EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF STEEL SLAG WITH FINE AGGREGATE IN RCC ELEMENTS

Mr. I. Michael raj [1], Mr. J.Venkatesh [2]

[1]*Assisstant Professor, Department of Civil Engineering, RVS Technical Campus, Coimbatore-641402, India,*
[2]*PG student, Department of Civil Engineering, RVS Technical Campus, Coimbatore-641402, India*

Abstract - *The construction industry is the largest consumer of natural resources which led to depletion of good quality natural sand (Fine aggregates). This situation led us to explore alternative materials and granular slag a waste industrial by-product is one such material identified for utilization it as replacement of natural sand.*

Steel Slag is produced locally in great amount which leads in causing many environmental problems alike natural depletion when disposed. To over-come this issue, slag is the sound choice in favor of ecology being used as fine aggregate in rapid concrete sector. This work includes the determination of different properties of locally available steel slag. The utilization of steel slag in the concrete element by replacing it partially with fine aggregate (sand).The use of steel slag in concrete would be a greater advantage in enhancing the strength of concrete. Material study and the Mix proportions are calculated for M_{40} Grade of Concrete.

Casting, curing and testing of the structural element (beam) will be carried out in phase II of this project work.

INTRODUCTION

1.1 GENERAL

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Since aggregates occupy 70-80 percent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. All along in India, we have been using natural sand in concrete manufacturing. The infrastructure development such as highway projects, power projects and industrial developments have started now. Availability of natural sand is getting depleted and also it becoming costly. There is need for conserving resources and environment and for proper utilization of energy. Hence, there has to be an emphasis on the use of wastes and by-products in all areas including construction industry. As 75% of concrete is composed of aggregates it is imperative that we look to maximize the use of waste as aggregate input in concrete making.

1.2 OBJECTIVES

- To find out a suitable and effective / alternative material for partial replacement of fine aggregate.
- To find out possible utilization of waste materials in construction industry that in turn considerably minimize the usage of fine aggregate and ultimately reduce construction cost.
- To explore possibilities of improving mechanical properties of concrete using steel slag instead of fine aggregate partially.
- To evaluate the effect of using steel slag in concrete.

1.3 SCOPE OF THE WORK

The main scope of this project work is to arrive the mix proportion of M40 concrete made up of replacing some percentage of fine aggregate with steel slag. Flexural strength for various trial mixes of slag and fine aggregate proportioned concrete element is to be found out.

1.4 NEED FOR THE STUDY

Here in this work an attempt is made to utilize steel slag, a waste material obtained from AGNI Steel Industry-Ingur, in concrete as a partial replacement material for sand. Slag fines may be used as a substitute for sand without any deleterious effect. Volume stability, good sulphate resistance, and corrosion resistance to chloride solutions make reinforced slag concrete suitable for many applications.

1.5 RESEARCH SIGNIFICANCE IN INDIAN CONTEXT

Presently, use of slag in India is to the tune of 15 to 20 % by cement industry rest is mostly unused. The use of industrial by-products in concrete and mortar not only helps in reducing greenhouse gases but helps in making environmental friendly material. Fine aggregates are part of all the three major applications of construction namely masonry, plastering & concreting which is used to the tune of 25 to 40 % by total volume of aggregates and hence provides great opportunity to utilise slag – a waste material in big volume.. Research study explores the possibility of using steel production waste by-product as replacement of natural sand.

1.6 NECESSITY OF STEEL SLAG

Generally, steel slag aggregates can replace natural aggregates in almost every situation. The exception to this is where the density of the aggregate is a crucial design consideration as in cement. For example, where the dead load of a structure needs to be kept to a minimum, or in structural concrete applications where the strength to density ratio of natural stone is normally better than steel slag. For bulk concrete uses, like large foundations high density concrete (nuclear applications) and marine structures, steel slag has some merit. When considering steel slag for structural concrete applications, special care must be taken to confirm that the aggregate is totally stable, and that the Alkali Silica Reaction potential is within specified limits. Steel slag has been used extensively around the world as: railway ballast, trickling filter bed media, pipe bedding, water course protection, land reclamation, bulk fill embankments and gabion stone. Some of the more unusual uses include: agricultural soil conditioning and marsh land reed beds, where the chemical composition of the material Vis á Vis leachable elements, is important.

