ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

The Performance of Concrete Mix Containing Steel Slag and Compare it With The Conventional Concrete Mix

D.Rakesh
Department of Civil Engineering,
Amara Institute of Engineering and Technology.

K.Srinu
Department of Civil Engineering,
Amara Institute of Engineering and Technology.

INTRODUCTION:

1.1. Introduction :

Concrete is the most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is unique among major construction materials because it is designed specifically for particular civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together. Concrete plays a critical role in the design and construction of the nation"s infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete.

1.2 AGGREGATES:

Natural aggregates are obtained from natural rocks. They are inert, filler materials and depending upon their size they can be separated into coarse aggregates and fine aggregates. COARSE AGGREGATE: The coarse aggregate fraction is that retained on 4.75 mm (No 4) sieve. For mass concrete, the maximum size can be as large as 150 mm. FINE AGGREGATE: The fine aggregates fraction is that passing the 4.75 mm (No 4) sieve and retained on the 75µ (No 200) sieve.According to some estimates after the year 2010, the global concrete industry will require annually 8 to 12 billion metric tons of natural aggregates. "During the past 25 years, the production of crushed stone has increased at an average annual rate of about 3.3 percent. Production of sand and gravel has increased at an annual rate of less than 1 percent. Production of crushed stone, which is expected to increase by more than 20 percent, will be about 1.6 billion metric tons, while production of sand and gravel will be just under 1.1 billion metric tons, an increase of 14 percent. In essence the amount of crushed stone to be produced in the next 20 years will equal the quantity of all stone produced during the previous century i.e. about 36.5 billion metric tons."Therefore the use of alternative sources for natural aggregates is becoming increasingly important.

1.3 SLAG:

Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

The blast furnace (BF) is charged with iron ore, fluxing agents (usually limestone and dolomite) and coke as fuel and the reducing agent in the production of iron. The iron ore is a mixture of iron oxides, silica, and alumina. From this and the added fluxing agents, alkaline earth carbonates, molten slag, and iron are formed. Oxygen in the preheated air blown into the furnace combines with the carbon of the coke to produce the needed heat and carbon monoxide. At the same time, the iron ore is reduced to iron, mainly through the dioxide. The oxides of calcium and magnesium combine with silica and alumina to form slag. The reaction of the carbon monoxide with the iron oxide yields carbon dioxide (CO_2) and metallic iron.

The fluxing agents dissociate into calcium and magnesium oxides and carbon dioxide. The oxides of calcium and magnesium combine with silica and alumina to form slag.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Depending on the cooling method, three types of BF slag are produced: air-cooled, expanded, and granulated. Allowing the molten slag to cool slowly in air in an open pit produces the air-cooled slag. Air-cooled blast furnace slag is defined in ASTM standard C-125 (American Society for Testing and Materials, 1999) as "the material resulting from solidification of molten blast furnace slag under atmospheric conditions. Subsequent cooling may be accelerated by application of water to the solidified surface."

The solidified slag has a vesicular structure with closed pores. The rough vesicular texture of slag gives it a greater surface area than smoother aggregates of equal volume and provides an excellent bond with Portland cement, as well as high stability in asphalt mixtures. Expanded slag is formed through controlled rapid cooling of molten slag in water or in water with combination of steam and compressed air. Steam and other gases enhance the porosity and vesicular nature of the slag, resulting in a lightweight aggregate suitable for use in concrete. Quenching the molten slag into glass granules by using high-pressure water jets produces granulated slag.

Quenching prevents the crystallization of minerals constituting the slag composition, thus resulting in a granular, glassy aggregate. This slag is crushed, pulverized, and screened for use in various applications, particularly in cement production, because of its pozzolanic (hydraulic cementations) characteristics. Slags are also co products of steelmaking processes. Production of steel calls for the removal of excess silicon by mineralization and of carbon by oxidation from pig or crude iron. Steel slag is a hard, dense material somewhat similar to air-cooled iron slag. It contains important amounts of free iron, giving it its high density and hardness, which make it particularly suitable as a road construction aggregate. Slag is transported to processing plants, where it undergoes crushing, grinding, and screening operations to meet various use specifications.

