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Analysis of Steel Slag Sand: An Eco-Friendly Fine Aggregate for Construction

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Abstract:
Industrial waste slag is a major issue concerning the environmentalists today. The steel making industry produces a large amount of byproduct which is termed as Slag. Slag is produced during the steel-making operations that utilize Electric Arc Furnaces (EAF) and operate by smelting iron ore in the Basic Oxygen Furnace (BOF). Steel slag finds numerous uses in the construction industry e.g in the applications involving hot mixture asphalt, in Stone Matrix Asphalt (SMA), berms and embankments constructions, main ingredient in manufacturing of Portland cement, as fine and coarse aggregates, to name a few. But steel slag has a negative impact on the environment when disposed of. In that case a wide variety of use of steel slag becomes relevant. Steel Slag is a perfect candidate to replace the coarse and fine aggregates in the traditional concrete used in the construction industry. Most of the volume of concrete is aggregate. Steel Slag can be used as replacement to these aggregates in a more prominent way. In this research study, we will be making steel slag as substitution for raw fine aggregate. Fine aggregate would be replaced by these wastes in different proportions (20%, 40%, & 60 %) by weight of fine aggregate. The aim of this study is to investigate the compressive strength, split tensile strength and Material properties of concrete with partial replacement for fine aggregate. We will be performing pull off test on the applications of this modified concrete and checking the results for strength and durability.

Keywords: steel slag; fine aggregate; concrete; compressive strength; tensile strength

Introduction

Concrete is one among the widely used materials after water, certainly not exaggerating. The Quality of concrete determines the quality of infrastructure and in turn the economy of the region. Concrete is a composite material which contains a coarse granular material known as aggregates or filler brought together in the form of a thick paste with the help of the cement or binding material that occupies the space between the aggregated particles and binds them together. Aggregates used in concrete are usually obtained from natural rocks, river beds, crushed stones or natural gravels.

According to some estimates after the year 2020, the global concrete industry will require annually 8 to 12 billions metric tons of natural aggregates (U.S.G.S and nationalatlas.gov, accessed Nov 2008). 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. Based on these numbers, by 2020 U.S. crushed stone production is projected to increase by more than 20 percent and this number will be around 1.6 billion metric tons, whereas production of sand and other aggregates used in concrete will be just under 1.1 billion metric tons with an increase of 14 percent. To summarize, the amount of crushed stone to be required in the next 20 years will be equal to the quantity of all stone produced during the previous century which is about 36.5 billion metric tons.. (U.S. Geological survey). Additionally there have been problems related to durability characteristics of these natural aggregates in addition to their availability.

In the past 20"century, steel slag was found to be an excellent aggregate for road paving. Chemical composition of a steel manufacturing firm's waste material, which would perform a major role in future consist mainly Si02, Al2O3, CaO, MnO, MgO, TiO2, P205 and fe203. The steel slag is considered as the material for various types of structures due to its durability in the construction field. Concrete is a widely used construction. For a long time it was considered as the durable material requiring a little or no maintenance. In recent times it was too harsh environments, deterioration of concrete will occur, when reinforced concrete structures are exposed due to many reasons like chloride and sulphate attack, acid attack, corrosion failure etc. On other hand, the aggregates used for the concrete are having greater demand and are facing shortage.

Utilization of industrial soil waste or secondary materials has been encouraged in the construction field for the production of cement and concrete. There are very few investigators on the use of Steel slag in cement concrete. Not much research has been carried out in India and other countries concerning the incorporation of Steel slag in concrete. Our main objective is to generate experimental data demonstrating the comparison between steel slag and natural aggregate.

More than three quarters of the total concrete volume is composed of aggregate. This indicates that important properties of concrete such as strength, durability and serviceability etc. largely depends upon the property and quality of aggregates used.

The solution to this problem is to introduce suitable alternatives to natural aggregates and it has always been challenging. Utilizing steel slag in concrete mixes has proven to be useful in resolving some of the many problems encountered in the concrete industry. Steel slag was used in conventional concrete with an aim to improve its mechanical, physical, and chemical properties. Moreover for environmental purposes the recycling of industrial waste slag is an important component of sustainable development. The only problem with steel slag aggregate is its expansive characteristics and unwanted reactions between slag and components of concrete.

