COMPARITIVE STUDY OF STEEL SLAG WITH COARSE AGGREGATE AND TESTING ITS BINDING PROPERTIES WITH BITUMEN

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Abstract— **This paper deals with the study of steel slag with coarse aggregate and testing its binding properties with bitumen. Steelslag is a by-product produced from the steel industries. In India more than 50 iron and steel industries are available and around 72.20 million metric tonnes of steel is produced. The amount of waste generated is 19 million metric tonnes worldwide. Due to lack of utilization of these steel slag huge amount of waste are dumped in the agricultural land and pollute the environment. The main objective is to make proper utilization of the waste disposal material produced from the steel industries into effective construction materials. These materials are broken down to smaller sizes to be used as aggregate in pavement layers. The purpose of this study is to review the engineering properties of steel slag and its utilization for road construction in different way.**

Keywords — **Steel slag, industrial waste materials, engineering properties, construction materials.**

I. INTRODUCTION

The huge quantities of waste (such as scrap tires, glass, blast furnace slag, steel slag, plastics, construction and demolition wastes) accumulating in stockpiles and landfills throughout the world are causing disposal problems that are both economically and environmentally expensive. Dealing with the rising trouble of disposal of these materials is a matter that requires management and commitment by all parties involved. One of key solution to a portion of the waste disposal problem is to recycle and use these materials in the construction of highways.

During the production of three tons stainless steel around one ton of steel slag is generated. It has been noticed that per year fifty million tons of steel slag is generated from different steel industries throughout the world. It contain minerals of cementing properties such as C2S and C2S.SO.steel slag is industrial waste resulting from steel refining plants in conversion process. The method followed for the production is two type they are basic oxygen steel (BOS) and electric arc furnace(EAF).From EAF method the aggregate produced is used in road construction because of its sustainable characteristics.

The waste material is neutral and non organic hazardous is natural as per chemical analysis report of central pollution control board India (CPCB).the quantity of generation of this steelslag is around 24 lakhs metric ton per year from different steel industries in India CRRI 2010.the steel slag is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non metallic components present in the steel scrap.

This research deals with the sustainable replacement of natural aggregate, in which coarse aggregate were partially replaced with steel slag aggregate in the construction of roads and also review the engineering properties of steel slag.

II. PREPARATION PROCESS OF STEEL SLAG

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Virtually all steel is now made in integrated steel plants using a version of the basic oxygen process or in specialty steel plants (mini-mills) using an electric arc furnace process. The open hearth furnace process is no longer used.

In the basic oxygen process, hot liquid blast furnace metal, scrap, and fluxes, which consist of lime (CaO) and dolomitic lime (CaO.MgO or "dolime"), are charged to a converter (furnace). A lance is lowered into the converter and high-pressure oxygen is injected. The oxygen combines with and removes the impurities in the charge. These impurities consist of carbon as gaseous carbon monoxide, and silicon, manganese, phosphorus and some iron as liquid oxides, which combine with lime and dolime to form the steel slag. At the end of the refining operation, the liquid steel is tapped (poured) into a ladle while the steel slag is retained in the vessel and subsequently tapped into a separate slag pot.

There are many grades of steel that can be produced, and the properties of the steel slag can change significantly with each grade. Grades of steel can be classified as high, medium, and low, depending on the carbon content of the steel. High-grade steels have high carbon content. To reduce the amount of carbon in the steel, greater oxygen levels are required in the steel-making process. This also requires the addition of increased levels of lime and dolime (flux) for the removal of impurities from the steel and increased slag formation.

There are several different types of steel slag produced during the steel-making process. These different types are referred to as furnace or tap slag, raker slag, synthetic or ladle slags, and pit or cleanout slag. Figure presents a diagram of the general flow and production of different slags in a modern steel plant.

The steel slag produced during the primary stage of steel production is referred to as furnace slag or tap slag. This is the major source of steel slag aggregate. After being tapped from the furnace, the molten steel is transferred in a ladle for further refining to remove additional impurities still contained within the steel. This operation is called ladle refining because it is completed within the transfer ladle. During ladle refining, additional steel slags are generated by again adding fluxes to the ladle to melt. These slags are combined with any carryover of furnace slag and assist in absorbing deoxidation products (inclusions), heat insulation, and protection of ladle refractories. The steel slags produced at this stage of steel making are generally referred to as raker and ladle slags.

Fig.1 Steel Slag

III. PREPARATION PROCESS OF STEEL SLAG

Pit slag and clean out slag are other types of slag commonly found in steel-making operations. They usually consist of the steel slag that falls on the floor of the plant at various stages of operation, or slag that is removed from the ladle after tapping. Because the ladle refining stage usually involves comparatively high flux additions, the properties of these synthetic slags are quite different from those of the furnace slag and are generally unsuitable for processing as steel slag aggregates. These must be segregated from furnace slag to avoid contamination of the slag aggregate produced.