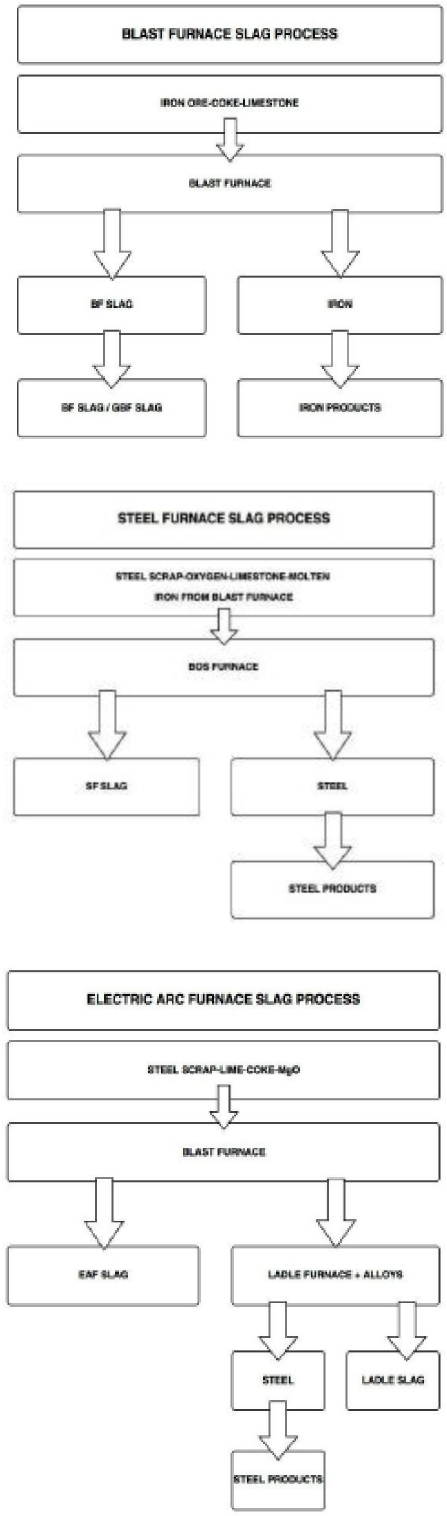

Fig 1.3. Flow Chart Showing the Processes of Various Slags

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

1.4 STEEL SLAG AND ITS PRODUCTION:

Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF). The molten liquid is a complex solution of silicates and oxides that solidifies on cooling and forms steel slag. Steel slag is defined as "a non-metallic product, consisting essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium that are developed simultaneously with steel in basic oxygen, electric arc, or open hearth furnaces". The chemical composition and cooling of molten steel slag have a great effect on the physical and chemical properties of solidified steel slag.

Steel furnace slag is produced in a Basic Oxygen Furnace (BOF) or Electric Arc Furnace (EAF) as a byproduct of the production of steel. In the Basic Oxygen Furnace (BOF), the hot liquid metal from the blast furnace, scrap and fluxes, which contain lime (CaO) and dolomitic lime, are charged to a furnace. A lance is lowered into the converter and then oxygen in injected with high pressure. The oxygen then combines with and removes the impurities as shown in Fig.1.4.1. These impurities consist mainly of carbon in the form of gaseous carbon monoxide, silicon, manganese, phosphorous and some iron as liquid oxides, which combine with lime and dolomitic lime to form steel slag. At the end of the refining stage, the steel in the liquid form is poured into the ladle while the slag is retained at the top in the vessel and is then subsequently removed in separate slag pot. This slag is in molten state and is then processed to remove all free metallic impurities with help of magnetic separation and then sized into construction aggregates.

Unlike the Basic Oxygen Furnace (BOF) process, the Electric Arc Furnace (EAF) does not use hot metal, but uses cold steel scraps. Charged material is heated to a liquid state by means of an electric current. The electricity has no electrochemical effect on the metal, making it perfectly suited for melting scrap. During the melting process, other metals are added to the steel to give the required chemical composition. Meanwhile oxygen is blown into the EAF to purify the steel. This slag which floats on the surface of molten steel is then poured off.