Literature Survey

Bashar Taha (2009) [1] in his research “Utilization waste recycled glass as sand/cement (RSG) and pozzolanic glass powder (PGP)” was examined in their study. There is no major difference found in compressive strength while replacing RSG while compressive strength reduced by 16% whereas 10.6% decrement noted at 28 and 364 days when 20% of Portland cement was replaced by PGP. British Standard BS 812 Part 123:1999 was followed by an experiment for monitoring the potential expansion of concrete due to alkali-silica reaction (ASR). This research work failed to show good results with that of sand/cement both.

Girish Sharma(2015)[2] studied in his work “Beneficial effects of steel slag on concrete” with the aim of replacing steel slag of M35 grade with aggregates(fine & coarse), the percentage from 0% to 55% and tested on its 7th and 28th day after curing. Their deep analysis concludes that there is constant increment when replaced with that of steel slag and can be used practically. Decrement is mentioned after 55% in case of coarse aggregate.

P. Jyotsna Devi et.al.(2014)[3] in their work "A Study on the Flexural and Split Tensile Strengths of Steel Fibre Reinforced Concrete at High Temperatures "mixing with 1% volume of steel fibers to evaluate its performance at normal (M30) and high strength concrete (M60).They introduced good results with that of steel fibres.By adding steel fibers flexural resistance can be increased. The test is carried out for 7, 28 and 91 days

Electric arc furnace slag (EAFS) contains a low percentage of amorphous silica whereas they have a very high content of ferric oxides while having low, or no, pozzolanic activities when compared with blast furnace slag (BFS). This is the reason it is not appropriate to be used in blended cement production. However much research work has been conducted on the evaluation of use of steel slag usage in road construction and use of blast furnace slag in concrete mixes, some research has been conducted considering the utilization of steel slag in concrete. [4]

Alizadeh et al. carried out a research to evaluate the effect of using electric arc furnace steel slag on hardened concrete. Experimental results indicated that such steel slag aggregate concrete achieved higher values of compressive, tensile and flexural strength and modulus of elasticity, compared to natural aggregate concrete[5]

Experimental study of blast furnace slag concrete - Authors : Gurjeet singh, sanjay sangwan, Mohd.usman Ultra-fine aggregate. Different strength parameters such as compressive strength, flexural strength, split tensile strength etc. are evaluated and shown that by incorporating slag partially or fully in concrete, the mechanical properties of concrete can be improved. However, using blast furnace slag as a fine aggregate in concrete mixture has not been studied yet. Hence, in the present study, blast furnace slag is used as a fine aggregate in different proportions i.e. 0%, 20%, 40%, 60%, 80% and 100%. The compressive strength, split tensile strength and flexural behavior of reinforced beams are evaluated and compared with that of the strength of the control mix. [6]

Utilization of steel slag in concrete as a partial replacement material for fine aggregate -Authors: P.S kothai, Dr.R.Malathy is a detailed study of the potential health risks regarding environmental application (eg. Fill, road base, landscaping) of iron and steel manufacturing was performed using characterization data of 73 samples of slag which were collected from blast furnaces, basic oxygen furnaces and electric arc furnace.As part of study, the Characterization data was compared to regulatory health based benchmarks and then used to determine constituent of interest anatomy, Beryllium, Cadmium, Trivalent and hexavalent chromium, manganese, thallium and vanadium was measured above screening levels and were examined. This main purpose of this research was to study the effectiveness of using steel slag aggregate (SSA) in improvising the strength and other engineering properties of local asphalt concrete (AC) mixes. The research began by evaluating the toxicity and chemical and physical properties of the steel slag. The structures are then exposed to various stress conditions and chemical combinations like chloride and sulphate attack, acid attack, corrosion failure etc. Utilization of industrial soil waste or secondary materials has been encouraged in the construction field for the production of cement and concretes.[7]

What is Steel Slag?

