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Durability Studies on Concrete with Ferro Chrome Slag as Partial Replacement of Fine Aggregate

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***Abstract* - Concrete is a mixture of fine and coarse aggregates &cement with water. It is a material that is widely used for construction building and other civil engineering structures. The basic objective of this study was to identify alternative source of good quality aggregate because the natural stone quarries are depleting very fast due to rapid pace of construction activities in India. During the production of stain less steel in industries, Ferro chrome slag is produced in process of calcinations at 1700 degree centigrade in liquid state, at certain temperature conditions and then hardened in solid form which is a waste material. Thus the waste material can be used as partial replacement of fine aggregates in concrete. In this study, M30 grade of concrete is designed and tests were carried out with different percentage of slag as a partial replacement of fine aggregate in concrete. The sand is replaced with the slag from 0, 10, 20, 30& 40%. For strength parameters the compressive, tensile and flexural strength of specimens are casted and cured for 7 & 28 days and tested for hardened concrete and for fresh concrete slump and compaction factor test is carried to know the workability of concrete. For durability study, acid & alkaline tests are carried out.**

Keywords: Ordinary Portland cement, Ferro chrome slag, River sand, water and coarse aggregate

1. INTRODUCTION

Owing to liberalization, globalization and privatization, the construction of important infrastructure projects like, buildings, roads, airports etc. in India is increasing year after year. Such developmental activities consume large quantity of precious natural resources. This leads to faster depletion of natural resources on one side and manifold increase in the cost of construction of structures on the other side pose severe problem for the construction sector. To overcome this, people have started searching for suitable other viable alternative materials which could be used either as a substitute or as a partial replacement to the conventional ingredients of concrete so that the existing natural resources could be saved to the possible extent and could be made available for the future generation.

The main objective of this study is to identify the alternative source of good quality aggregate against river sand. In this work we partially replace the fine aggregate with Ferro chrome slag (FCS). FCS is replaced as a fine aggregate in the percentage of 0,10,20,30 and 40. Tests are carried out on this concrete whether it is susceptible to acid and base curing and check its durability characteristics.

EXPERIMENTAL INVESTIGATION:

The experimental investigation consists of casting and testing of 10 sets along with control mix. Each set comprises of 3 cubes, 3 cylinders and 3 prisms for determining compressive, split tensile and flexural strength of concrete at the age of 7 and 28 days of curing respectively. River sand is replaced with FCS with different percentages of 0, 10, 20, 30 and 40. After a day of casting, the specimens are de-moulded. Then the cubes, cylinders and prisms are placed in the curing tanks which has water, acid (diluted Hcl) and base (NaOH) after de moulding.

The cement used was ordinary Portland cement of 53 grades in accordance with IS: 12269-1987. The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible. Table 1 gives the physical properties of cement

Table 1. Properties of cement

S.No	Property	Test results
1.	Normal consistency	29%
2.	a) Initial setting time b) final setting time	28 min 5hr 45min
3.	Fineness of cement	3.6%
4.	Specific gravity	2.89

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Natural River sand and Ferro chrome slag was adopted as fine aggregate. The coarse aggregate used was crushed granite stone and gravel conforming to IS 383-1970. Machine crushed hard granite chips of 67% passing through 20 mm sieve and retained on 12 mm sieve and 33% passing through 12 mm and retained on 10 mm sieve was used a coarse aggregate throughout the work. Table 2 shows properties of natural river sand and ferro chrome slag as fine aggregate. Table 3 gives the properties of Coarse aggeregate.

Table 2: Properties of fine aggregate and Ferro chrome slag

S.No	**Property**	**Fine aggregate**	**Ferro chrome slag**
1	Specific gravity	2.39	2.38
2	Bulk of sand	10%	8%
3	P_H	8	8
4	Fineness modulus	2.68	2.38
5	Grading zone	II	II

Table 3. Properties of coarse aggregate

S.No	Property	Test result
1	Abrasion value	25%
2	Specific gravity(G)	2.87
3	Fineness modulus	7.289
4	Crushing value of aggregate	21.25%
5	Impact value of aggregate	21.58%

Potable water is used in the investigation. The chemical properties of water is as given in Table 4. Table 5 gives the concrete mix details adopted.

