Processing of GBS to Match characteristic Properties of PGBS with natural Sand

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Abstract:
With restrictions on indiscriminate dredging of river sand and stone crushing there has been a growing need in civil fraternity for identification of alternative fine aggregates. One promising alternative has been granulated slags generated in steel plants, but were limited to partial replacements due to property variations. Most of this slag is presently dumped. Granulated blast furnace slag (GBS) is physically similar to sand but has low density and has strength issues when used in concrete. In the present work a new processing technique has been explained to convert this slag into fine aggregate to match with river sand, for construction purpose. This multiple stage processing involves change in structure and shape of the slag granules. Properties like texture, specific gravity, water absorption and partical distribution of processed granulated blast furnace slag (PGBS) were found to meet the standard requirements Fine aggregate. This innovative processed granulated blast furnace slag or slag sand is an economically viable and environmentally acceptable alternative material for replacing river sand having tremendous economic impact, conservation of natural resources and gainful re-cycling of process by-products. This slag sand is now extensively utilized and marketed by JSW Steel Vijayanagar works, India.
Keywords: granulation, concrete, fine aggregate, gradation, Physical properties, Chemical properties.

1 INTRODUCTION

1.1 GENERAL

Concrete is one of the most fed on material in volumes and India being a developing with in the country will require concrete in huge proportions. Approximately three-fourths of the extent of concrete is occupied by way of coarse and fine aggregates. Coarse aggregates are presently sourced from breaking huge rocks and mountains which has long term environmental effects. Fine combination or sand is mined from river bed which is also getting depleted and exhausted, and its excessive mining has led to the ecological imbalance. In India the demand for aggregates is constantly increasing. As in keeping with a current estimate, India fed on 3330 MT of total aggregates (coarse and first-rate) in 2015 and will require 5075 MT of aggregates by using 2020. With restrictions on mining of river sand and stone crushing, there has been a growing want in civil engineering fraternity for identity of alternative aggregates. In order to mitigate environmental impact, alternative materials to be used as satisfactory aggregates are being notably investigated all around the world. Slag has been one of the maximum sought alternative aggregate material due to its similarity with aggregates and quantity generated by using steel industries suits properly into the call for deliver gap. Until these days, slags were not regularly utilized in civil production due to the benefit of availability of natural materials, lack of attention of its advantages, non-availability of application tips and constrained slag processing strategies. Further, availability of slags only in regions close to metal plants, logistic problems of transportation and most importantly regulations or non-availability of requirements on utilization of non-natural aggregates in construction have greatly impaired the use of slag into creation enterprise. With ecological concerns and environmental restrictions, availability of natural aggregates particularly river sand is significantly decreased and most of the evolved countries have amended their combination standards to permit opportunity or artificial aggregates consisting of slag in construction works. Steel makers have now commenced adopting contemporary slag processing techniques to convert slag as a product to meet the standards for creation necessities. Present improvement is a good sized pass towards safety of environment through introducing processed granulated blast furnace slag as an eco-friendly opportunity to river sand. This initiative is first of its kind within the country.

1.2 SCOPE OF STUDY

The important scope of this study is to reach the Properties Granulated blast furnace slag (GBS) to match natural sand after processing. Comparison of PGBS with other fine aggregate materials like crushed stone sand.

1.3 AIM OF THE STUDY

Comparing the each physical and chemical properties of processed granular blast furnace slag (PGBFS) with River sand and crushed stone sand.

1.4 OBJECTIVE OF STUDY

- To find out an appropriate and 100% alternative of pleasant fine aggregate.
- To find out viable usage of waste substances in production industry that during flip significantly reduce the use of excellent aggregate and ultimately reduce production cost.
- To evaluate the impact of the usage of steel slag in concrete.

2 LITERATURE REVIEW

Many studies were accomplished With ecological issues and environmental regulations, availability of natural aggregates in particular river sand is significantly reduced and most of the superior international locations have amended their aggregate necessities to allow alternative or synthetic aggregates alongside slag in roads and advent.