1.7 ADVANTAGES OF USING STEEL SLAG

- Steel slag concrete mixes have very high stabilities and satisfactory flows and excellent stripping resistance.
- Steel slag used as surface course has good wear and skid resistance.
- Steel slag mixes have good heat retention and compatibility.
- When in contact with moisture, steel slag has a potentially expansive nature up to 10% attributed to the hydration of the free Cao and magnesium hydrates.

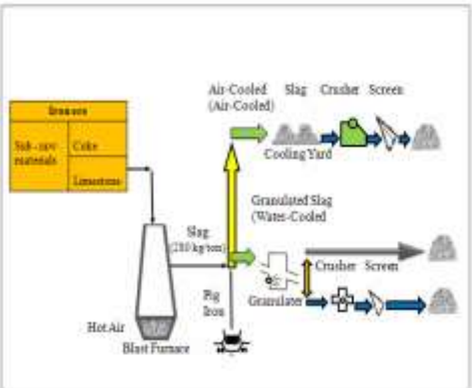

FIG 1.1 GENERAL SCHEMATIC VIEW OF BLAST FURNACE OPERATION AND SLAG PRODUCTION

2. LITERATURE REVIEW

J. Emery (1980) reported that the use of pelletized light weight slag as aggregate in concrete shows better results than that of the ordinary slag. Pelletized expanded slag has significant production and usage advantages when compared to conventional expanded vesicular slag. The major current use of pelletized slag is in lightweight concrete blocks. Structural concrete applications have generally been in semi-lightweight mixes. Other uses such as in slag cement manufacture are outlined.

Pelletized slag use in lightweight structural concrete (cast-in-place or precast), while involving a somewhat higher unit cost than normal weight concrete, can provide a significant overall reduction in construction costs through reduced dead loads and attendant savings in concrete quantities, steel, formwork, foundations, etc. Pelletized slag is currently being used in slag cement manufacture as it can be produced with a high degree of vitrification for cementitious applications.

D.W. Lewis (1982) describes that the slag from the iron and steel industries are sometimes erroneously classified, and often looked upon, as industrial waste materials. In actual fact, these by-products are valuable and extremely versatile construction materials. The history of slag use in road building dates back to the time of the Roman Empire, some 2000 years ago, when broken slag from the crude iron-making forges of that era were used in base construction. Applications were quite sporadic until the last century, when large quantities began to be used for a number of purposes. In relatively recent years, the need for maximum utilization and recycling of by-products and recovered waste materials for economic and environmental reasons has led to rapid development of slag utilization. In some areas, nearly all of the iron and steel slag are now being used, and use is rapidly growing in many others.

This discussion will briefly cover the composition, properties, and uses of iron blast furnace slag and of steelmaking slag. The major basis will naturally be the experience developed in the U.S., with mention of the uses in other countries. Although other slags are sometimes used, only the major slag produced by the iron and steel industries will be considered.

Cerjan et al (1986), Steel slag is generated as a melt at about 1600°C during steelmaking from hot metal in the amount of 15%–20% per equivalent unit of steel. The function of this slag is to refine the steel of sulphur and to absorb the oxides formed as a result of deoxidation during steel production. Steelmaking slag are composed principally of calcium silicates, calcium aluminoferrites, and fused calcium oxides, iron, magnesium, and manganese. Organic, semi-volatile and volatile compounds are not present in the steel slag due to the fact that they are made at high temperatures during production process. Practically all steel slag are air-cooled, but the current technology of slag production cannot always provide its immediate cooling which can influence its quality. As a consequence, it is not always suitable for further usage and that is the reason why quality control of steel slag production must be provided Long since steel slag had been extensively used as protective armour stones for rivers, sea and coastal erosion schemes and in various land reclamation projects due to their high density, but a certain amount of produced steel slag is still dumped (National Slag Association 1982).