Table 4. Analysis of water (limitations as per IS: 456-2000)

S.NO	Impurity	Max. limit	Results
1	pH Value	6 to 8.5	7.6
2	Suspended matter mg/lit	2000	220
3	Organic matter mg/lit	200	20
4	Inorganic matter mg/lit	3000	150
5	Sulphates (SO_4) mg/lit	500	30
6	Chlorides (Cl) mg/lit	2000 for P.C.C. 1000 for R.C.C	60

Table:5 Mix proportions by weight

Cement	Fine aggregate	Coarse aggregate	w/c ratio
432.5	585.18	1146.518	186
1	1.35	2.65	0.43

TEST RESULTS & DISCUSSIONS:

Compressive strength at the age of 7and 28 days of curing:

Table 6 presents the compressive strengths of various proportions of M30 grade concrete mix with various replacement levels of Ferro chrome slag at 7 days and 28 days of curing. Compressive strength values were increased with increase in percentage of ferrochrome slag replacement. This trend can be seen in Fig.1. Similar trend was observed even for the base and acid curing. This shows that the adoption ferrochrome slag in concrete is effective in aggressive environments.

Table 6 Compressive strength at the age of 7 and 28 days

S.No	% Replacement of Ferro chrome slag	Compressive strength 7 days (MPa)			Compressive strength 28 days (MPa)		
		Water curing	Acid curing	Base curing	Water curing	Acid curing	Base curing
1.	0%	40.46	37.53	37.68	45.7	34.2	45.8
2.	10%	37.90	35.82	40.19	50.8	40.1	47.1
3.	20%	42.3	43.03	38.39	50.8	40.9	49.5
4.	30%	42.54	43.21	39.63	49.7	46.1	51.2
5.	40%	43.08	43.9	41.24	62.3	52.2	56.6

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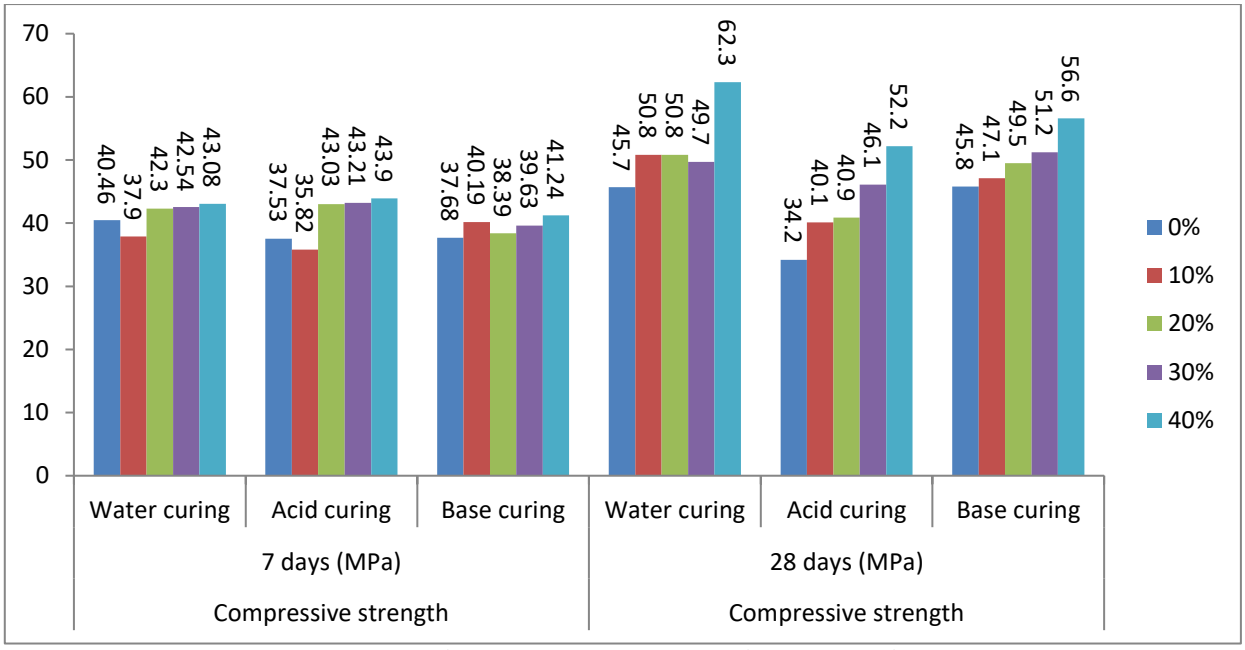

Fig 1. Variation of Compressive strength at the age of 7 and 28 days of curing

From the Fig 1 it was clear that The compressive strength of 10% replacement of Ferro chrome slag at age of 7 days of curing is 2.59, 7.33 and 1.33% more than 0% replacement in water , acid and base curing respectively.