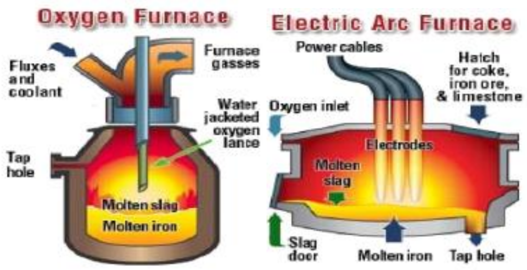

Fig1.4 Schematic illustration of Basic Oxygen Furnace and Electric Arc Furnace.

1.5 CURRENT USES OF STEEL SLAG:

Some of the current uses of steel slag are as follows:

- Steel slag is used as an ideal aggregate in hot mix asphalt (HMA) surface mixture application due to its high frictional resistance and skid resistance characteristics. The cubical nature of steel slag and its rough texture provides more resistance than round, smooth and elongated aggregates.
- It is also used in making Stone Matrix Asphalt (SMA) because the particle-to-particle contact of the aggregate does not break down during the manufacturing, laying down, or compaction process. Illinois Department of Transportation (IDOT) has successfully specified steel slag SMA bituminous mixes on roadways.
- It is also used for manufacture of Portland cement.
- It is used in base application, construction of unpaved parking lots, as a shoulder material, and also in the construction of berms and embankment.
- It is also used in agriculture because it has minerals like iron, manganese, magnesium, zinc and molybdenum which are valuable plant nutrients.
- It is environment friendly. During the production of cement, the CO2 emissions are reduced as slag has previously undergone the calcination process.
- Steel slag aggregates are used for soil stabilization or soil improvement material and for remediation of industrial waste water run-off

THEORY AND LITERATURE REVIEW

2.1 GENERAL

Structural concrete is one of the most commonly used construction material in the world. The use of concrete in various conditions is a well-known fact. Concrete is the only major building material that can be delivered to the job site in a plastic state. The unique quality makes concrete desirable as a building material because it can be moulded to virtually any form or shape.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Concrete provides wide latitude in surface texture and colours and can be used to construct a wide variant of structures, such as highway and streets, bridges, dams, large buildings, airport run ways, irrigation structures, break waters, piers and docks, sidewalks, silos and farm buildings, homes and even ships. In the present experimental work, Steel slag was used as partial replacement for fine aggregate in the concrete mix.

2.2 CONCRETE:

Concrete is the mostly widely used man – made construction material in the world, and is secondly only to water as the most utilized substance on the planet. It is obtained by mixing cementitious material, water and aggregate (and sometimes admixtures) in required proportions. The mixture when placed in the forms and allowed to cure, hardens into a rock-like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continuous for a long time, and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of large particles (coarse aggregate) are filled by the smaller particles (fine aggregate) and the voids fine aggregate are filled with cement.

2.3 CEMENT:

Cement is a material that has adhesive and cohesive properties enabling it to bond mineral fragment into a solid mass. The process of manufacturing of cement consists of grinding the raw materials, mixing them intimately in certain proportion depending upon their purity and composition and burning them in a kiln at a temperature of about 1300◦C to1500◦C, at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3% to 5% of gypsum. The product formed by using this procedure is Portland cement.

2.4 WATER:

The water has two roles in concrete mixture. First is the chemical composition with cement and perform cement hydration and second is to make the concrete composition fluent and workable. The water which is used to make the concrete is drinking water. The impurity of water can have undesirable effect on concrete strength.

2.5 AGGREGATES:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates, good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

2.5.1 Requirements of the aggregates:

1. It should be hard, strong and durable.
2. It should be free from inorganic materials, oils etc.
3. Porosity should be reduced.
4. It should be angular shaped.
5. Low thermal conductivity.
6. Should not react with cement or steel.
7. Should be well graded
8. Should be free from deleterious materials.

2.5.2 Coarse aggregate:

The aggregates most of which are retained on the 4.75 mm IS sieve and contain only that much of fine material is termed as coarse aggregate. Locally available coarse aggregate having the maximum size of 20mm was used in the present work. Often referred to as gravel it normally consists of a distribution of particles, the minimum size being approximately 3/8 inch in diameter and the maximum being defined or restricted by the size of the finished structure. A common maximum size for the coarse aggregate in structural concrete is 1.6 inches.