There are two landfills of air cooled steel slag in the Republic of Croatia—near the towns of Sisak and Split. The slag originating from Sisak steel plant is spread out over the area of around 25 ha in the total amount of around 1.5 million tons. At the moment this type of slag is utilised in road construction (as a stabilisation layer) and in agriculture (fine fractions are used for soil improvement). The slag from Split landfill in total quantity of 30.000 tons has not found its application till now. High price of slag disposal imposes the need for finding new fields of its utilisation. Due to high hardness of steel slag its grinding turned out to be unprofitable to be used as cement addition and that is why the intensive research work if focused on the use of steel slag as an aggregate in concrete. Steel slags have already been researched as an aggregate in concrete and results were affirmative.

Keru Wu et al. (1990) investigated the effect of metallic aggregate on strength and fracture properties concrete. The results showed the increase of compressive strength up to 22.1%, splitting tensile up to 19.1 and fracture energy up to 71.5% by the increase in metallic aggregate replacement volume.

- In general, incorporation of steel slag coarse aggregate increases the mechanical properties of high-strength concretes may be due to the strength characteristics of steel slag and the stronger bonding between copper slag aggregate and the cement paste matrix.

- The ratios of splitting tensile strength of the copper slag aggregate concretes to limestone aggregate concretes were higher than the ratios of the corresponding compressive strengths up to 91 days.

Alizadeh et al. (1996) evaluated the effect of electric arc furnace steel slag on hardened concrete. They concluded that using steel slag aggregate concrete leads to higher values of compressive, tensile, flexural strength and modulus of elasticity compared to natural aggregate concrete.The resort to artificial aggregates such as the granulated and crystallized slag allows us to extended construction material scale, to limit over use of natural resources and to value the slag products, that are piled up into blast furnace of El had jar (Algeria) without being able to find valuable solutions.

- Addition of the admixtures generally reduced the capillary water absorption and increase in binder content led to reduce capillary absorption.
- The mixtures containing pozzolana admixtures showed more weight loss and it was particularly apparent for nanoparticles blended mixtures.
- The results showed that the mixtures containing blend of silica fume and SiO_2 nanoparticles have more packed microstructure, less capillary absorption and more thermal weight loss.

L.Zeghichio(2001) shows that the choice of aggregates is important, their quality plays a great role, they can not only limit the strength of concrete but owing to their characteristics, they affect the durability and performance of concrete (Neville, 2000).Generally, sands and natural gravels obtained by screening, or sometimes through crushing are satisfactory, as the igneous rocks or those sedimentary crushed ones.

The blast furnace slag is a by-product obtained in the manufacture of pig-iron in the blast furnace, and is formed by the combination of the earthly constituents of iron ore with the Blast furnace slag issues from blast furnace as a molten stream at a temperature of 1400- 1500°, it may be treated trough various methods following the desired type. This forms the material used as a concrete aggregates, it is a real silico calcareous rock, similar to the basalt, of angular aspect, rugous and of micro alveolar structure (Venuat, 1989).When the molten slag is chilled very rapidly either by pouring into a large excess of water, or by subjecting the slag stream to jets of water. The quenching breaks up the material into small particles, solidifies as a glass. The product is called granulated slag and is used as cement or as sand for concrete (Venuat, 1984).

