PERFORMANCE OF CONCRETE BY PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH FERRO CHROME SLAG AGGREGATE

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Abstract : Concrete is the commonly used construction material due to its structural stability, durability and strength. The demand on concrete is increasing day by day due to growing population, urbanization, transportation and industrialization. To conserve the natural resources and effective utilization of industrial waste. Industrial waste can be used in concrete for saving environment from the industries. Ferrochrome slag can be used as an alternate material for coarse aggregate in concrete. Ferrochrome slag is a major by-product got during the manufacturing of Ferrochrome alloy (FeCr). The Ferrochrome slag has good mechanical properties suitable for utilization as an aggregate material in concrete. In this experimental study, M35 grade concrete is used and replaced ferrochrome slag with conventional coarse aggregate in concrete for every incremental of 25% and up to 100%. The fresh properties of concrete are determined by slump cone test, compaction factor test. To determine the hardened properties of concrete by casting cubes, cylinders and prisms for compressive strength, split tensile strength and flexural strength for 3 days, 7 days, 14 days and 28 days curing. The results are obtained and compared with conventional coarse aggregate concrete.

KEYWORDS: ***Ferrochrome slag, Compressive strength, Split tensile strength, Flexural strength.***

1. INTRODUCTION

1.1 GENERAL:

Any country prestige is solely depends on the planning, designing, developing, maintenance and construction of the Structural buildings and monuments. For construction of any structure concrete plays a vital role. The life of the structure is mainly depends on the quality of the materials used and the mix proportions. Though being in a rapid developing country like India there is a lot of demand over the concrete and finally results in the scarcity of the natural resources like coarse aggregate and fine aggregate that are used as the main constituents for the preparation of the concrete.

Normally the coarse aggregates (kankar) are widely used as they are the conservation of the natural resources and pollution free environment is achieved so in the same view we should find out another aggregate which should be comparatively as strong as an aggregate in terms of all the strength properties. Lack of availability of good quality aggregates within reasonable distance brings out the need to identify the sources of new aggregate. The material selected should be that even after disposing and recycling it should give a new aggregate.

In civil construction some industrial wastes are utilized in various works. The principal objective of this project is to evaluate the potential use of Ferrochrome Slag aggregate as alternative aggregates in concrete, a major construction product. 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.

We all know that India is one of the largest producer of iron and steel so keeping an eye over that we have concluded to use the ferrochrome slag aggregate (which is a waste material obtained during the preparation of Ferro-chrome alloys) in the place of coarse aggregate. The waste material used in a construction industry can solve the shortage of natural aggregate. Very limited studies were conducted to study the effect of FeCr slag on the properties of cement mortars and concrete. These studies were focused mainly on the use of FeCr slag as aggregate substitute.

This work emphasizes on the use of ferrochrome slag (FeCr) as coarse aggregate in concrete. Ferrochrome (FeCr) is the regular alloy material for the generation of stainless steel. In India, the current production capacity of most preferred bulk Ferro-alloys is about 3.36 million tonnes per annum, which is contributed by more than 118 plants operating total 229 furnaces.

FeCr metal is produced in electric arc furnaces by a physical-chemical process from the oxide of chromium ore with coke as the reducing agent at a temperature of about 1700 °C. Both the molten FeCr metal and the slag flow out into ladles. After gravity separation from the metal, the molten slag slowly cools in the air, forming a stable, dense, crystalline product having excellent mechanical properties.

The physical properties of Ferrochrome slag offers advantages compared to other aggregates. It lacks clay and organic ingredients in its composition, has a rough and porous surface, good adhesion and good abrasion resistance. Physico-mechanical experimental studies indicated the suitability of the slag as aggregate material in concrete work.

The chemical composition of FeCr slag includes three major elements: Silicon (Si), Aluminium (Al), and Manganese (Mg). Together with their oxides, these components make up 83% of the slag. On the other hand, the water absorption rate is partially high because of the porous nature of the slag. The typical ferrochrome slag composition is 30 % of SiO_2, 26 % of Al_2O_3, 23 % of MgO and 2 % of CaO. The chrome content in the slag is about 8 % and the iron content 4 % respectively and with minor traces of ferrous/ferric oxides.

The use of Ferrochrome slag is limited when associated to its generation. They are used in civil engineering works and highway 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. Fairly small amount of this material is used in useful applications whereas the vast majority of the material produced annually is disposed of site without further reuse.

In the present study, Ferrochrome Slag is assessed for its suitability to partially and fully replace the conventional coarse aggregate in M35 Grade concrete.

