

Study on the partial replacement of fine aggregate using induction furnace slag

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Abstract: - This paper highlights the feasibility study on the utilization of induction furnace slag as an alternative for conventional fine aggregate. In this study the compressive strength characteristics of mortar and concrete made with partial replacement of fine aggregate using induction furnace slag was considered. For the experimental investigation, mixes were prepared with fine aggregate replacement using 20 percent, 30 percent, 40 percent, 50 percent and 60 percent induction furnace slag. Compressive strength test on mortar and concrete were conducted and the test results indicated that fine aggregate replacement using 30 percent induction furnace showed a better performance compared to control mix.

Keywords : - Induction furnace slag; superplasticizer; compressive strength; slump test

I. INTRODUCTION

Concrete is a composite construction material composed mainly of cement, aggregate and water. The cement and other cementitious materials such as fly ash and slag cement, serve as a binder for the aggregate. The aggregates are of two kinds, coarse aggregate such as crushed limestone or granite and fine aggregate such as river sand or manufactured sand. Various chemical admixtures can also be added to achieve varied properties. Water is mixed in concrete so that the concrete gets its shape and then gets hardened through a process called hydration. The aggregates occupy almost 70-75 percent of the total volume of concrete [1]. The civil engineering construction particularly in the field of reinforced concrete has increased and as a consequence the availability of aggregate has reduced by a large amount, which has led to hike in its cost. To meet the global demand of concrete in the future, it is becoming a challenging task to find suitable alternative construction materials which can fully or partially replace the natural aggregate without affecting the property of concrete. The different materials that can be used as an alternative for natural fine aggregate include blast furnace slag, manufactured sand, crushed glass, copper slag, recycled aggregates, fly ash aggregate, steel slag etc. The use of such materials not only result in conservation of natural resources but also helps in maintaining good environmental conditions by effective utilization of these by-products which will otherwise remain as a waste material. Steel slag is such materials which could be used as a partial replacement for fine aggregate [2]. Induction furnace steel slag is a by-product of steel manufacturing industry, which is produced in an induction furnace. These materials are otherwise considered to be a potential waste material which is been dumped near the industrial area. Through the present work, the use of induction furnace slag as a partial replacement for the fine aggregate in cement mortar and cement concrete is studied.

R. Alizadeh et al. [3] studied on the utilization of electric arc furnace slag as aggregates in concrete. The physical, chemical and mechanical properties of steel slag and the steel slag concrete were studied in their work. The study on steel slag revealed that its properties are comparable with those of natural aggregates. The mechanical properties of hardened concrete incorporated with steel slag showed a better result compared to conventional concrete. The experimental study conducted by I. Netinger et al. [4] on performance of concrete containing steel slag aggregate after high temperature exposure studied the properties of four steel slag based concrete mixtures with different types of cement pastes prior and after heating up to 800°C. The percentage replacement of fine aggregate using steel slag was adopted to be 60 percent. Dolomite based concrete mixture was studied as a reference mixture and the results revealed that the mechanical properties of concrete made with steel slag aggregate are comparable to that of dolomite concrete up to the temperature of 550°C. The

compressive strength and modulus of elasticity of steel slag concrete was comparable with dolomite based mixture up to a temperature of 600°C beyond which it decreases. Mahmoud Ameri et al. [5] conducted a study on evaluation of the use of air cooled steel slag as a replacement for natural aggregate in concrete pavements. The steel slag from basic oxygen furnace was been used for the study. Compressive strength tests were conducted on samples with slag ratios of 0, 25,50, 75 and 100% and cement contents of 200, 300 and 350 kg/m³. The maximum compressive strength value was seen to occur at 25% fine aggregate replacement and the compressive strength goes on decreasing beyond this value. Flexural strength of steel slag concrete is greater when compared to conventional concrete for all replacement ratios.

II. NEED FOR THE STUDY

Induction furnace slag is a by-product of steel manufacturing industry. These waste materials are otherwise not useful and so is been dumped as landfill in the vicinity of the industry. Unprocessed waste can result in environmental issues and consequently waste disposal becomes a major issue. Thus, the effective utilization of this material could bring about economy and will no longer be of environmental concern. This study aims at use of induction furnace slag as an alternative for fine aggregate.