LITERATURE REVIEW:

Slag is used as substitute to previous clinker. The slag otherwise would have been a waste and used as a filler material slag, if used properly, will conserve valuable limestone deposits required for production of cement. Portland Slag Cement (PSC) has advantages of better performance, durability and optimal production cost, besides being eco-friendly. A brief review of the work carried out by various researchers on use of slag in concrete is presented below. Monshi and Asgarani (14) (1999) producing Portland cement from iron and steel slags after magnetic separation are mixed with limestone of six different compositions.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Samples with higher lime saturation factor developed higher C3S content and better mechanical properties. Blending 10% extra iron slag to a cement composed of 49% iron slag, 43% calcined lime, and 8% steel slag kept the compressive strength of concrete above standard values for type I ordinary Portland cement. From the six different mixtures of limestone, blast-furnace slag, and converter slag, samples M3, M5, and M6 showed relatively good mechanical properties. Cement M3 was blended with 10% iron slag as in the Portland blast furnace cement, and compressive strengths of 140.3, 193.8, 333.3 kg/cm2 were obtained after 3, 7, and 28 days, respectively. The bare minimum compressive strength of concrete for type I Portland cement according to ASTM C150-86 for 3, 7, and 28 days are 12, 19, and 28 MPa, respectively (about 120, 190, and 280 kg/cm^2).

Aldea et al. (1) (2000) studied the effects of curing conditions on properties of concrete by partial replacement of slag. He replaced 0% slag (control), 25% slag, 50% slag, and 75% slag with the cement. The specimen size 75 × 75 mm was used according to ASTM C 496-90. There is small effect of slag replacement up to 50% upon strength, whereas higher replacement results in a fall in compressive strength. The 25% and 50% slag replacement have a valuable effect compared to control, as tensile strength increases for all the curing types. The 50% slag replacement provides tensile strength to some extent higher to no slag replacement, whereas the 75% slag replacement reduces the tensile strength regardless of the curing type used.

Bakharev et al. (4) (2001) investigated the durability of alkali-activated slag (AAS) concrete in sulfate environment. He conducted two tests to find out resistance of alkali-activated slag (AAS) concrete to sulphate attack. These tests involved immersion in 5% magnesium sulphate and 5% sodium sulphate solutions. He observed that the strength decrease was up to 17% for alkali-activated slag (AAS) concrete and up to 25% for ordinary Portland cement (OPC) concrete after 12 months exposure to sodium sulphate solution. After the same time of exposure to the magnesium sulphate solution, the compressive strength decrease was more up to 37% for OPC and 23% for alkali-activated slag (AAS). The Visual examination of OPC concrete shows expansion, cracking, and loss of concrete at the corners of OPC concrete specimens immersed in MgSO4 solution.

OPC concrete experienced larger expansion in sodium sulphate than in magnesium sulphate solution, but the cracking and loss of concrete was more significant in the magnesium sulphate solution. The compressive strength reduction up to 60 days, was the same for AAS and OPC concretes in both environments. Later than, the strength reduction in OPC was higher than that in AAS samples in both environments.Rai et al. (19) (2002) investigated the possibility of using high MnO and low MnO metallurgical slags on samples obtained from an alloy plant of Maharashtra. Electros melt Ltd., Chandrapur, India, could be used as a partial replacement for ordinary Portland cement to make Portland slag cements in India. Low MnO granulated slag was used in making blended slag cement with common Portland cement (OPC). Addition of slag lowered the compressive strength of the blended cement as compared to that of OPC used.

The results, clearly show that by increasing the slag content, there is a fall in compressive strength, yet the 50:50 composition shows 22 MPa and 33 MPa at 7 and 28 days, respectively, of wet curing to conform to IS 455:1989. The rising the slag content beyond 50% causes lowering of the minimum compressive strength specific in the Indian standard condition. High MnO 29 slags could not be recommended for use in slag cements because of the deleterious effects of high MnO content.

METHODOLOGY:

3.1 MATERIAL PROPERTIES:

The materials used in the experimental work namely cement, Steel slag, Fine aggregate, Coarse aggregate (20mm passing and 10mm retained) have been tested in laboratory for use in the mix design. The details are presented below.