In addition to slag recovery, the liquid furnace slag and ladle slags are generally processed to recover the ferrous metals. This recovery operation is important to the steelmaker as the metals can then be reused within the steel plant as blast furnace feed material for the production of iron.

S No	DESCRIPTION	VALUES
1.	Specific gravity of coarse aggregate (as per IS-383)(2.6-2.8)	2.75
2.	Specific gravity of steel slag aggregate	2.67
3.	Water absorption of coarse aggregate	1.65%
4.	Water absorption of steelslag aggregate	3.5%

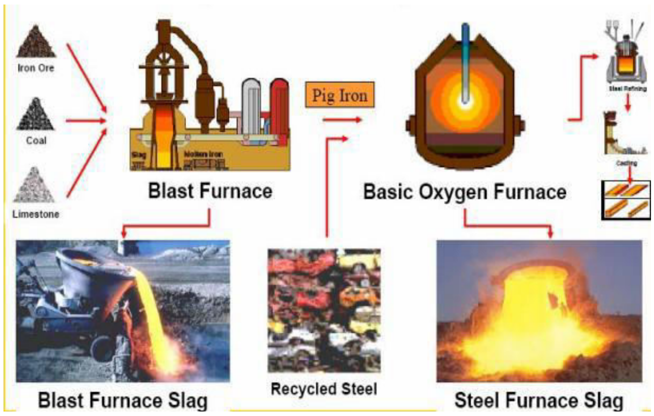

Fig.2 Production of Steel Slag

IV. PROPERTIES OF STEEL SLAG

Table.1 Material Properties of Steel Slag

Table.2 Chemical Properties of Steel Slag

S.No	CHEMICAL COMPOSITION	RANGE
1.	Calcium oxide(CaO)	34-43%
2.	Silicon dioxide(SiO_2)	10-20%
3.	Aluminium oxide(Al_2O_3)	7-12%
4.	Magnesium oxide(MgO)	7-15%
5.	Iron(FeO or Fe_2O_3)	0.2-1.6%
6.	Manganese oxide(MnO)	0.15-0.76%
7.	Sulphur(S)	1.0-1.9%

Table.3 Physical Properties of Steel Slag

S No	DESCRIPTION	PROPERTY
1.	Colour	Black
2.	Specific gravity	2.67
3.	Apperance	Crystalline
4.	Compacted unit weight(kN/m^3)	10.98-13.34
5.	Absorption %	3.5

THERMAL PROPERTIES:

Steel slag, has a potential to retain the heat as longer than natural aggregate. The heat retention property of steel slag aggregate is an advantage. It helps to prepare hot mix asphalt concrete to coat the aggregates properly specially repairing of pavements surface in cold weather

OBJECTIVES:

1) To investigate the Physical properties of Steel slag.

2) To replace natural aggregate with Steel slag.

3) To study of Marshall Properties (Flow and Stability) of Bituminous mixes using Steel slag.

4) To verify whether it is strong enough to withstand the load that is applied during the transportation.

V. METHODOLGY

Experimental Investigation:

The comparison work is based on the laboratory studies and analysis of different test carried out in the laboratory. The different test carried out on the steel slag aggregate such as the sieve analysis ,impact value test, crushing value test, water absorption test, specific gravity test, abrasion test and to determine the binding properties with bitumen Marshall stability test is conducted and for strength determination stripping test is conducted as per IS:6241-1971.

Sieve analysis:

Weigh the sample to the nearest 0.1 g by total weight of sample. This weight will be used to check for any loss of material after the sample has been graded. Select suitable sieve sizes in accordance with the specifications. Next the sieves in order of decreasing size from top to bottom and begin agitating and shaking the sample for a sufficient amount of time. The final total of the weights retained on each sieve should be within 0.3% of the original weight of the sample prior to grading. Particles larger than 3 in. (75 mm) should be hand sieved. When passing large stones through sieves, do not force the aggregate through the sieve openings.

Specific Gravity:

Steel slag contains sufficient amount of iron oxide, therefore it has greater value of specific gravity as compare to the natural aggregates. Number of researchers has evaluated the specific gravity of other construction materials and that of steel slag fall within the range of 3 to 4. Steel slag is about 20 % heavier than the lime stone and granite. This may be an economic disadvantage, but is not considered, as it provides more advantages like high strength and durability.

Impact value:

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows. Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (**W2**) to the total weight of the sample (**W1**).