The compressive strength of 20% replacement of Ferro chrome slag at age of 7 days of curing is 4.34, 12.78 and 1.849% more than 0% replacement in water , acid and base curing respectively.

The compressive strength of 30% replacement of Ferro chrome slag at age of 7 days of curing is 4.88, 13.14 and 5.04% more than 0% replacement in water , acid and base curing respectively

The compressive strength of 40% replacement of Ferro chrome slag at age of 7 days of curing is 6.08, 14.5 and 8.63% more than 0% replacement in water , acid and base curing respectively

The compressive strength of 10% replacement of Ferro chrome slag at age of 28days of curing is 9.98, 2.24 and 2.84 % more than 0% replacement in water , acid and base curing respectively

The compressive strength of 20% replacement of Ferro chrome slag at age of 28 days of curing is 13.40, 21.37 and 7.43% more than 0% replacement in water , acid and base curing respectively

The compressive strength of 30% replacement of Ferro chrome slag at age of 28 days of curing is 7.74, 14.94 and 10.61% more than 0% replacement in water , acid and base curing respectively

The compressive strength of 40% replacement of Ferro chrome slag at age of 28 days of curing is 26.57, 33.79 and 19.10 % more than 0% replacement in water , acid and base curing respectively

Split tensile strength at the age of 7 and 28 days:

Table 7 presents the split tensile strengths of various proportions of M30 grade concrete mix with various replacement levels of Ferro chrome slag at 7 and 28 days of curing. Fig 2 gives the variation in split tensile strength at 7 and 28 days.

Table 7 Split tensile strength at the age of 7 and 28 days

S.No	% Replacement of Ferro chrome slag	Split tensile strength 7 days (MPa)			Split tensile strength 28 days (MPa)		
		Water curing	Acid curing	Base curing	Water curing	Acid curing	Base curing
1.	0%	2.56	2.64	2.63	2.84	2.82	3.09
2.	10%	2.81	2.65	2.67	3.12	2.86	3.12
3.	20%	2.87	2.86	2.82	3.28	3.12	3.19
4.	30%	2.97	2.96	2.87	3.32	3.28	3.4
5.	40%	3.12	3.21	2.88	3.83	3.59	3.46

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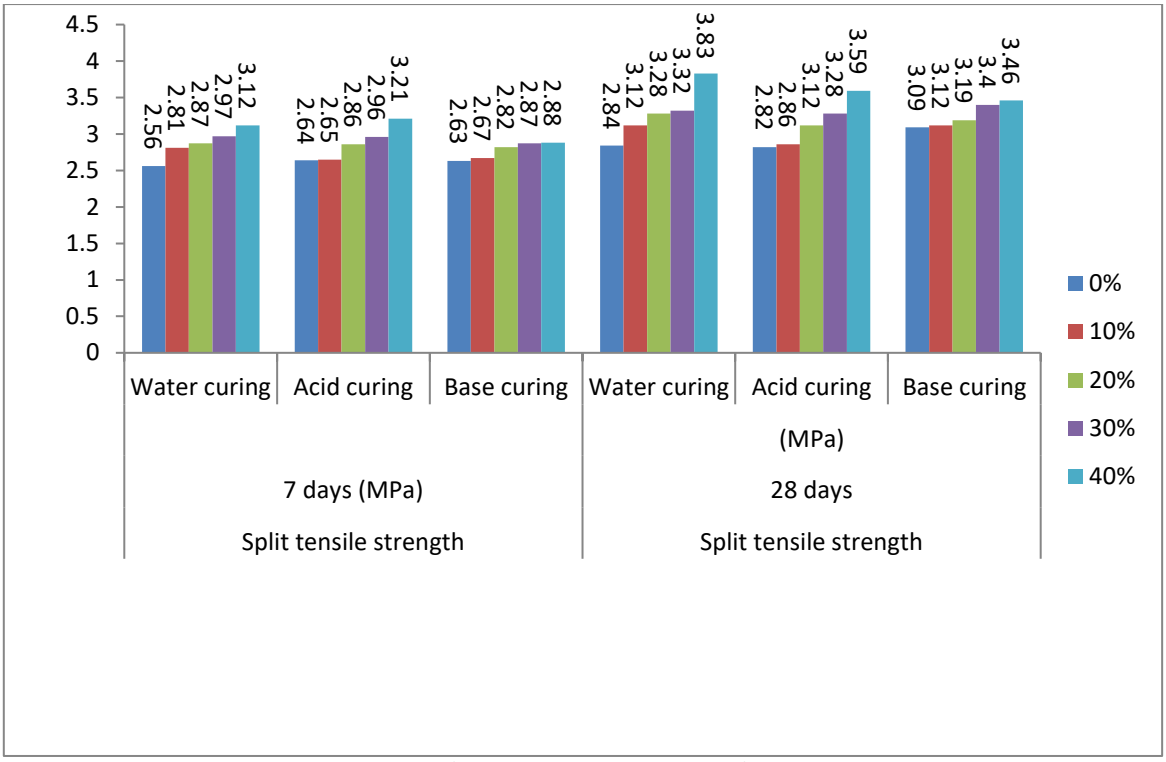