III. MATERIAL CHARACTERISATION

4.1 Aggregates

The fine aggregate used for the study is manufactured sand. The coarse aggregates were of 12mm and 20mm size. Tests were carried out on fine aggregate and coarse aggregate in-order to obtain their physical properties.

Table 1 Physical properties of fine aggregate

Property	Fine aggregate		Coarse aggregate		Test method
	M sand	IFS	12 mm	20 mm	
Specific gravity	2.53	2.78	2.74	2.75	IS:2386(Part III)- 1963
Water absorption (percent)	1.35	Nil	0.57	0.45	IS:2386(Part III)- 1963
Sieve analysis	Zone II	Zone II	Nil	Nil	IS:383- 1970

4.2 Cement

The cement used for this work is OPC of 53 grade. The specific gravity of cement was tested as per IS: 4031(Part III) -1988 and was found to be 3.12.

IV. MIX PROPORTIONING

The mix design is carried out as per IS: 10262 (2009). The grade of concrete adopted for this study is M35. Maximum size of aggregate taken is 20mm and grading of sand is zone II. The superplasticizer used is ADVA 950 which is polycarboxylate ether. The water cement ratio adopted for concrete mix was 0.4 and mix proportion was carried out for a slump of 100 ± 20 mm with superplasticizer addition. The quantity of materials required for 1m³ of concrete is given below.

Table 2 Quantity of materials per cubic meter of concrete

Material	Quantity in kg per cubic meter of concrete
Cement	420
Water	168
Fine aggregate	862
Coarse aggregate: 20mm	576
Coarse aggregate: 12mm	471
Superplasticizer dosage (0.5 percent)	2.1

V. TEST AND RESULTS

6.1 Mortar

The mortar specimens were cast with desired mix proportion and tested for compressive strength at 3, 7 and 28 days. The test specimens are of cubical shape with 50 cm² face area. Specimens were made following the specifications as per IS: 4031 (Part 6) - 1988 and stored in water curing tank for the specified time period. The control mixes were tested for mortar cube compressive strength. There are two different control mixes, of which one is prepared without any superplasticizer addition (CMR) and the other one with superplasticizer addition (CMA). The compressive strength test was also conducted on specimens with different percentage

replacement of fine aggregate using induction furnace slag. There are 5 different mixes using induction furnace slag with 20%, 30%, 40 %, 50% and 60 % replacements of fine aggregate.

Table 3 Results of 3, 7 and 28 day compressive strength of control mortar cubes

Mix ID	Average compressive strength (MPa)		
	3 day	7 day	28 day
CMR	14.2	18.3	25.4
CMA	17.2	22.8	32.9

From table 3, it is clear that the control mix without any superplasticizer (CMR) is having a lower compressive strength when compared to control mix with superplasticizer (CMA). The addition of superplasticizer in mortar helps in increasing the viscosity of cement paste. Thus, even at water cement ratio of 0.4 the mix seems to be workable and together with that, reduced water content can improve the strength of mortar.