3.1.1 Cement:

Ordinary Portland cement of 43 grade was used in the experiment. The details of tests conducted on cement are described below.

a)Specific gravity of cement:

Specific gravity of the cement is calculated by using density bottle method. Cement specific gravity: 3.15

b) Fineness test on cement:

Fineness test on cement can be calculated by sieve test or air permeability method, in commercial cement it is suggested that there should be about 25 to 30% of particles less than 7 microns in size. Fineness of test cement: 92% .

c) Initial and final setting time on cement:
Initial and final setting time on cement is obtained by vicat‟s apparatus, for the initial setting time of the cement vicat‟s needle should penetrate to a depth of 33 to 35 mm from the top, for final setting time the vicat‟s needle should pierce through the paste more than 0.5mm.We need to calculate the initial and final setting time as per IS:4031 (Part 5) –1988. Initial setting time of test cement: 90mins Final setting time of test cement: 3hrs 30mins (210 mins)

d) Standard consistency test:
The standard consistency test of a cement paste is defined as that consistency which will permit vicat‟s plunger having the 10mm diameter and 50mm length to penetrate to a depth of 33 to 35 from the top of the mould. The basic aim to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031(Part4)-1988.
Standard consistency of test cement :33%

3.1.2 Fine aggregate:
Aggregates smaller than 4.75mm and upto 0.075 mm are considered as fine aggregate. The details of test conducted on fine aggregate are described below.

a)Specific gravity:
The specific gravity of fine aggregate is 2.64

b) Fineness modulus:
The standard definition of fineness modulus is as follows “An empirical factor obtained by adding the total percentages of a sample of the aggregate retained on each of a specified series of sieves, and dividing the sum by 100.”Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part1)-1963.

3.2 CONCRETE SAMPLING:
Acceptance of the concrete in the site is performed based on the results of the compressive tests of concrete samples. The concrete samples must be taken from the final consumption place.

3.2.1 Preparation of cubes:
Materials used for concrete cubes are cement, fine aggregate, coarse aggregate and water. After testing the materials and also after the mix proportion concrete cubes are made by following procedure.

1. Making, curing and testing cubes should be carried out in the correct manner. Even small deviations from the standard procedures will usually lead to strength results which are lower than the true strength of the concrete.
2. It is very important that the concrete put into the moulds should be a representative sample of the concrete that is going into the works.
3. Moulds should be filled in three approximately equal layers (33mm deep). A compacting bar is provided for compacting the concrete. During the compaction of each layer with the compacting bar, the strokes should be distributed in a uniform manner over the surface of the concrete and each layer should be compacted to its full depth. During the compaction of the first layer, the compacting bar should not forcibly strike the bottom of the mould. For subsequent layers, the compacting bar should pass into the layer immediately below. The minimum number of strokes per layer required to produce full compaction will depend upon the workability of the concrete, but at least 35 strokes will be necessary except in the case of very high workability concrete. After the top layer has been compacted, a trowel should be used to finish off the surface level with the top of the mould, and the outside of the mould be wiped clean.

4. During the compaction of each layer by means of a vibrating hammer, the mould should preferably be placed on a level piece of timber. The concrete should be vibrated by holding the foot of the hammer against a piece of timber placed over but not completely covering the top of the mould. The applied vibration by either vibrating hammer or table should be of the minimum duration necessary to achieve full compaction of the concrete. Vibration should cease as soon as the surface of the concrete becomes relatively smooth and air bubbles cease to appear.

5. Test cubes should be demoulded between 16 and 24 hours after they have been made. If after this period of time the concrete has not achieved sufficient strength to enable demoulding without damaging the cube then the demoulding should be delayed for a further 24 hours.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

When removing the concrete cube from the mould, take the mould apart completely. Take care not to damage the cube because, if any cracking is caused, the compressive strength may be reduced.

6. Cubes must be cured before they tested. Unless required for test at 24 hours, the cube should be placed immediately after demoulding in the curing tank or mist room. The curing temperature of the water in the curing tank should be maintained at 27-300C.

