Al_2O_3. The slag also includes Cr and Fe oxides and calcium oxide. Common phases in the slag are glass, spinels (Al_2O_3–MgO) and forsterite (MgO–SiO_2) , and small amount of CaO

Table 1.1: Trace Elements in Ferrochrome Slag

Test Sample	Cr-VI mg/kg	Ni mg/kg	Mn mg/kg	Zn mg/kg	Cd mg/kg	Hg mg/kg	As mg/kg	Se mg/kg	S mg/kg	Pb mg/kg
Ferrochrome Slag	6.8	69.4	1037.2	73.8	0.10	0.45	0.05	6.2	2.0	19.2

2. MATERIAL PROPERTIES

2.1 Cement

Cement used in this experimental program is Ordinary Portland cement (OPC) of 53-grade cement. The cement properties are determined from experimental investigations as given in IS: 4031-6(1988) and presented in Table 2.1. The cement is confirming to the IS: 12269-2013.

TABLE 2.1: PROPERTIES OF CEMENT

Property	Result Obtained	Requirement as per IS 12269:2013
Normal Consistency	32%	30-35%
Initial Setting Time	30 minutes	30 minutes minimum
Fineness	8%	Not more than 10%
Specific Gravity	3.15	3.15
Compressive Strength 3 Days 7 Days 28 Days	 29 N/mm^2 42 N/mm^2 55.0 N/mm^2	 27 N/mm^2 37 N/mm^2 53 N/mm^2

2.2. Natural Fine Aggregate River Sand

The Fine aggregate we used is River sand. The properties of Fine aggregate are determined from laboratory test and presented in Table 2.2. The Fine aggregate is confirming to IS: 383-1970.

TABLE 2.2: PROPERTIES OF FINE AGGREGATE

Property	Laboratory Test Results
Specific Gravity	2.69
Fineness modulus	2.55
Bulk modulus	1655.47 kg/m^3
Grading as per Is IS: 383-1970	Zone - II

2.3. Fine Aggregate Stone Dust

Stone dust is collected from local stone crushing units of Shimoga, Bengaluru. It was initially dry in condition when collected and was sieved by IS: 90 μ sieve before mixing in concrete. Stone dust is of grey color and shape of particles is irregular. Properties are mentioned in Table 2.3.

TABLE 2.3: PROPERTIES OF STONE DUST

Property	Laboratory Test Results
Specific Gravity	2.5
Fineness modulus	2.36
Grading as per Is IS: 383-1970	Zone - II
Water Absorption(%)	0.5%

2.4 Coarse Aggregate

2.4.1 Natural Coarse Aggregate

Coarse aggregate is obtained from a local quarry. The properties of conventional coarse aggregate are determined and presented in Table 2.3. The Coarse aggregate is confirming to IS: 383-1970.

TABLE 2.4.1: PROPERTIES OF COARSE AGGREGATE

Property	Lab Test Results
Specific Gravity	2.75
Maximum nominal size in mm	20
Flakiness Index(%)	7.85
Elongation Index(%)	19.18
Water absorption(%)	0.8
Fineness modulus	7.3
Impact Value(%)	22.8
Crushing Value(%)	25.8

2.4.2 Ferro-Chrome Aggregate

Ferrochrome Slag samples were collected from the Ferrochrome manufacturing industries located in Kalinga Nagar Industrial area in Odisha, Eastern part of India. The Ferrochrome slag aggregate properties are determined and tabulated in Table 2.4. The Ferrochrome slag aggregate is confirming to IS: 383-1970.

TABLE 2.4.2: PROPERTIES OF FERROCHROME AGGREGATE

Property	Lab Test Results
Specific Gravity	2.9
Maximum nominal size in mm	20
Flakiness Index(%)	6.2
Elongation Index(%)	24.1
Water absorption(%)	3.0
Fineness modulus	6.3
Impact Value(%)	9.1
Crushing Value(%)	13.1

3. MIX DESIGN AND MIX PROPORTION

The grade of concrete adopted for experimental investigations is M25. 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 workability decreases with increase in replacement of conventional coarse aggregate with ferrochrome slag aggregate. Therefore, to achieve the required slump super plasticizer is added. The maximum size of coarse aggregate and ferrochrome slag aggregate is 20mm.

4. PREPARATION OF SPECIMEN

In the present investigation, to evaluate the 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 and stone dust fine aggregate are studied by casting cubes.

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.

Vibrations 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 30-50 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 is complete are removed from the moulds after 24 hours and details of specimen with date are to be marked on the top surface for identification. Specimen submerged in a water tank for curing. The Specimens are removed after a curing period of 7days, 14days, 28days.

4. TESTS ON CONCRETE

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

4.1 Test 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.

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 15cm x 15cm x 15cm sizes are tested for compressive Strength. Three cylinders of 10cm diameter x 20cm height size are tested and three prisms of 50cm x 10cm x 10cm size are tested for flexural Strength

4. RESULTS AND DISCUSSION

4.1 Results

The test results of various tests performed on fresh and hardened properties of conventional concrete and concrete with replacement of Ferrochrome slag as coarse aggregate and stone dust as fine aggregate are presented in Tables 4, 5, 6 and 7.