2.1 EXPERIMENTAL EXAMINE ON 100% REPLACEMENT OF RIVER SAND WITH GRANULATED BLAST FURANCE SLAG SAND.

1. **D. Satish Kumar, Praveen Kumar, Rameshwar Sah, Marutiram Kaza and SMR Prasad (2016)** performed study on **"Converting Granulated Blast Furnace Slag into Fine Aggregate".**

Present improvement is a large circulates in the direction of protection of surroundings via introducing processed granulated blast furnace slag as an green alternative to river sand. This initiative is first of its kind within the country.Results of this research show that The bodily characteristics of slag samples have substantially advanced after the processing. The debris shape has progressed. The processed granulated blast furnace slag (PGBS) changed into just like the actual river sand. The shapes of the natural river sand and PGBS debris resemble closely. Size distribution of the processed granulated slag become also similar to river sand. PGBS matched the required physical homes of fine aggregate for use in concrete.

2. **Ganesh Khatri, L. Aparna, P.Thrivikrama Reddy (2018)** performed study on **"A Replacement Slag – Slag Sand".**

Commonwealth Scientific & Industrial Research Organisation (CSIRO) carried out investigations for price- brought method for slag and proved some of technically viable and commercially interesting packages of slag. The programs consist of (i) base route and top direction for asphalt roads, (ii) anti-skid surfacing for roads on twist of fate prone intersections, (iii) low power concrete for footpaths, (iv) controlled low strength fill for backfill required for trench stabilisation and (v) concrete sub-base for rigid pavements.

3. **Prem Ranjan Kumar, Dr. Pradeep Kumar T.B (2015)** performed study on **"Use of Blast Furnace Slag as an Alternative of Natural Sand in Mortar and Concrete".**

To examine the impact of partially replace best aggregates with blast furnace slag and find its impact on the energy characteristics of concrete and mortar. Study of energy residences of mortar and concrete at the ages of 3, 7 days and seven, 28 days respectively for 0%, 25%, 50%, 75% and 100% substitute of herbal sand. Comparative have a look at of strength houses consequences of both the grades (20 M Pa, and 30 M Pa) of concrete and mortar with percentage (1:4) containing herbal sand and blast furnace slag.

4. **M C Nataraja1, P G Dileep Kumar, A S Manu and M C Sanjay (2013)** performed study on **"USE OF GRANULATED BLAST FURNACE SLAG AS FINE AGGREGATE IN CEMENT MORTAR".**

This paper investigates the opportunity of utilizing Granulated Blast Furnace Slag (GBFS) as a sand alternative in cement mortar, so that you can reduce environmental issues associated with combination mining and waste disposal. The float characteristics of the numerous mixes and their compressive strengths at various a while are studied. From this take a look at it's far discovered that GBFS could be applied in part as alternative construction fabric for natural sand in mortar applications. Reduction in workability expressed as glide may be compensated via including suitable percentage of notable plasticizer.

The end result of the research for the replacements of natural sand with GBFS became discussed. The substitute changed into taken as 0, 25, 50, 75 and a hundred% for 1:3 mortars mixes proportions for 0.5w/c and a 100% replacement of GGBS for w/c of 0.4 and 0.6 respectively.

3 MATERIALS

3.1 INTRODCTION

The substances used for construction have progressed with time, relationship again to the early days of the Roman Empire. Advancements in techniques with which those materials are characterized and implemented to pavement structural design have accompanied this advancement in materials.

The materials which we have used for our project are as follows.

3.1 RIVER SAND

Sand is a granular material composed of finely divided rock and mineral particles. It is described by length, being finer than gravel and coarser than silt. Sand can also talk over with a textural class of soil or soil kind; i.e., a soil containing more than 85 percent sand-sized particles with the aid of mass. The composition of sand varies, depending on the local rock resources and situations, but the maximum common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), commonly in the form of quartz. The second maximum commonplace kind of sand is calcium carbonate, for example, aragonite, which has in the main been created, over the last 1/2 billion years, by using diverse styles of existence, like coral and shellfish. For instance, it is the number one form of sand apparent in areas in which reefs have ruled the environment for hundreds of thousands of years like the Caribbean. Sand is a non-renewable useful resource over human timescales, and sand appropriate for making concrete is in high demand. Desert sand, although considerable, isn't suitable for concrete. 50 billion heaps of seashore sand and fossil sand is used each year for creation. Possibility of silt presence in river sand is high. Properties of have been mentioned in **table 2.**