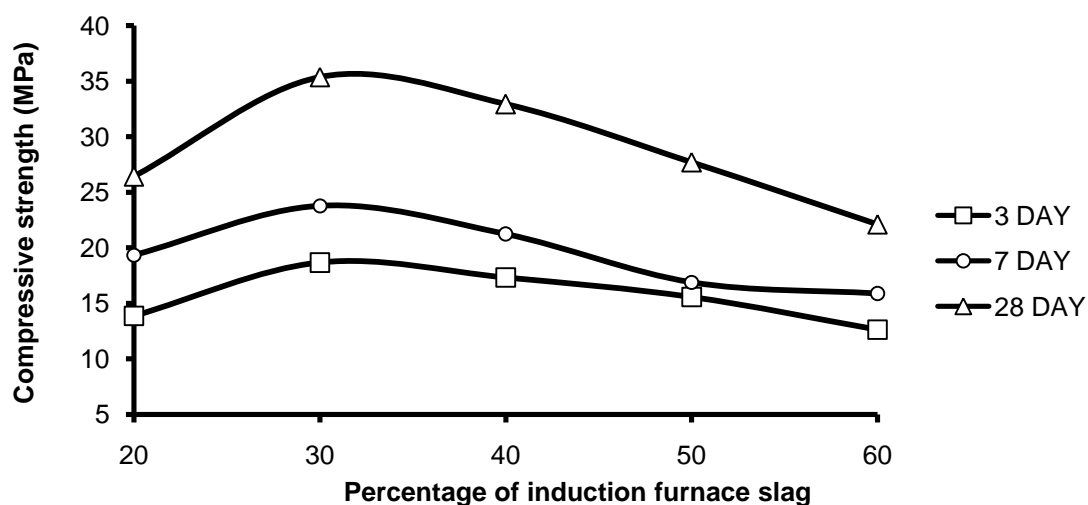


Fig. 1 compressive strength of mortar containing of IFS

Fig 1 shows the 3, 7 and 28 day compressive strength of mortar cubes prepared with different percentage replacements of fine aggregate using induction furnace slag. The compressive strength of control mix with superplasticizer (CMA) was found to be comparable with that of mixes with different percentage replacement of fine aggregate using induction furnace slag. The maximum compressive strength for 3, 7 and 28 day was corresponding to 30 percent replacement of fine aggregate using induction furnace slag (30SA). The compressive strength of mortar cube was seen to increase initially and beyond 30 percent replacement of fine aggregate it tends to decrease. The increase in compressive strength of mortar with the increase in induction furnace slag replacement is attributed to the pozzolanic activity of induction furnace slag. The further reduction in the strength value is mainly due to the angularity of steel slag aggregates which demands more water in the mixture to wet the surface of the particle.

6.2 Concrete

6.2.1 Slump test

The workability of fresh concrete is measured using slump test. Slump test was carried out as per IS: 1199 - 1959. CMR is the control mix in which no superplasticizer is been used. CMA corresponds to the control mix prepared with 0.5 percent superplasticizer (ADVA 950). The slump test conducted on the control mix CMR resulted in a zero slump value, whereas, the control mix CMA had a slump value of 100mm.

The fig 2 shows the variation of slump with different percentage replacement of fine aggregate using induction furnace slag. It was found that the value of slump increases with the incremental percentage of induction furnace slag till 40 percent replacement of fine aggregate and beyond that the slump value goes on decreasing. The initial increment in workability of concrete with the increase in induction furnace slag is attributed to the low water absorption characteristics of induction furnace slag. The reduction in the value of slump with an increased percentage of induction furnace slag beyond 40 percent is mainly due to the angularity

of steel slag aggregates. Higher specific surface area requires more water in the mixture to wet the surface of the particle adequately in-order to maintain the specified workability.