Crushing value:

The aggregate passing through 12.5mm IS sieve and retained on 10mm IS sieve IS selected for standard test. The aggregate is dried and heated to a temperature of 100^{o}c to 110^{o}c and cooled to room temperature. The cylindrical mould is filled by the sample in three layers of approximately equal depth and each layer is tamped 25 times by tamping rod. The cylinder with test sample and the plunger is position is placed on compressing testing machine. Load is then applied through the plunger at a uniform rate of 4 tonnes per min until the total load is 40 tonnes and then the loads are released. Aggregate including the crushed portion are removed from the cylinder and sieved on a 2.36mm sieve. The material which passes this sieve is collected.

Marshall Stability Test:

Marshall Method is applied with penetration bitumen or viscosity grade bitumen. It requires the preparation and evaluation of a series of tests with different bitumen content of each other. The Marshall test uses standard cylindrical test specimen that are 10 cm diameter by about 7.5cm high. The specimens are prepared using a prescribed procedure for heating, mixing and compacting the bitumen-aggregate mixtures. The two principle features of the Marshall method of mix design are a density-voids analysis and a stability-flow test of the compacted test specimens. The stability test is a type of unconfined compressive strength The Marshall stability of each test specimen is the maximum load resistance in Newton that the specimen develops, whilst the Marshall Flow value is the total movement or strain occurring in the specimen between no load and maximum load during the stability test.

The specified gradation of mineral aggregates and bitumen as per IRC 29-1968.The aggregate and Stone dust are mixed together in the desired proportion as per the design requirements and fulfilling the specified gradation. The required quantity of the mix is taken so as to produce compacted bituminous mix specimen of thickness 63.5 approximately. Approximately 1200g of aggregate in which 10%, 20% and 30% (weight of the Mix), the steel slag and stone dust are taken and heated to a temperature of 175^{o}C to 1900^{o}C. The bitumen is heated to temperature of 120 ^{0}C to 138^{0}C and the required quantity of first trial percentage of bitumen 4 % by weight of mineral aggregate is added to the heated aggregate and mixed together. The mixing is temperature about 160 0C. The mix is placed in mould and compacted by rammer with 75 blows on each side. Then the sample was extracted and heat at 60 0C according to the standard procedure.

Fig.3 Testing in Laboratory

VI. TEST RESULTS

Table 4 - Sieve Analysis

S No	IS SIEVE	Weight retained(gms)	Cumulative weight retained	Cumulative % of weight retained	% of passing
1	80	0	0	0	100
2	60	0	0	0	100
3	40	1295	1295	25.9	74.1
4	20	1690	2985	59.7	40.3
5	10	1025	4010	80.2	19.8
6	4.75	840	4850	97	3
7	2.36	150	5000	100	0
8	1.18	0	5000	100	0
9	600	0	5000	100	0
10	300	0	5000	100	0
11	150	0	5000	100	0

Table 5 - Comparison of Steel Slag with Coarse Aggregate

Steel slag aggregate		Natural aggregate	
Finess modulus	7.63	Fineness modulus(as per IS-383-6to8)	6.50 to 8.00.
Average impact value%	47.2	Average impact value%	<20% stronger

Table 6 – Marshall Stability Test

% of bitumen	Marshall stability value in (kg)	Flow value	Bulk density(g/cm^3)	Air voids % (w)	% volume of bitumen (V_b)	VMA	VFB %
4	638	8	1.883	5	8.84	13.84	63.87

Table 7 - Permissible value of normal aggregate

Test Property	Specified Value
Marshall stability, kg	340 (minimum)
Flow value, 0.25 mm units	8 - 17
Percent air voids in the mix **Vv%**	3-5
Voids filled with bitumen **V FB%**	60-80

UTILIZATION OF STEEL SLAG IN THE CONSTRUCTION OF ROADS:

Steel slags have been successfully utilized for the construction of roads in wearing course, base and sub base as well. It is observed that the use of steel slag for low volume roads economical as compare to the natural aggregates. from the various laboratory test performed on steel slag and result were collected. the test result shows good and within the indian specification. the steel slag aggregate satisfy the basic requirements for used as aggregate. Properly weathered steel slag has been investigated for the construction of low volume roads as a base material. Satisfactory results of resilient modulus were obtained from steel slag as compare to the natural aggregates.

1. The Steel slag physical properties like Impact Value, Abrasion Value, Specific Gravity and water absorption are as per requirements of Indian standards.
2. The Marshall Stability and Flow value are satisfied for the 20 % steel slag proportion.
3. The result of conventional mix and steel slag aggregate mix shows almost same properties.

VII. Conclusion

Steelslag has a number of advantages with high engineering properties. It has been declared a useful construction material not an industrial waste. The overall conclusion drawn from the experimental investigation is it can be utilized as a partial replacement for aggregate in road construction It is concluded based on chemical and mineralogical

composition, the properties of steel slag are different compared to the natural aggregate. So, the guidelines of natural aggregate are being followed for steel slag is not appropriate. Economically the steel slag may be cheaper if utilized in urban roads but it would be expensive for rural roads due to the transportation charges.

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