Steel Slag forms one of the major components of solid wastes from the steel making processes in an integrated steel plant. During manufacturing of steel through the furnace route in which carbon rich molten pig iron is converted to steel, all of the unwanted impurities are removed using different fluxing agents as steel slag so that the maximum amount of steel can be manufactured from iron by lowering the carbon content and the alloy can be achieved. According to Indian Mineral Book 2018, steel slag output is somewhere around 20-30 percent by weight of the crude steel production in India, which generates around a total 18.5 million tonnes of solid steel slag annually in India. This quantity is projected to increase to 30 million tonnes by 2030 with an approximate increase in the production of steel as per the National Steel Policy 2017. A vast majority of steel slag generated after metal recovery ends as waste dump in landfill material. The amount of Steel slag waste generated every year in India forms the most proportional waste material in the landfills. Proper management of this waste is an important aspect from an environmental point of view. With increase in technology this waste management process has improved but still there are many improvements needed. The major chemical components of steel slag are CaO, SiO2, Fe2O3, Al2O3, MgO, MnO, FeO, fCaO, etc. This chemical composition proportions can vary based on raw material, smelting technology and steel type. The major mineral components of steel slag are tricalcium silicate, dicalcium silicate, dicalcium ferrite, calcium-magnesium peridotite, calcium-magnesium rose-pyroxene, RO phase (solid solution formed by MgO, FeO and MnO) and free lime. This mineral composition of steel slag can be different, and the influencing factors are the chemical composition of steel manufactures, majorly the basicity of steel slag. Su[10] stated that olivine, rosaceous pyroxene and RO phase are the main minerals of low-basicity slag, dicalcium silicate and tricalcium silicate are the major minerals of medium-basicity slag and tricalcium silicate are the main minerals of high-basicity slag. The major mineral components of steel slag are tricalcium silicate, dicalcium silicate, dicalcium ferrite, calcium-magnesium peridotite, calcium-magnesium rose-pyroxene, RO phase (solid solution formed by MgO, FeO and MnO) and free lime.

Methodology

The following were the main aspects of the research:

A. Conventional concrete mixes of 25, 35 and 45 MPa cube strength are used. All the mixes are prepared and curated to obtain concrete with medium workability (slump 8-12 cm).
B. The above mixes were tested for workability according to ASTM C 143.
C. The mixes of fresh density were measured according to ASTM C138 and a few Cubes of 100 mm side were prepared, cured and tested at the ages of 3. 7, 28. 90 and 180 days for compressive strength. At each age. at least three cubes were chosen randomly and tested in saturated surface dry condition.
D. 1(X) x 100 x 500 mm prisms were used for testing flexural strength and were tested at the ages of 7, 28 and 90 days.at each age three prisms were tested using three point loading method described in ASTM C78.
E. Steel slag mixes were prepared replacing sand by 15%. 30%. 50%, and 100% by weight of sand.
F. Steel slag concrete cubes and prisms were prepared. We performed a check for pozzolanic activity using ASTM C 618. C. Results

Material Used

1. **Cement:** Ordinary Portland cement of grade 53 was used. The specific gravity of the cement used for the sample is 3.15 while the setting time is 30 minutes.
2. **Fine Aggregate:** Fine aggregate used was clear sand passing through 4.75 mm sieve with a specific

gravity of 2.6.

3. **Water:** We have used portable drinking water with a pH value of 7 and conforming to IS 456 – 2000 for concreting.
4. **Steel Slag:** We have used Steel slag obtained from conversion of iron to steel in a Basic Oxygen Furnace(BOF)

Conclusion

The demand for aggregates, especially fine aggregates, is increasing rapidly and so is the demand for concrete. Due to this reason, it is becoming very important to find suitable alternatives for concrete aggregates in the future. Our research results showed that properties that steel slag possessed are similar to natural aggregates and it would not cause any harm if mixed into concrete. From the research studies discussed the important conclusions on using steel slag as fine aggregate are as follows. The use of steel slag as aggregate affects workability in adverse manner but it improves the tensile strength and compressive strength to a considerable point. The negative effect on workability can be compensated for by using appropriate admixtures. When replacement percentages are between 15 and 30% , best results are obtained for compressive strength. The tensile strength increases by 1.1-1.3 times. The use of steel slag improves tensile strength of nixes with 01 replacement ratios. It has also better durability and freeze thaw properties. Up to 50 to 75 % of steel slag aggregates when incorporated in the traditional concrete, there would not be much change in the durability of concrete. A much more extensive field study on a concrete structure made with steel slag aggregates used in the mixture should be conducted and changes in durability and mechanical properties
should be investigated and correlated to laboratory results.

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