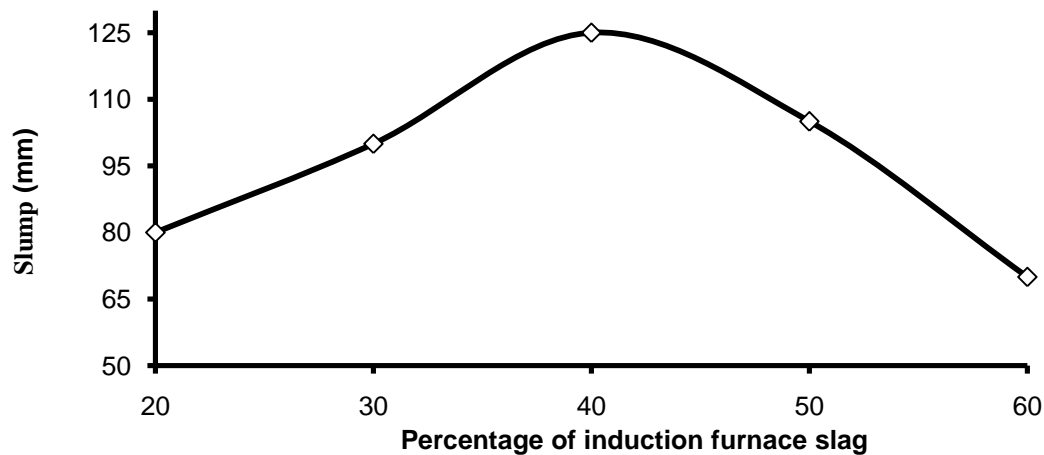


Fig. 2 slump of fresh concrete containing induction furnace slag

6.2.2 Compressive strength test

The concrete specimens were cast with the specified mix proportion and tested for compressive strength at 3, 7 and 28 days. The test specimens are of cubical shape with sides 150mm x 150mm x 150mm. Specimens were made following the specifications as per IS: 516 -1959 and stored in water curing tank for the specified time period. Hand compaction technique was adopted. Three specimens each were tested at each age on a compression testing machine. Concrete control mixes were tested for their cube compressive strength. There are two different control mixes, of which one is prepared without any superplasticizer addition (CMR) and the other one with superplasticizer addition (CMA). The compressive strength test was conducted on specimens with different percentage replacement of fine aggregate using induction furnace slag. There are 5 different mixes with 20, 30, 40, 50 and 60 percentage replacements of fine aggregate using induction furnace slag.

Table 4 Compressive strength on concrete cubes

Mix ID	Average compressive strength (MPa)		
	3 day	7 day	28 day
CMR	11.1	25.1	38.2
CMA	22.8	28.0	44.2

From the table 3, it is clear that the control mix without any superplasticizer (CMR) is having a lower compressive strength when compared to control mix with superplasticizer (CMA). This variation in strength has arisen due to the addition of superplasticizer.

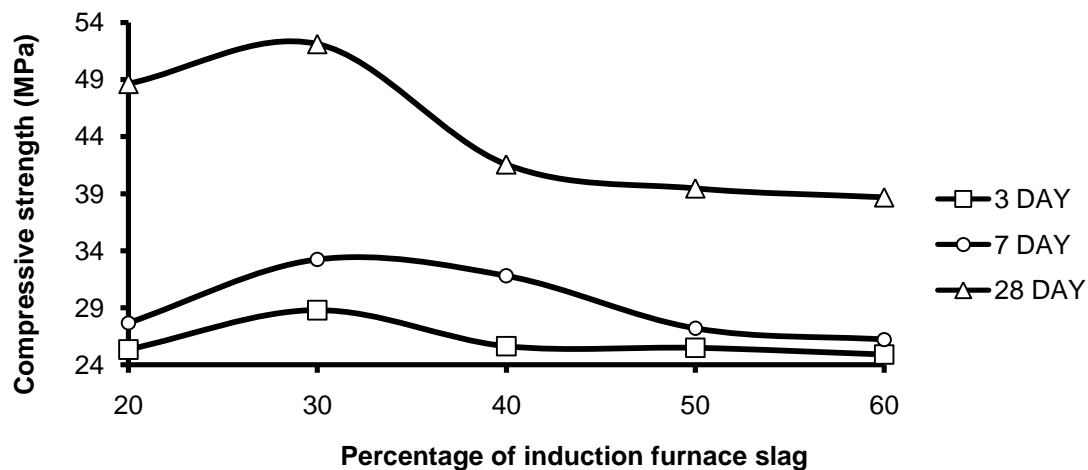


Fig. 3 Compressive strength of concrete containing IFS

The 3, 7 and 28 day compressive strength of control mix, CMA, was found to be comparable with that of induction furnace slag concrete 20SA, 30SA, 40SA, 50SA and 60SA. The maximum compressive strength for 3, 7 and 28 day was corresponding to 30 percent replacement of fine aggregate using induction furnace slag (30SA). When the percentage of IFS increases, the free water available in the mix also increases. This may lead to the formation of pores in the concrete structure. The increased porosity of concrete weakens the bond between the concrete components causing a reduction in the concrete compressive strength.

VI. CONCLUSIONS

Based on the present study the following conclusions were derived:

- The compressive strength of mortar and concrete containing induction furnace slag up to 30 percent is found to be comparable with the strength of corresponding control mortar mix with superplasticizer containing no slag.
- The compressive strength of mortar and concrete containing induction furnace slag greater 30 percent is found to be lower than the corresponding control mortar mix containing no slag.
- The slump of concrete containing induction furnace slag up to 30 percent is found to be greater compared to all other mixes.

Hence it may be concluded that the slag fines can be used as fine aggregate in concrete. The replacement ratio of the fine slag shall be limited to 30 percent. However, more durability studies are to be conducted for the evaluation of the performance of concrete containing fine induction furnace slag.

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