The present investigation aims at conducting a feasibility study of producing concrete with available Ferrochrome slag aggregate as coarse aggregate in concrete as an increment of 25% up to 100% for different specimens like cubes, cylinders, beams will be cast for 7, 14, 28 days of curing and tested for obtaining strength properties like compressive strength, tensile strength and flexural strength.

From the physical properties test results it has been revealed that there are several potential uses of FeCr slag. It can be used as an aggregate in concrete and hot mix asphalt and concrete pavements, as a base or sub-base material, and as an embankment and landfill material.

The results indicates the technical acceptability and the environmental compatibility of the slag as concrete aggregate material.

1.2 Need for the study

The program of work undertaken is summarized below:

Characteristics of Ferro chrome slag aggregates in concrete. In order to assess the characteristics of Ferro chrome slag aggregates, the following aspects were considered:

1. Mix design
2. Workability
3. Ease of preparation and finishing.

The workability was assessed using Standard testing equipment and procedures, including Slump cone test.

Characteristics of hardened concrete by replacement of coarse aggregate by Ferro chrome slag. The following tests were carried out to establish the engineering properties of Ferro chrome slag aggregates in concrete:

1. Compressive strength
2. Split tensile strength
3. Flexural strength

The above properties were determined using Standard testing equipment and procedures.

1.3 Objectives of the project

The present investigation aims at conducting a feasibility study of producing concrete with available Ferrochrome slag aggregate as coarse aggregate in concrete. Different specimens viz., cubes, cylinders, beams will be cast and tested for obtaining properties like compressive strength, tensile strength and flexural strength. Accordingly, the specific objectives of the present work are listed below.

Objectives of the present work

1. To establish engineering properties of Ferrochrome slag aggregate and to assess suitability as coarse aggregate in concrete.
2. To study the strength characteristics of M35 concrete mixes with different volumes with partial and full replacement of conventional aggregate by Ferrochrome slag aggregate.
3. To assess the Compressive, Split Tensile strengths of M35 Grades Ferrochrome slag aggregate concrete.
4. To compare with conventional aggregate concrete.
5. A detailed experimental program is carried out on various Ferrochrome slag aggregate concrete mix (M35) produced with Ferrochrome slag aggregate.
6. To study the effect of Ferro chrome slag in concrete and its benefits.
7. To improve the overall durability and long-term performance of concrete structures.
8. To reduce pollution by using a waste material like Ferro chrome added with Ferro chrome slag.

2. LITERATURE REVIEW

Concrete Portland Cement (OPC) was used in concrete mixes in all of the investigations (Alietal, 1993;Rostamietal, 1993; Eldon and senouci,1993; Topco, 1995; Fattah and Clark, 1996; Khatib and Bayomy,(1999) The reason for using Ordinary Portland Cement in their investigations is that this is by far the most common cement in use and is highly suitable for use in general concrete construction when there is no exposure to sulphates in the soil or ground water (Neville, 1997).

Concrete mixes containing pulverised fuel ash (PFA) were also used by Rostamietal. (1993) and Fattuhi and Clark (1996). According to Fattuhi and Clark (1996), the objective in sussing PFA was to reduce cost by adding another waste product to the concrete mixtures.

Bojanowskai et al (2001) worked on Recovery of Chromium from Sludge Formed after Neutralization of Chromic Wastewater. The method includes precipitation of the chromium (III) hydroxide and its dissolution, oxidation of chromium (III) to chromium(VI), solvent extraction and re extraction of chromium(VI). The chromium recovery yield of each procedure stage was in the range of 92 to 99%. Overall chromium recovery yield was about 90%.

Binder et al., also worked on chromium recovery from industrial waste water. It was found that crystallization is possible only after transformation of the initial sulphate containing chromium (III)-complex (green solution) to the chromium (III)-aqua complex (violet or purple solution).

Abass Esmaeili et al (2005) worked on Chromium (III) Removal and Recovery from Tannery. Wastewater by Precipitation Process. Removal and recovery of chromium were carried out by using precipitation process using three precipitating agents like calcium hydroxide, sodium hydroxide and magnesium oxide. The effects of pH, stirring time, settling rate and sludge volume were studied in batch experiments. Results show that the optimum pH is 8-9.

Lind et al (2001) studied the environmental impact of Ferro chrome slag used in road construction and reported that a small increase of adsorbed chromium (adsorbed to amorphous iron hydroxide) was detected in the upper most soil horizons near the covered road and leaching from the Ferro chrome slag to the ground water was low for all the elements analysed.

Zelic (2004) reported that the properties of Ferro chrome slag matched with the properties of the conventional aggregate for concrete production. The use Ferro chrome slag in road construction in filtering and supporting layers was reported Pekka Niemal et al (2007).