Yuksel, Isa, et.al (2006) reported that the results of some experimental studies on the use of non-ground-granulated blast-furnace slag (NGGBFS) as fine aggregate in concrete. Two groups of concrete samples were produced. The NGGBFS/sand ratios were 0% (reference), 25, 50, 75, and 100%. The first group (C1) contains only 0 to 7 mm (0 to 0.276 in.) sand as fine aggregate. The second group (C2) contains two sub-types of fine aggregates that are 0 to 3 mm (0 to 0.118 in.) and 0 to 7 mm (0 to 0.276 in.) sands. NGGBFS replaces 0 to 7 mm (0 to 0.276 in.) sand in both groups. Strength and durability characteristics of concrete were compared with respect to control samples and vice versa. According to the results, if the NGGBFS/sand ratio is high in the C1 type, the concrete is porous and has relatively low compressive strength. In the C2 type, however, concrete strength and durability characteristics were better than those in the C1 type. It was concluded that the non-ground-granulated blast-furnace slag can be used as fine aggregate under some conditions.

Quasrawi et al. (2009) conducted a research on the utilization of steel slag as fine aggregate. Compressive strength and 28-day tensile strength tests were performed based on different slag ratios. The results indicated the improvement of compressive strength for replacement slag ratios of 15-30% and tensile strength for replacement slag ratios of 30-50%.

The total substitution of natural fine aggregate with crystallized slag affects positively the tensile, flexural and compressive strength. The partial substitution of natural aggregate with slag aggregates permits a gain of strength at long term. The entire substitution of fine aggregates with slag aggregates should be avoided, it affects negatively the strength.

3. PROPERTIES AND MATERIAL USED

3.1 Coarse aggregate

Table 3.1-Properties of coarse aggregate

S. No	Properties	Value	Requirements of IS 383:1970
1	Specific	2.75	2.5-3.0

	Gravity		
2	Fineness Modulus	5.67	3.5-6.5
3	Bulk Density	1507.5 kg/m^3	-
4	Water Absorption	0.80%	0.2%-4%

3.2 Fine aggregate

Table 3.2- Properties of Fine Aggregate

S. No	Properties	Value	Requirements of IS 383:1970
1	Specific Gravity	2.66	2.5-3.0
2	Percentage of voids	25.50%	<40%
3	Fineness Modulus	2.876	2-3.5
4	Bulk Density	1670 kg/m3	-
5	Water Absorption	1.30%	<2%

3.3 Cement

Table 3.3- Physical properties of cement

S. No	Properties	Value	Standard values
1	Specific Gravity	3.15	3.10- 3.20
2	Standard Consistency	26%	25 – 35
3	Initial Setting Time	43 minutes	>30 min
4	Final Setting Time	510 minutes	<600 min

3.4 Steel Slag

Table3.4- Properties of steel slag

Property	Value
Specific gravity	3.2-3.6
Unit weight kg/m^3	1600-1920
Absorption	Up to 3%

3.5 Chemical Composition

Constituent	Composition (%)
CaO	40 - 52
SiO_2	10 - 19
FeO	10 - 40 (70 - 80% FeO, 20 - 30% Fe_2O_3)
MnO	5 - 8
MgO	5 - 10
Al_2O_3	1 - 3
P_2O_5	0.5 - 1
S	< 0.1
Metallic Fe	0.5 - 10

4. MIX DESIGN

4.1 Mix proportion-Control mix

Cement	= 514.28 Kg
Fine aggregate	= 614.02 Kg
Coarse aggregate	= 1199.97 Kg
Water cement ratio	= 0.35
Mix proportion in M_{40}	**= 1:1.018:2.33**

5. CONCLUSION

Different views of various authors on bond strength flexural strength of concrete, steel slag and recycled aggregate have been discussed. This gives theoretical knowledge about utilization of steel slag and recycled aggregate to replace the cement, fine aggregate, course aggregate from the conventional concrete by various ratios. From the literature review, the scope and idea to replace various concrete components can bring several characteristic changes in concrete physical and mechanical properties. The material testing for various materials used in the project are carried out to determine their properties, convenient to obtain required quality and strength. Design of concrete mix had done in this phase for the M40 concrete and the mix proportion for control mix is 1:1.018:2.33.

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