3.2 CRUSHED STONE SAND

Crushed stone sand has surfaced as a possible alternative to Natural River sand and is being now used typically at some stage in the arena as high-quality combination in concrete. It is synthetic through crushing the quarried stone to a length that will completely skip through 4.75 mm sieve. it contains about 1.62% FeO, 1.82% CaO, 71.95% Silica(SiO_2), 0.71% MgO, 14.40% Al_2O_3, 4.12% K_2O and 3.68 % Na_2O and 1.7% others.

The source of Crushed sand is a quarry. It is manufactured via Crushing rocks, quarry stones or larger aggregate pieces into sand size debris in a manufacturing facility or quarry. It is artificially synthetic so there are no oversized substances. The compressive electricity as well as the flexural power of concrete made from Crushed sand is higher than natural sand. Properties of crushed stone have been mentioned in **table 2.**

3.3 GRANULATED BLAST FURNACE SLAG

Impact heater is an iron making unit which changes over iron mineral into liquid iron through decrease responses, in nearness of coke and motions. Notwithstanding liquid iron, the heater produces slags in the scope of 250 to 500 kg for each ton of hot metal. "Slag" is a non-metallic item, comprising of glass containing silicates and alumino silicates of lime and is a side-effect of the change forms. Overall, it contains about 0.5–0.8 % FeO, 32–42% CaO, 35–40% SiO_2, 8–9% MgO, 10–19% Al_2O_3, 0.3–1.0% MnO and 0.7–1.5%S in weight. Granulated impact heater slag is acquired by quickly chilling (extinguishing) the liquid slag at around 1,500°C from the heater by methods for water and air. During this procedure of extinguishing, the liquid slag experiences quickened cooling under controlled water stream condition and gets changed over into polished sand with 97 % of the strong granulated slag particles under 4 mm. Granulated BF slag is consistently utilized by concrete industry for making Portland slag concrete; anyway transformation of this slag into fine total and use as substitution of stream sand is a creative and novel way to deal with reuse slags.

Increasing wishes of infrastructural development and declining deliver of river sand because of its indiscriminate mining have brought about discover other change fabric for production purpose to lessen the intake of scarce and highly-priced river sand. R&D RINL has taken initiative on this environmental issue and assessed the suitability of GBF Slag as an green opportunity to river sand .The chemical and physical properties of Granulated Blast Furnace (GBF) slag is extra strong and constant than the ones of river sand. Approximately BF slag production is one 0.33 of overall warm steel produced. With a view to utilize BF slag in civil creation, the opportunity of use of GBF slag as quality mixture as replacement to river sand is taken up for examines.

3.4 PROCESSED SLAG SAND

“Slag”, a non-metal product consisting essentially of glass containing silicates and alumino-silicates of lime. This is a by-product acquired inside the manufacture of pig-iron in blast furnaces at excessive temperatures (1,400°C-1,500 °C) inside the molten form. The granulated slag is shaped via quenching (the molten ash from the furnace) by water or air and steam. Slag is transported to processing flowers, where it undergoes crushing, grinding, and screening operations to meet numerous use specs. Processed slag is both shipped to its customer for immediate use and, in slack seasons, stored. Depending at the cooling technique, three varieties of BF slag are produced: air-cooled, multiplied, and granulated. The use of slags has become a not unusual exercise in Europe on the turn of the nineteenth century.