Table 4: Test Results of Workability

SL.No	%of Coarse Aggregate replacement	% of Fine Aggregate replacement	W/C Ratio	Compaction Factor	Vee Bee Time (Sec)
1	0	0		0.90	5
		25		0.92	4
		50		0.95	2
		75		0.91	5

2	25	0	0.40	0.89	6
		25		0.91	4
		50		0.92	4
		75		0.90	5
3	50	0		0.87	7
		25		0.91	5
		50		0.92	5
		75		0.85	8
4	75	0		0.86	8
		25		0.87	8
		50		0.90	7
		75		0.89	7
5	100	0		0.85	8
		25		0.88	7
		50		0.90	7
		75		0.83	6

Table 5: Compressive strength of concrete cubes for various percentages of Fine and Coarse Aggregate

SL NO	%of Coarse Aggregate replacement	% of Fine Aggregate replacement	Compressive Strength (N/mm^2)	
			7 days	28 days
1	0	0	17.04	29.11
		25	18.53	32.14
		50	19.58	36.59
		75	15.25	28.49
2	25	0	18.31	30.29
		25	21.20	33.71
		50	23.56	38.68
		75	19.52	30.55
3	50	0	21.17	32.66
		25	22.36	34.85
		50	25.68	40.22
		75	19.78	33.61
4	75	0	20.35	30.87
		25	21.21	35.68
		50	26.45	41.59
		75	23.82	33.57
5	100	0	17.22	31.28
		25	21.15	32.87
		50	23.46	35.68
		75	22.11	28.45

Table 6: Split Tensile strength of concrete cubes for various percentages of Fine and Coarse Aggregate

SL NO	%of Coarse Aggregate replacement	% of Fine Aggregate replacement	Split Tensile Strength (N/mm^2)	
			7 days	28 days
1	0	0	1.39	2.04
		25	1.51	2.25
		50	1.72	2.52
		75	1.55	1.99
2	25	0	1.52	2.12
		25	1.86	2.34
		50	1.92	2.72
		75	1.61	2.10
3	50	0	1.73	2.24
		25	1.95	2.44
		50	2.01	2.81
		75	1.62	2.35
4	75	0	1.66	2.13
		25	1.8	2.37
		50	2.21	2.80
		75	1.95	2.45
5	100	0	1.41	1.97
		25	1.75	2.35
		50	1.95	2.36
		75	1.92	2.19

4.2 Discussion

4.2.1 Suitability of Material

4.2.1.1 Ferro-Chrome Slag

The specific gravity of ferrochrome slag (2.9) is greater than conventional coarse aggregate (2.75). 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 (6.3) is less than that of conventional coarse aggregate (7.3). Hence indicates that ferrochrome slag affects 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.

4.2.1.2 Stone dust

Stone dust is collected from local stone crushing units of Bharatpur, Rewa road, Uttar Pradesh. It was initially dry in condition when collected and was sieved by IS: 90 μ sieve before mixing in concrete. Stone dust is of grey colour and shape of particles is irregular. The specific gravity of river sand(2.69) is greater than stone dust(2.5). The Fineness modulus of Stone dust(2.36) is less than that of river sand(2.55).

4.2.2 Fresh Properties of concrete

From the Vee bee consistometer and compaction factor lab test, We found that workability decreases with increase in percentage of ferrochrome slag and stone dust. From the compaction factor test it is observed that M25 grade concrete is High workable. In Vee bee consistometer 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 between 5-8 sec.

4.2.3 Hardened properties of concrete

From the experimental values presented in Table 5 and 6, corresponding to curing period of 7days and 28 days it can be observed that compressive strength and Split Tensile Strength of M25 Grade concrete increased with increase of ferrochrome slag and stone dust aggregates up to 75% replacement and 50% respectively and after that it decreases.

5. CONCLUSIONS

Based on the experimental conducted by replacing fine aggregate and coarse aggregate by stone dust and ferrochrome slag respectively for M25 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 and fine aggregate stone dust and sand has almost similar properties.
2. Workability of M25 grade concrete decreased with increase of ferrochrome slag and stone dust.
3. The replacement of conventional coarse aggregate with ferrochrome slag aggregate in concrete up to 75% and stone dust up to 50%has resulted in increased strength in compression and split tensile strength by conventional curing.
4. Ferrochrome slag can be considered as alternative to conventional coarse aggregate in M25 grade concrete mix due to its higher strengths achieved and Stone dust as a filler.
5. The usage of ferrochrome slag and stone dust as coarse aggregate and fine aggregate respectively in concrete reduces the usage of conventional coarse aggregate resulting in reduction of Environmental pollution.

6. SCOPE FOR FURTHER STUDY

1. Further testing and studies on the Ferro-Chrome coarse aggregate concrete and stone dust is highly recommended to indicate the strength characteristics of aggregate for application in high strength concrete.
2. More investigations and laboratory tests should be done on the strength characteristics of Ferro-Chrome coarse aggregate. It is recommended that, the testing can be done on concrete slabs, beams and walls.
4. More trials with different particle sizes of Ferro-Chrome coarse aggregate and various percentages of replacement of Ferro-Chrome coarse material and stone dust is recommended to get different outcomes and higher strength characteristics in the Ferro-Chrome coarse aggregate concrete.

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