Fig3.2 Curing tank

3.3. TESTING OF SPECIMENS FOR COMPRESSIVE STRENGTH

Concrete specimens cubes are used to determine compressive strength of concrete and were tested as per IS 516-1959. On the date of testing i.e. after 28 days of using the cube specimens were removed from the water tank and placed on flat surface for 10 minutes to wipe off the surface water and grit, and also removes the projecting fines on the surface of the specimens. Before placing the specimen in the testing machine the bearing surface of the testing machine was wiped clean and the cube specimen also cleaned. The cube specimen was placed in the machine, of 2000kn capacity .the load was applied at a rate of approximately 140 kg/cm2/min until the resistance of the specimen to the increasing load can be sustained , was shown in fig.

Fig3.3 Compression testing machine

3.4. TESTING OF SPECIMEN FOR FLEXURAL STRENGTH:

Concrete specimen beams are used to determine flexure strength of concrete and were tested by applying two point loading as per IS 516-1959. The prism specimens were removed from the water tank on 28th day and placed for 10 minutes to wipe off the surface water. The dimensions of each specimen were noted before testing. The test specimen was marked for third point load as show in fig.Before placing the specimen in the testing machine the bearing surface of the supporting and loading rollers were wiped off clean and any loose sand or other material was removed from surface of the specimen.

The specimen was placed in the machine in such a manner that the load was applied to the upper most surface as casted in the mould, along two lines spaced 13.33 cm apart. The axis of the specimen was carefully aligned with the axis of loading device. The load was applied through two similar steel rollers, 38mm in diameter, mounted at the third point of the supporting span that is spaced at 13.33cm centre to centre. The load was applied without shock and increasing continuously at the rate of 180kg/min until the specimens during the test was recorded. The appearance of the fracture faces of concrete and unused features in the types of failures was noted.

Fig 3.4 Universal testing machine

RESULTS AND DISCUSSION:

Tests like Compressive strength, Split tensile strength, Workability, Flexural strength and Stress- Strain curves behavior are conducted for concrete made of different replacements of sand with steel slag for 7 and 28 days of curing. The specimens are tested for 7 and 28 days for 0%, 10%, 20%, 30%, 40%, 50% replacement of steel slag. Durability studies were carried out for the cubes immersed in MgSO4,

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Na_2SO_4 and HCL for 28 and 56 days of curing. The results are tabulated and discussions have been made.

4.1 SLUMP CONE TEST:

The Variation of slump with increase in percentage of steel slag 0%, 10%, 20%, 30%, 40%, 50% are tabulated and the graph is plotted below.

Table 4.1 Workability in terms of Slump Cone test

Sl.No	Description	Slump (mm)
1	Plain concrete	55
2	Steel slag 10%	58
3	Steel slag 20%	63
4	Steel slag 30%	67
5	Steel slag 40%	70
6	Steel slag 50%	65

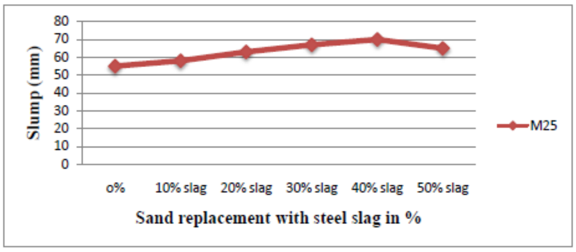

Fig 4.1 Variation of Slump

Description of result:

 From Fig 4.1.,The variation of slump for the partial replacement of Fine aggregate with Steel slag increased in the order of 55, 58, 63, 67, and70mm for 0%, 10%, 20%, 30% and 40% proportions and decreased to 65 mm for 50% replacements respectively.

4.2 COMPRESSIVE STRENGTH TEST:

Concrete cubes of size 150mm x 150mm x 150mm were cast for 0%, 10%, 20%, 30%, 40%, 50% steel slag replacement. The compressive strength for M25 grade is tested for 7 and 28 days of curing and the results are tabulated and plotted below.