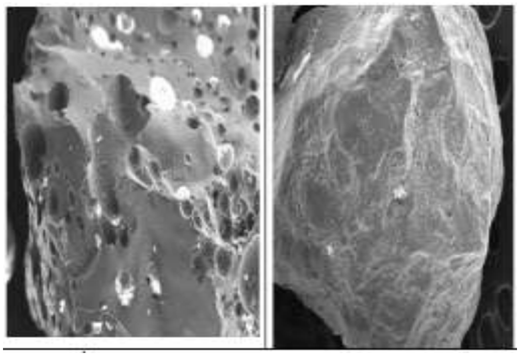


Figure.1: Comparison of particle morphology (a) River sand (b) GBS

4 PROBLEME

Granulated blast furnace sags (GBS) are available with steel industry for decades but were never accepted as a fine aggregate in construction activities till this developmental work. Several test have been carried out which confirms that granulated blast furnace slag is inert, non-toxic, free from traditional impurities (i.e. organic impurities, shells, clay) and is chemically similar to an aggregate. Though it looks alike sand, granulated blast furnace slag (GBS) does not meet the physical property requirement of the aggregate specifications and when used in civil applications has resulted in lower strengths. There has been numerous published works on utilization of BF slag sand as replacement of river sand under various conditions and varying proportions in mortar and concrete. Most of the papers recommend the usage of granulated BF slag as replacement of river sand in the range of 50 - 75 %. This difference is due to the variation in the quality of BF slag sand being used from different sources. Here, it is pertinent to mention that the property requirement in granulated slags for use in cement and as aggregate is different. Slags to be used for cement making requires high glassy phase (>90%) whereas slags to be used as fine aggregate must have sufficient density (> 1400 kg/m3) or specific gravity (> 2.5). This standard property is required to meet the weight requirement in cubic meter of concrete. Most of the studies used the granulated slag with the density range of 950-1100 kg/m3 and this can be seen as the primary reason for reduction in strength with increasing proportions.

Reasons for its reduced strengths and developing a processing technology for converting GBS into acceptable fine aggregate has explained. A major drawback identified with the use of GBS in construction is the lesser bulk density (1000 -1100 kg/m3) in comparison to the of river sand (1300-1600 kg/m3) which results in lower strength of concrete. Higher water absorption and lower specific gravity also contributed to its lower properties. Comparison of GBS properties with river sand is shown in Table 1. Microscopy studies showed that lower density in slags is due to its vesicular structure with micro pores present in the slag grains. The porous structure of GBS grains is shown in **Figure.1**. Size distribution showed that the particles are mostly in coarse zones of standard size distribution and lack finer component. When used in concrete it lower down the compaction and reduces the strength. The coarser GBS particles have irregular shape and appear porous with sharp edges, whereas the finer GBS particles have needle or flaky shape with sharp edges. The glossy needle like particles renders the GBS difficult to handle with bare hands. Hence, if the GBS has to be used as fine aggregate as a replacement of river sand, its physical properties especially density, size distribution and shape must be modified. Various tests conducted under this study have confirmed that GBS can be used as 100% replacement of natural sand in concrete mix design if slag density can be increased to greater than 1400 kg/m3.

Table 1: Comparison of Physical Properties

Properties	River Sand	GBS	Crushed Stone Sand
Size	IS 383 - Zone II (Fine)	IS 383 – ZoneI (Coarse)	IS 383 - Zone I (Coarse)
Density, Kg/m3	300 - 1600	1000-1100	1600
Sp Gravity	2.6 - 2.8	2.3 – 2.5	2.51
Water Absorption,%	1 – 3	4 - 6	<3

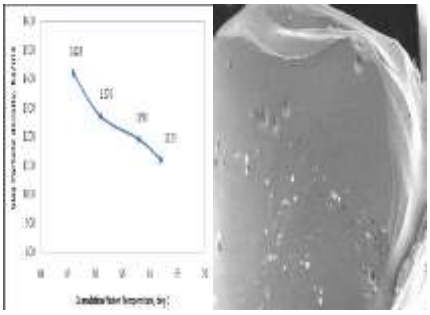
5 PROCESSING

Conversion of GBS into a fine aggregate requires improvement structure and shape.

The developed conversion process involves improving the physical properties in two stages.