Altan yilmaz et al (2009). This research indicated that the physical and mechanical properties of Ferro chrome slag are as good as or better than those of natural aggregates.

Nkohla (2006) investigated that the best practices for the characterization of ferrochrome smelter slag by following the robust and accurate analytical techniques which is essential for process control, and he discussed its implications to the performance of the smelting process. Slag samples from a ferrochrome smelter were analysed using an XRF powder pellet an analytical technique in contrast to the ICP technique used at the plant laboratory, to determine their composition.

Tossavainen (2005) noted that the extraction of rock material and ore for construction and metal production involves large quantities of wastes and by-products such as iron and steel making slag has durability qualities and latent cementious properties which are positive in construction.

Konarbaeva *et al.*, (2010) mineralogical composition of low-carbon ferrochrome slags was studied by means of petrographic analysis. Ferrochrome was produced with ferrosilicon-aluminum used as a reductant. Petrographic analysis of slags indicates the presence of helenite in various forms. Isolated impregnations of melilite, larnite and vitreous phase are distinctly separated which proves the possibility of their separation from helenite phase in further processing.

Shao-peng et al., (2003) analysed to use steel slag stone matrix aggregate (SMA) is usable as a concrete materials for design. This material was found to highly rigid and excellent friction resistance on the basis of its characteristics.

Tossavainen (2005) noted that the extraction of rock material and ore for construction and metal production involves large quantities of wastes and by-products such as iron and steel making slag has durability qualities and latent cementious properties which are positive in construction.

Kauppi et al., (2007) reported that the structure of the slag is partly crystalline and partly glassy. Significant phases are amorphous glass, Fe-Mg-Cr-Al-spinels, forsterite, Mg-Al-silicate and metal alloy. The ferrochrome slag products are chemically very stable.

3. MATERIALS AND TEST PROCEDURES

3.1 Properties of cement

Various properties of cement such as Specific gravity, Normal consistency, Initial & Final setting time of cement are performed. The cement properties are determined from experimental investigations and presented in Table 3.1. The cement is confirming to the IS: 8112-1989.

Table 3.1 Properties of Cement

S. No.	Properties	Results
1	Specific Gravity	3.16
2	Fineness	3.2%
3	Normal Consistency	32%
4	Initial Setting Time	27 minutes
5	Final Setting Time	600 minutes

3.2 Properties of fine aggregates

The properties of Fine aggregates such as Specific gravity, Fineness modulus, Water absorption, Grading of fine aggregates are determined from experimental investigations and presented in a Table. 3.2. Fine aggregate confirming to IS 383-1970.

Table 3.2 Properties of Fine Aggregates

S. No.	Property	Results
1	Specific Gravity	2.66
2	Fineness Modulus	3.78
3	Water Absorption	2%

3.3 Properties of coarse aggregates

The properties of coarse aggregates such as maximum nominal size, Specific gravity, Water absorption, Fineness modulus, Toughness, Hardness, Bulk density are studied. The properties of coarse aggregates are determined by using IS: 383-1970. Coarse aggregates properties are determined from experimental investigations and presented in Table 3.3.

Table.3.3 Properties of Coarse Aggregates

S. No.	Property	Results
1	Maximum nominal size	20 mm
2	Bulk density	1800 kg/m^3
3	Specific gravity	2.8089
4	Toughness	10.4%
5	Hardness	9.5%
6	Fineness modulus	3.4193
7	Water absorption	2%

3.4 Ferro chrome slag

Ferrochrome slag, a waste bi-product generated during the manufacturing of Ferro chrome alloy. Ferro chrome alloy is manufactured in a submerged electric arc furnace by physiochemical process at the temperature of 1700ºC. 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.

Fig.3.1 Ferrochrome slag aggregates

3.4.1 Properties of Ferro chrome slag aggregates

The properties of Ferro chrome slag aggregates such as maximum nominal size, specific gravity, water absorption, fineness modulus, toughness, hardness, bulk density are performed. The properties of coarse aggregates are determined by using IS: 383-1970.

Table 3.4 Properties of Ferro Chrome Slag Aggregates

S.No.	Property	Results
1	Maximum nominal size	20 mm
2	Bulk density	1783 kg/m^3
3	Specific gravity	3
4	Fineness modulus	5
5	Toughness	9.4%
6	Hardness	7.65%
7	Water absorption	1.5%

3.5 Tests on fresh concrete

The fresh properties of concrete are determined by its measure of its workability. In this study, the Slump Cone Test is used to measure the workability.

