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Production of Pelletized Cold Bonded GGBS Aggregates

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Abstract: *Aggregates plays a major role in the field of construction, the requirements of conventional natural aggregates are increasing immensely. Replacement to this very substance with a relevant substitute is prominent. GGBS a hazardous waste product of iron industry have proven to constitute high cementatious properties when treated with alkalis like Sodium hydroxide and Sodium silicate. The production of mentioned artificial aggregates can be done using a laboratory scale pelletizer, whose angle of rotation and speed of rotation is adjustable. The aggregates are produces in different mixes based on alterations in the molarity of alkaline solution. The produced aggregates are introduced to cold bonding method, which is intended to increase the intermolecular strength. The properties of aggregates produced from optimal mixes are characterized according to standard specification. Tests like sieve analysis, crushing strength are conducted on the prepared aggregates.*

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I. Introduction

Aggregate constitutes the major part of any concrete construction. They include fine aggregates which passes through IS 4.75mm sieve, coarse aggregates which retain on IS 4.75mm sieve and ' all in aggregates 'which constitutes all of the major fractions. Conventional aggregates are obtained directly from nature. The major problem associated with conventional aggregates is the depletion of resources. Once they are used in concrete it cannot be brought back into its original form. The harm caused to the environment is tremendous. So, the requirement of proper substitution for conventional aggregate is a matter of immediate importance.

Ground-granulated blast-furnace slag (GGBS) is obtained as a byproduct from blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical compositions of GGBS depend on the raw materials used in the production of iron while the physical properties depend on the cooling process used to cool down the molten materials. GGBS produces lower heat during the hydration process, enhances resistance from chloride and sulfate attack.

Artificial aggregates can be manufactured from GGBS from various processes such as sintering, pelletization and cold bonding. GGBS reduces the likelihood of concrete thermal cracking, and it improves concrete's resistance to damage from alkali-silica reaction, Sulphates and Chlorides. Concrete in aggressive environments is much more durable with the use of GGBS as a partial replacement for the cement. GGBS is proven to exhibit binding properties when treated with certain chemicals like sodium silicate and sodium hydroxide. By utilizing this advantage we can produce artificial aggregates from GGBS with a comparatively minimal cost rather than the existing techniques like sintering and autoclaving. The production is done on a laboratory pelletizer whose angle and speed can be adjusted. Since alkaline solution is used as a binder the cost of production is decreased and that too without compromising the efficiency of production. This paper is used to study the production of artificial aggregates using alkaline solution as a binder and the effect of the heat curing hardening process on the produced aggregate.

II. Material And Methods

2.1 Materials

2.1.1 GGBS

GGBS is a waste product obtained as a byproduct from blast furnaces used to make iron. It is obtained as fine powder and is proven to be extremely hazardous component. GGBS particles are generally angular in shape. The average particle size of GGBS is 9.2 μm. GGBS has a high degree of reactivity. In addition GGBS reduces the energy consumption and also the emission of CO_2. Blast-furnaces operate at temperatures of about

1,500°C and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore is reduced to iron and the remaining materials form a slag that floats on top of the iron. This slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The quenching optimizes the cementitious properties and produces granules similar to coarse sand. This 'granulated' slag is then dried and ground to a fine powder. The chemical composition of GGBS is as in table 3.1. The physical properties of GGBS is as in table 3.2.

Figure 2.1 GGBS

Component	Percentage (%)
CaO	40
SiO_2	35
Al_2O_3	13
$Mg(Oh)_2$	8

Table 2.1a: Composition of GGBS

Color	Off White
Specific Gravity	2.9
Bulk Density	1000-1100 kg/m^3 (loose) 1200-1300 kg/m^3 (Vibrated)
Fineness	>350m^2 /kg

Table 2.1b: Physical Properties of GGBS

2.1.2 Alkali Solution

Alkali solution was prepared using sodium hydroxide and sodium silicate. Sodium hydroxide in pellet form and sodium silicate in solution form was taken for the study. Initially sodium hydroxide solution of 10 M was prepared and after that experiments were also done using 12 and 14 molar. The sodium hydroxide to sodium silicate ratio was taken as 1:1.5 and this solution was added to GGBS.