5.1 Stage 1: Altering granulation parameters

Slag Granulation is primarily affected by water temperature, water pressure and water flow rate. When the material solidifies under slow cooling conditions, escaping gases leave behind micro pores in the cooled mass. When formed under controlled rapid cooling, the slag tends to be hard and dense, making it suitable for use in all concrete applications. It was conceptualized that density and specific gravity of granulated slags can be increased by optimizing granulation parameters such as water temperature and flow rate to produce slag sand similar to river sand. Based on this concept, several trials were conducted at blast furnace slag granulation plant, with varying water temperature and flow rates. The granulated slag samples were collected and analyzed for specific gravity, bulk density and structure through microscopy. It was found that reducing the jet water temperature reduced the porosity in the slag granules. The highly porous structure of earlier granulation slag has improved to much denser structure resulting in improved density. **Figure 2(a)** shows the effect of slag granulation water temperature on density. It was found that under optimum conditions of granulation parameters, the bulk density of the slag can be increased to > 1350 kg/m3 as more compact structure can be developed in slag granules. Micro-graphs of the low temperature water spray granulated material shows



(a) (b)

Figure 2: Structure of Low temperature water cooled slag

lower porosity contributing to the increased density as shown in **Figure 2(b)**. It was found that, to achieve the best result the jet water temperature has to be less than 50 °C and minimum water flow rate to be kept at 2500 m3/hr. Accordingly the process parameters were changed to meet the optimized conditions. However, the shape and size distribution did not change much and the issue of needle or flaky shape particles still existed and required further modifications.

5.2 Stage 2: Shaping and Screening The second stage of processing was to address the needle or flaky shape of the particles by subjecting it to customized shaping and screening process. The purpose was to increase the finer portion of material (<300 microns) and to convert individual particles into rounded shape without breaking grains. Increase in the finer fraction would have also helped in increasing the bulk density. It was conceptualized that the slag particles should be subjected to abrasion process and not grinding to meet the shape and size requirement. As no customized equipment was available for abrasion process, it was decided to tune a vertical shaft impactor for achieving the desired function. Normally, a vertical shaft impactor is used for crushing stones. In a shaft impactor, feed material drops through the feed tube onto the impeller table or enclosed rotor which, through centrifugal force, throws the material against stationary anvils made up of composite metal alloys. When the rock particles impact the anvils, it shatters along natural stress lines, creating a uniform cubical product. This method of crushing is simple and economical to operate.

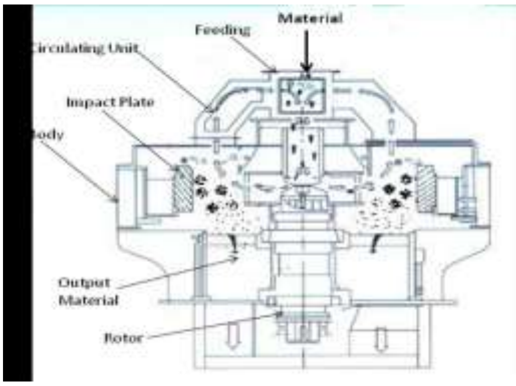


Figure 3: Vertical Shaft Impactor

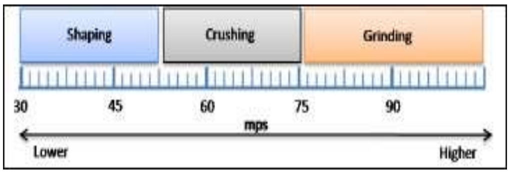


Figure 4: Effect of rotor velocity on particles in Vertical Shaft Impactor

A pilot scale vertical shaft impactor was brought and modified for studying the feasibility of achieving an abrasion function for slag particles. A simple design of shaft impactor is shown in **Figure 3**. In an impactor, the particle projectile velocity and impact force with which it hits the anvils decides whether the particle will get shaped, crushed or ground. Higher speeds results in pulverizing and grinding as shown in **Figure 4**. Hence the size and shape of the processed slag particle generated are controlled by feed rate and rotor speed. It was found that by manipulating the rotor speeds the feed material can be subjected to only shaping. Series of experiments were conducted by varying these variables and an optimized range of feed rate and rotor speed were established where the slag particles does not break and only change the shape. These parameters require continuous fine tuning based on the input mean average size particle. The impactor processed slag granules were of rounded shape but the size distribution required some alteration. Hence these shaped particles were subjected to screening to get the desired size range fitting to the standard. After the second stage of processing, the bulk density of the slag has further increased to 1500 kg/m3 and is close to the value of natural river sand. Water absorption reduced from 8% to < 3% and no needle shaped particles left out in the final processed material.