Table 3.5 Slump cone test results

S. No.	Ferro chrome slag replacements in concrete (%)	Slump (mm)s
1	0	25
2	25	28
3	50	30
4	75	32
5	100	34

4.0 Strength tests

4.1Tests 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, one cube of 150mm x 150mmx 150mm sizes are tested for Compressive Strength, one cylinder of 150mm diameter x 300mm height size are tested for Split Tensile Strength and one beam of 500mm length x 100mm length x 100mm width are tested for Flexural Strength.

Table 4.1.Compressive Strength for Cube 7 days

Control of mix	Compressive strength in N/mm^2 at 7 days				
	FCS(0)%	25%	50%	75%	100%
M35	26.32	26.41	28.76	31.83	26.88

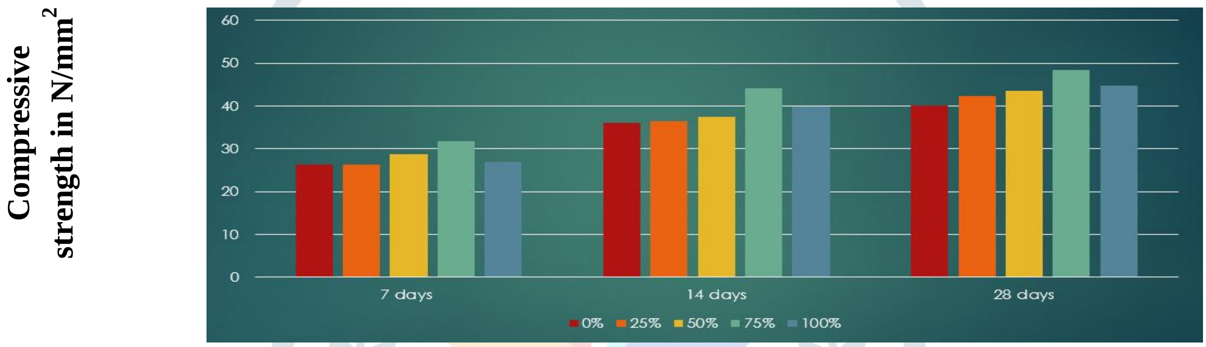
Table 4.2 Compressive Strength for Cube 14days

Control of mix	Compressive strength in N/mm^2 at 14 days				
	FCS(0)%	25%	50%	75%	100%
M35	36.05	36.35	37.45	44.06	39.85

Table. 4.3 Compressive Strength for Cube 28days

Control of mix	Compressive strength in N/mm^2 at 28 days				
	FCS(0)%	25%	50%	75%	100%
M35	40.16	42.25	43.58	48.47	44.76

Graph for Compressive strength results



Graph 4.1 Compressive Strength Results

Table 4.4 Split Tensile Test for Cylinder 7days

Control of mix	Split tensile strength in N/mm^2 at 7 days				
	FCS(0)%	25%	50%	75%	100%
M35	3.24	3.28	3.32	3.97	3.48

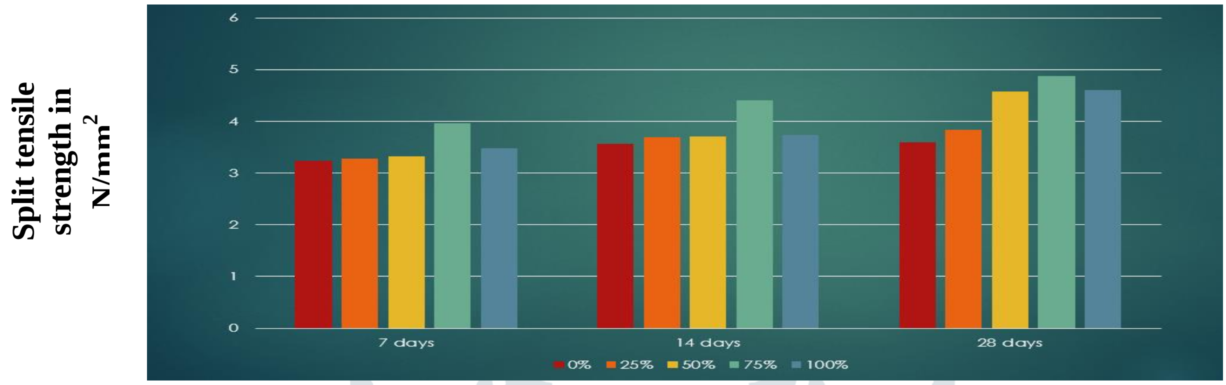
Table 4.5 Split Tensile Test for Cylinder 14days