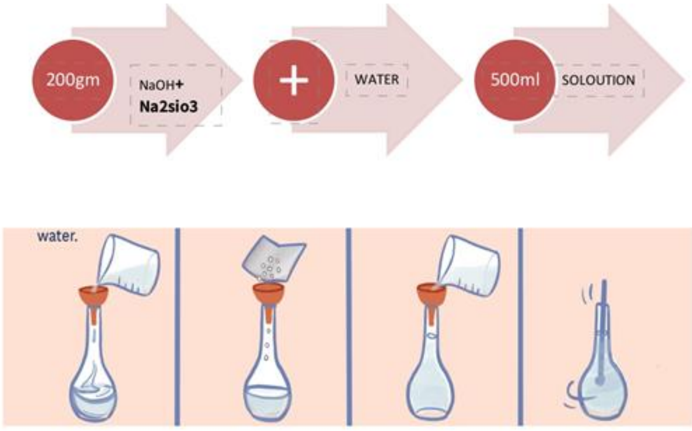

Figure 2.1.2: Preparation of Solution

2.2 Machine Design

The design of a laboratory scale disc pelletizer is important because of their low market availability and high price. Most common models starts from a price range of near lakhs. So, it is economical to design a pelletizer which suits the mode of operation of low scale aggregate manufacture. The following design concept enables a fairly good production efficiency and simplicity in handling.

Pan: - it enables the placing and mixing fly ash powder with the binders by providing a circular motion. The pan is made of GI sheets and it has a diameter of 450mm and height of 100mm. The pan is connected to the rotating shaft of a gear box at its center to enable the circular motion.

Motor: - A 3phase 0.5hp AC motor is used in the design. The motor has an rpm of 1440. A three-phase motor is selected because of the factor that it can provide more torque for very low speeds.

Gear box :- The pelletizer is designed to work in very low rpm. So, a gear box of ratio 1:20 is used to convert the rpm output of the motor from 1440 to merely 72 without compromising the torque.

VFD :- A Variable Frequency Drive is used to alter the frequency of their output by rectifying an incoming AC current into DC and then using voltage pulse-width modulation to recreate the waveform of AC current and voltage. The motor will receive the input through a VFD which is so programmed that the rpm of the disc can be varied from 0 to 72 in this case. VFD also helps in converting single phase input to three phase output so that the motor can work without damage.

Steel frame : Steel frame provides support to the setup and also a bolt and screw arrangement is provided to change the angle of the disc with the horizontal. The angle can be varied from 00 to 350 which can be further increased by increasing the length of the screw and the ground clearance.

Blades : blades are provided on a frame connected steel beam spanning through the diameter of the disc inclined to the direction of motion. The circulating particles collides with blades and gets deflected to the pan bottom resulting in the formation of round pellets.

Push on/off button : it is provided to turn on and off the machine. It provides a less fragile platform suitable for rough use and also facilitates to shut down the machine in emergencies.

MCB and Potentiometer : these are components which are externally connected to the VFD for increasing the safety. MCB automatically trips when there is sudden voltage variation. Potentiometer is provided to adjust the speed of the machine without using the knob of the VFD so that it can be given full covering against dust.