Fig 2. Variation of Split tensile strength at the age of 7 and 28 days

From the Fig 2 it was clear that The split tensile strength of 10% replacement ofFerro chrome slag at age of 7 days of curing is 8.89 , 0.37 and 1.49% more than 0% replacement in water , acid and base curing respectively

The split tensile strength of 20% replacement of Ferro chrome slag at age of 7 days of curing is 10.80 , 8.33 and 6.73% more than 0% replacement in water , acid and base curing respectively

The split tensile strength of 30% replacement of Ferro chrome slag at age of 7 days of curing is 13.80 , 10.81 and 8.36% more than 0% replacement in water , acid and base curing respectively

The split tensile strength of 40% replacement of Ferro chrome slag at age of 7 days of curing is 17.9 , 17.75 and 8.68% more than 0% replacement in water , acid and base curing respectively

The split tensile strength of 10% replacement of Ferro chrome slag at age of 28 days of curing is 8.97 , 1.39 and 0.96 % more than 0% replacement in water, acid and base curing respectively

The split tensile strength of 20% replacement of Ferro chrome slag at age of 28 days of curing is 11.25, 9.61 and 3.13% more than 0% replacement in water, acid and base curing respectively

The split tensile strength of 30% replacement of Ferro chrome slag at age of 28 days of curing is 14.45, 14.02 and 9.11% more than 0% replacement in water, acid and base curing respectively

The split tensile strength of 40% replacement of Ferro chrome slag at age of 28 days of curing is 25.8, 21.44 and 10.6% more than 0% replacement in water, acid and base curing respectively

Flexural strength at the age of 7 and 28 days of curing:

Table 8 & Fig 3 gives Flexural strength of various proportions of M30 grade concrete mix with various replacement levels of Ferro chrome slag at 7 and 28 days of curing.

Table 8. Flexural strength at the age of 7 and 28 days

S.No	% Replacement of sea sand	flexural strength 7 days (MPa)			flexural strength 28 days (MPa)		
		Water curing	Acid curing	Base curing	Water curing	Acid curing	Base curing
1.	0%	4.68	2.56	3.08	5.068	3.462	3.6
2.	10%	4.78	4.76	3.48	5.07	5.32	5.06
3.	20%	5.00	4.96	3.58	5.144	5.388	5.4
4.	30%	5.18	4.82	5.07	5.248	5.396	5.48
5	40%	5.24	5.36	5.16	5.34	6.08	5.94