Table 4.2 Compressive strength with different replacement percentages of Steel slag

% of Steel Slag replacement	Average 7 Days compressive strength (N/mm^2)	Average 28 Days compressive strength (N/mm^2)
0%	20.36	32.07
10%	22.8	34.66
20%	23.16	36.10
30%	24.73	37.95
40%	26.8	40.79
50%	24.14	35.25

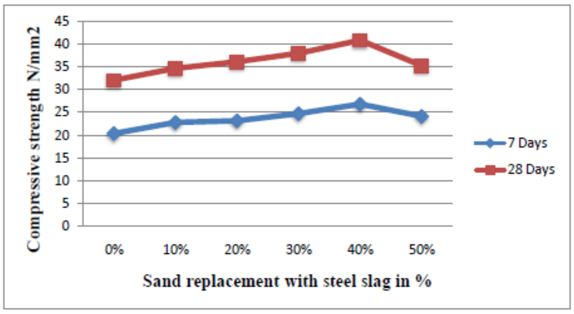

Fig 4.2 Compressive strength of concrete by partial replacement of sand with Steel slag

CONCLUSIONS:

Based on the analysis of experimental results and discussions there upon the following conclusions are made.

1. The compressive strength, flexural strength and split tensile strength of normal concrete and concrete with Steel slag as partial replacements are compared and inferred that the strength of the normal concrete is slightly lower than the Steel slag replaced concrete.
2. The compressive strength increases with increase in percentage of steel slag upto 40% by weight of fine aggregate. The enhancement in compressive strength is about 32% for 7 days of curing and 27.2% for 28 days of curing period.
3. The split tensile strength increases with increase in percentage of steel slag upto 40% by weight of fine aggregate. The enhancement in split tensile strength is about 48.2% for 7 days of curing and 31.2% for 28 days of curing period.
4. The Flexural strength increases with increase in percentage of steel slag upto 40% by weight of fine aggregate. The enhancement in Flexural strength is about 20.12% for 7 days of curing and 17% for 28 days of curing period.
5. From the results of compressive strength, split tensile strength, flexural strength at 7 and 28 days of curing, 40% replacement of fine aggregate by steel slag is the optimum percentage of replacement for M25 grade concrete.
6. From the Stress-Strain curve behavior of concrete, 40% Steel slag replaced for fine aggregate is similar to that of M25 conventional concrete.
7. The compressive strength of concrete gets decreased when compared to the control concrete for all the percentage replacements of Steel slag but However there is an increase in strength for 40% replacement of Steel slag but slightly less

than the strength compared to conventional concrete for 0.5% and 1% of HCL and $MgSO_4$(50g/l), Na_2SO_4(50g/l) at the ages of 28 and 56 days of strength.

8. The benefits of Cost reduction and Utilization of waste material is possible in construction by using Steel slag as a partial replacement material for fine aggregate in concrete.

REFERENCES:

1) Aldea C, M., Young F., Wang K., Shah S. P. (2000). "Effects of curing conditions on properties of concrete using slag replacement." Cement and Concrete Vol. 30 pp 465-472.

2) Ameri M., Kazemzadehazad.S. (2012) "Evalution of the use of steel slag in concrete". 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia.

3) Bakhareva T., Sanjayana J.G., Cheng Y.B. (2001) "Sulfate attack on alkali-activated slag concrete." Cement and Concrete Vol. 32 pp 211-216.

4) Bilim C., Atis C. D., Tanyildizi H., Karahan O. (2008) "Predicting the Compressive Strength of Ground Granulated Blast Furnace Slag Concrete using Artificial Neural Network". Advances in Engineering Software Vol. 40 pp 334–340.

5) Binici H., Temiz H.S., Kose M.M. (2006). "The effect of fineness on the properties of the blended cements incorporating ground granulated blast furnace slag and ground basaltic pumice."

6) Higgins D.D. (2003). "Increased sulfate resistance of ggbs concrete in the presence of carbonate." Cement and Concrete Composites Vol. 25 pp 913-919.

7) M.Soundar rajan. (2014). "study on strength properties of concrete by partially replacement of sand by steel slag."International Journal On Engineering Technology and Sciences Vol 1.

8) K.Chinnaraju,V.R.Ramkumar, K.Lineesh, S.Nithya, V.Sathish. (2013). "study on concrete using steel slag as coarse aggregate replacement and eco sand as fine aggregate replacement". International Journal of Research in Engineering & Advanced Technology, Vol 1, Issue 3.