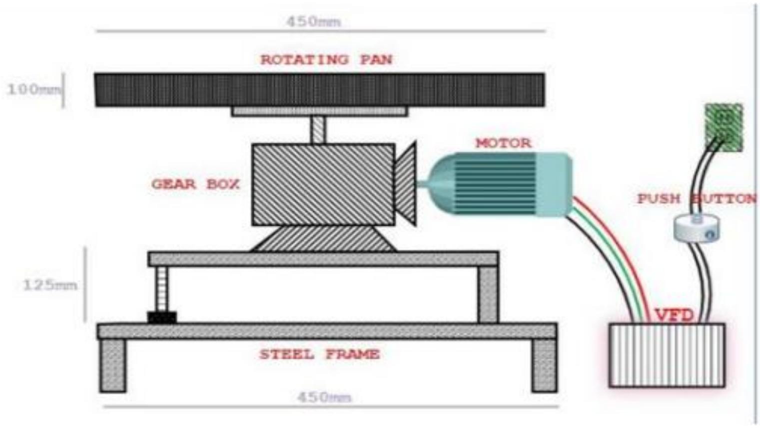

Figure 2.2a: Design model of disc pelletizer

Figure 2.2b: Manufactured disc pelletizer

Note: The motor can be replaced with a similar power DC motor but an extra rectifier has to be purchased and in that case the cost of manufacture may rise higher. The total cost of manufacture for the current mode of design is just around thirty thousand rupees including the cost of weld and work.

2.3 Aggregate Production and Testing

The pelletization process for the production of GGBS aggregates was basically carried out in a disc pelletizer. The GGBS is first spread on to the disc where the rpm at which the disc is rotated and the angle of rotation of the disc is adjusted. As the disc rotates with the GGBS, slowly a solution of sodium silicates and sodium hydroxide is added as drops which act as moderators.

Aggregate will be produced under different trial angles and rpm. 20, 40 and 60 were the rpms and 15, 25 and 35 were the degrees of the disc plate under the experiment. Sieve analysis was conducted for the produced aggregates and it was found that the disc plate with 25 degree and under 20 rpm worked more efficiently. This was because the maximum peak in sieve analysis was obtained under this set up.

In case of sodium hydroxide solution initially a 10 molar solution was prepared and after that experiments were also done with 12 and 14 molar solutions. The sodium silicates to sodium hydroxide ratio followed was 2.1 and this solution was added to GGBS.

The produced GGBS aggregates were then cold bonded for further strengthening. First the pellets were allowed to rest in the ambient temperature conditions for 12 hours, after that the pellets were immersed in normal water for 24 hours. Cold bonding intends to increase the bonding strength by the process of fusing in the absence of heat. The aggregates are then removed and kept in ambient temperature conditions until it is ready to test for aggregate properties.

Sieve analysis, specific gravity, bulk density, percentage voids, water absorption and crushing strength of individual pellets are the main tests conducted on the produced aggregates.

Figure 2.3a: Production of GGBS Aggregates

Figure 2.3b: Produced GGBS Aggregate

III. Result

3.1 Efficiency of Pelletization

Efficiency of pelletization is obtained by calculating weight of GGBS fine aggregate retained on the 4.75 mm IS sieve to the total weight of aggregate produced multiplied by 100.For calculating efficiency 1 kg of GGBS fine aggregate were taken. When the angle of the disc was set up for 36° the majority of aggregate produced was coarse aggregate but when angle of disc was at 25° and 15° the majority of aggregate produced was fine aggregate so major part of study deals with GGBS fine aggregates.

$$\text{Max Efficiency} = 0.469/1*100 = 47\%$$

So the efficiency obtained was 47% at 25° and 20 rpm. Based on these efficiencies following tests were conducted.

3.2 Specific Gravity of Aggregate

Specific gravity of fine aggregate is the ratio of the weight of the given volume of aggregate to weight of equal volume of water. Specific gravity is calculated by pycnometer method. 500 g of GGBS aggregate were taken. Apparent specific gravity is the weight of dry sample to the weight of equal volume of water. Specific gravity of fine aggregate $=W_2/W_2-(W-W_1)$

TRIAL NO	VALUE
1	1.9
2	2

3	1.9
AVERAGE VALUE	1.93

Table 3.1: Specific gravity of aggregate

3.3 Water Absorption of Aggregate

Water absorption capacity represents the maximum amount water the aggregate can absorb. It is calculated from the difference in the weight between saturated dried sample and oven dried sample expressed as a percentage of the oven dried sample. Weight of oven dried sample W_1, Weight of surface dried sample W_2. Water absorption= $(W_2-W_1)/W_1*100$