6 TESTS AND RESULTS

The physical characteristics of slag samples have greatly improved after the processing. The particles shape has improved. The particles develop blunter edges as compared to the needle or flaky shape with sharp edges in GBS. The processed granulated blast furnace slag (PGBS) was similar to the true river sand. Properties of GBS, PGBS river sand and Crushed stone sand are compared in Table 2. The shapes of the natural river sand and PGBS particles resemble closely. Comparison of particles of GBS, PGBS river sand and Crushed stone sand is shown in **Figure 5**. Size distribution of the processed granulated slag was also similar to river sand. PGBS matched the required physical properties of fine aggregate to be used in concrete. Size distribution of PGBS is shown in **Figure 6**. In addition to properties, the key advantage of slag sand over river sand is absence of impurities like clay and silt.

Figure 5: Particles of river sand, GBS, PGBS and crushed stone sand

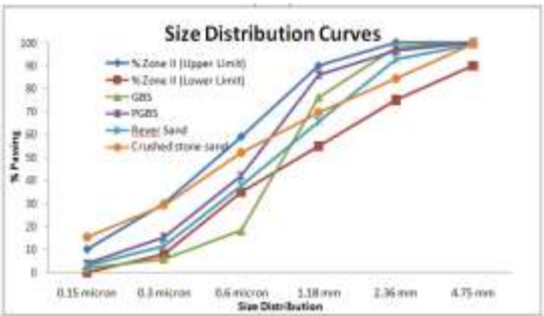


Figure 6: Size distribution curves of the GBS, PGBS River sand and Crushed stone sand

Table 2: Properties of GBS, PGBS and river sand

Properties	River Sand	GBS	PGBS	Crushed Stone Sand
Size	IS 383 – Zone-II	IS 383 – Zone-I	IS 383 - Zone II	IS 383 - Zone II
	(Fine)	(Coarse)	(fine)	(Fine)
Density, kg/m3	1300 - 1600	1000-1100	1500	1600
Sp Gravity	2.6 - 2.8	2.3	2.65	2.51
Water Absorption, %	1 – 3	4 -6	<3	<3

Figure 7: physical testing for various materials

PGBS was then experimented for Physical and chemical properties, to match Fine aggregate with it when used in concrete. The flow characteristics clearly indicate that properties with PGBS are equally good or marginally better than properties of river sand and Crushed stone sand. The slightly angular shape of some slag particles increases the amount of surface area for bonding with cement paste and reduces the high internal stress concentrations leading to higher strength values. The bond strength between the rebar and concrete with river sand and PGBS as fine aggregate is found in similar range.

7 CONCLUSION

The controlled granulation and impactor processed slag finally matched the specifications of the fine aggregate standard. This innovative processing methodology developed for blast furnace slag has converted a waste into a commercial product specially when availability of river sand is a serious concern and its prices are going up. Use of PGBS as fine aggregate in civil construction is a landmark development for steel and civil industry. As the civil fraternity resembles the fine aggregate with the word “sand” or “river sand”, a new terminology is coined as “SLAG SAND” for its easy identification and commercial advantage.

Tramp element studies proved that sags contain different types of heavy metals in very low concentrations and are well below the environmental norms and hence the newly developed slag sand does not have any environmental hazards and can be applied safely in aquatic environment, such as rivers, lakes or streams without impacting water quality or aquatic life. The use of slag as aggregate reduces the need for virgin material, energy and polluting emissions generated during the mining, processing and transportation of that material. This will also help in reducing the huge slag pile-ups by steel industries around their manufacturing units. Availability of a suitable alternative aggregate will help in controlling illegal and rampant mining of natural resources which causes disastrous impact on environment and economy

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