Control of mix	Split tensile strength in N/mm^2 at 14 days				
	FCS(0)%	25%	50%	75%	100%
M35	3.56	3.69	3.71	4.4	3.74

Table 4.6 Split Tensile Test for Cylinder 28days

Control of mix	Split tensile strength in N/mm^2 at 28 days				
	FCS(0)%	25%	50%	75%	100%
M35	3.6	3.84	4.5	4.82	4.60

Graph for Split Tensile Strength Results



Graph 4.2 Split Tensile Strength Results

Table 4.7 Flexural Strength for beams 7days

Control of mix	Flexural beam strength in N/mm^2 at 7 days				
	FCS(0)%	25%	50%	75%	100%
M35	4.6	5.22	5.8	7.0	6.5

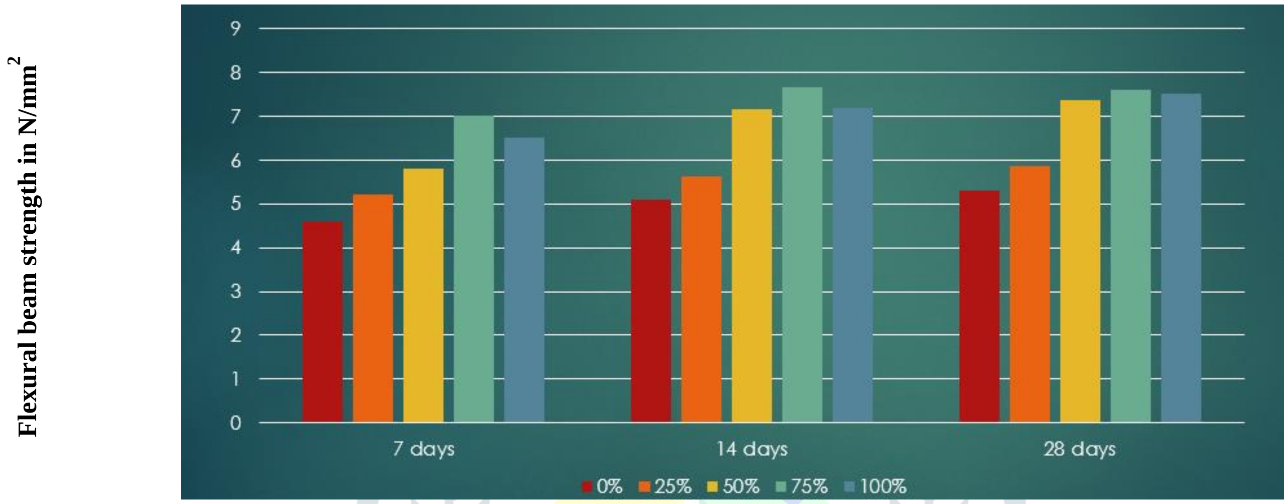
Table 4.8 Flexural Strength for beams 14days

Control of mix	Flexural beam strength in N/mm^2 at 14 days				
	FCS(0)%	25%	50%	75%	100%
M35	5.1	5.64	7.15	7.65	7.2

Table 4.9 Flexural Strength for beams 28days

Control of mix	Flexural beam strength in N/mm^2 at 28 days				
	FCS(0)%	25%	50%	75%	100%
M35	5.3	5.85	7.36	7.88	7.5

Graph for Flexural Strength Results



Graph 4.3 Flexural Strength Results

5. CONCLUSION& FUTURE SCOPE

5.1 CONCLUSION:

Based on the experimental investigation conducted on conventional coarse aggregate concrete and modified Ferrochrome aggregate concrete the conclusions are drawn out as follows:

The basic properties like Specific gravity, impact strength and crushing strength of ferrochrome slag aggregates are higher than conventional coarse aggregates.The replacement of conventional coarse aggregate with ferrochrome slag aggregate in concrete up to 75% has resulted in increased strength in compression, split tensile and flexure by conventional curing.Ferrochrome slag can be considered as alternative to conventional coarse aggregate in M35 grade concrete mix due to its higher strengths achieved.The usage of ferrochrome slag as coarse aggregate in concrete reduces the usage of conventional coarse aggregate resulting in reduction of Environmental pollution.So, we can conclude that 75% replacement is best replacement.

FURTHER SCOPE OF WORK:

In the present investigation, Ferrochrome slag aggregate has been used in producing concrete. Investigation may be carried out to conduct feasibility of using different types of aggregate produced at other industries. Experimentation may be carried out to investigate the possibility of using dosage of mineral admixtures. Investigation planned for the high performance concrete.

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