TRAIL NO	**VALUES**
1	4.2
2	4
3	4.2
AVERAGE VALUE	4.13

Table 3.2: Water absorption of aggregate

3.4 Bulk Density of Aggregate

Bulk density of aggregates is the mass of aggregates required to fill the container of a unit volume after aggregates are batched based on loose packed aggregates or compacted packed aggregate.
Loose bulk density = (Weight of container + Loose aggregate)-(weight of empty container)/volume of container
Compacted bulk density=(weight of container +compacted aggregate)-(weight of empty container)/volume of container

TRIAL NO	**LOOSE BULK DENSITY**	**COMPACTED DENSITY**
1	1272.66	1383.23
2	1272.56	1383
3	1272.65	1383.10
AVERAGE VALUE	1272.64	1383.23

Table 3.3: Density of aggregate

3.5 Percentage of Voids

Percentage of voids is the difference between specific gravity of the aggregate (Gs) and bulk density (γ) expressed as the percentage of specific gravity of aggregates. Percentage of voids = $(Gs-\gamma)/GS*100 = 24.69$

TRIAL NO	**VALUES**
1	24.69
2	24.66
3	24.6
AVERAGE VALUE	24.69

Table 3.4: Percentage of voids

3.6 Crushing Strength of Individual Pellets

The crushing strength of individual pelletized fly ash aggregate was determined using a crushing testing machine. P is the failure load and X is the size of the aggregate or distance between two plates.

Crushing strength can be obtained by equation: Crushing strength=(2.8*P)/(π*X2)

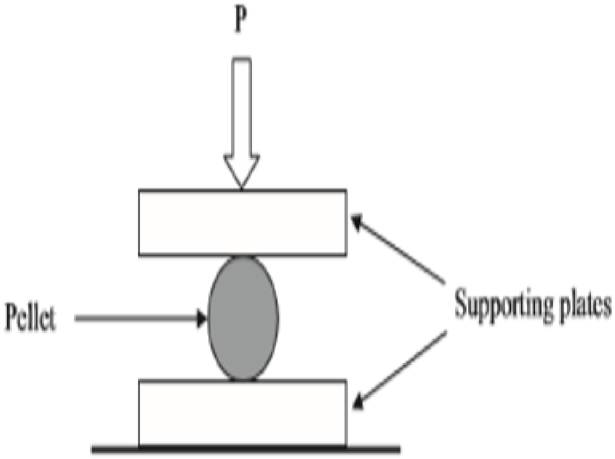

Figure 3.1: Crushing Strength of Aggregates

TRIAL NO	VALUES
1	1.13
2	1.12
3	1.13
AVERAGE VALUE	1.13

Table 3.3: Crushing strength

IV. Conclusion

The value obtained for specific gravity of GGBS aggregate was 2. Generally specific gravity value of river sand is 1.65, so the obtained value for GGBS aggregate is slightly greater value. The water absorption value obtained for GGBS aggregate is 4.2%. According normal fine aggregate water absorption range is less than1% which is lesser than the GGBS produced. The value of bulk density obtained for GGBS aggregate is 1272.66kg/m3. Generally bulk density for fine aggregates ranges from 1440 to 1680kg/m3, the produced GGBS fine aggregate value is within the limit. The value for percentage of voids for GGBS fine aggregate is 24.69. Normally fine aggregate percentage of voids ranges from 38 to 43%, the percentage of voids is lesser compared to normal fine aggregates. The value of crushing strength of individual pellet is 1.13MPa. According to normal coarse aggregate crushing strength is greater than 80MPa so our produced aggregate has lesser crushing strength. From all these, it is clear that artificial GGBS aggregates produced by geopolymerisation cannot be a proper substitute for natural aggregates under all cases. But the value of specific gravity and bulk density proves to be comparatively higher than several other forms of artificial aggregates currently under production. This implies the suitability of the produced GGBS aggregates to be used as substitute for normal aggregates for small scale construction works.

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