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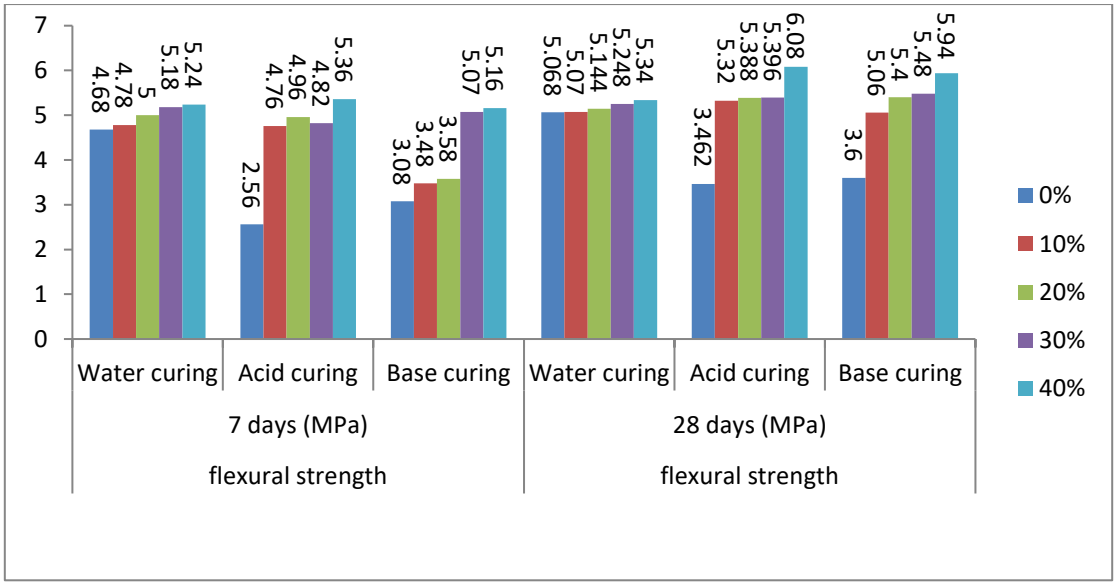

Fig.3 Variation of flexural strength at the age of 7 and 28 days

From the Fig 3 it was clear that The flexural strength of 10% replacement of Ferro chrome slag at age of 7days of curing is 2.09, 46.05 and 11.49 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 20% replacement of Ferro chrome slag at age of 7days of curing is 6.4, 48.38 and 13.96 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 30% replacement of Ferro chrome slag at age of 7days of curing is 9.65, 46.88 and 39.30 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 40% replacement of Ferro chrome slag at age of 7days of curing is 10.68, 52.28 and 40.30 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 10% replacement of Ferro chrome slag at age of 28days of curing is 0.3, 34.92 and28.85 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 20% replacement of Ferro chromeslag at age of 28 days of curing is 1.43, 35.74 and33.33% more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 30% replacement of Ferro chrome slag at age of 28days of curing is 3.429, 35.84 and 34.30 % more than 0% replacement in water ,acid and base curing respectively

The flexural strength of 40% replacement of Ferro chrome slag at age of 28days of curing is 5.09, 43.05 and 39.30 % more than 0% replacement in water ,acid and base curing respectively

CONCLUSIONS:

1. Compression strength of concrete at age of 28 days curing is maximum at 40% replacement of Ferro chrome slag i.e.62.3, 59.2 and 56.6 N/mm^{2}in water ,acid and base curing respectively
2. Compression strength of concrete at age of 7 days curing is maximum at 40% replacement of Ferro chrome slag i.e 43.1, 43.9 and 41.2 N/mm^{2}in water ,acid and base curing respectively
3. Split tensile strength concrete of at age of 7 days curing is maximum at 20% replacement of Ferro chrome slag i.e 3.1 and3.2 N/mm^2 in water and acid curing
4. Split tensile strength of concrete at age of 28 days curing is maximum at 20% replacement of Ferro chrome slag i.e 3.3 N/mm^2 in water curing. 3.6 and 3.5 N/mm^2 acid and base curing respectively
5. Flexural strength concrete of at age of 28 days curing is maximum at 40% replacement of Ferro chrome slag i.e. 5.3,6.1 and 5.9 N/mm^{2}in water ,acid and base curing respectively
6. Flexural strength concrete of at age of 7 days curing is maximum at 40% replacement of Ferro chrome slag i.e. 5.2, 5.4 and 5.2 N/mm^{2}in water ,acid and base curing respectively
7. From the entire experimental study it was observed that Ferro chrome slag is suitable up to 40% replacement in aggressive environment for both PCC and RCC works.
8. Ferro chrome slag when replaces with fine aggregate it resistant to acid and base attacks caused by water.

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