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A SURVEY ON SUITAINBILITY AND USE OF GGBF IN CIVIL ENGINEERING APPLICATIONS

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Abstract *:- The major part of cement is consumed in production of concrete in world. The production of concrete in Indian constructions industry is approx 400 million tons per year. Further the same production is responsible for addition of up to 4 to 6% of carbon dioxide (CO_2 gas) emissions leading to global warming crisis. Using alternative sustainable resource instead of cement can help in bring down the environmental burden. This paper covers the review on the use of Ground Granulated Blast Furnace Slag (GGBF) in cement, concrete, mortar and Grout. The partially use of GGBF in fresh concrete will increase the workability, and increase the setting time of concrete which decrease the risk of shrinkage in mass concreting work. Crease compressive strength and durability of structure. It also shows improved performance against sulphate attacks, chloride attacks, alkali silica attacks, and increase corrosion resistance of reinforcement in marine construction. Use of GGBF has remained beneficial in hot atmosphere. GBFF is useful for soil stabilization in black cotton soil. It also Increase the shear strength of soil.*

Keyword *— Ground Granulate Blast Furnace Slag (GGBF), Shrinkage, Chloride Resistance, Compressive Strength, Triaxial Test, California Bearing ratio,*

I. INTRODUCTION

The utilization of concrete is increased because of infrastructural development throught out the world which results in increasing the production of cement. The production of concrete in Indian construction industries is approx 400 millions tons per years. Due to high demand of use of cement which increase production of cement. Cement production is responsible for addition of up to 4 to 6% of carbon dioxide (CO_2 gas) emissions leading to global warming crisis. With the use of some additive material like Ground Granulated Blast Furnace slag in concrete to reduce uses of cement is promoted as a way to reduce the environmental impact of concrete. [1-2]

The material Ground Granulated Blast Furnace slag is by- product of iron pigmentation process in steel industry. GGBF is nonmetallic material essentially having glass silicates and aluminates of calcium. GGBF is the finesses material formed when molten iron blast furnace is rapidly chilled by immersion in water.

The total production of GGBF in India as per ISA (Indian slag Association Report) is 41 million tone per annum and its will increases up to 90 million tonne per annum by the year 2020. As per L.H. Rao, former Director of the National Council for Cement and Building Materials, approximately 30% of the raw material by volume is convert in to blast furnace slag. [3]. cementicious

II. HISTORY OF GGBF

- The application of ground granulated blast furnace slag (GGBF) as cementicious material from the 1774 year when loriot made a mortar using GGBF slag mixed with slaked lime.
- Glassy iron blast-furnace slag was found by Michaelies, Prussing, Tetmayer, Prost, Feret and Green.
- Pasow introduces the process of air granulation which played an important role in development of iron blast furnace slag as hydraulic binder.
- The first commercial use of slag cement was done in Germany in 1865 due to this development.
- In France, 1889 slag cement was used to build the Paris underground metro system. [4]

III. THE MANUFACTURING PROCESS OF GGBF

Ground Granulated Blast Furnace Slag is brought from the pigmentation process of steel called blast furnace. This works at a temperature of about 1500˚C and which are feed with combination of iron-ore, coke and limestone. The Slag produced from steel melting shop is known as steel slag. Normally iron ore containing 60 to 65% Iron and remaining is slag. The average production of Blast furnace slag is 300 to 540 kg per tonne of pig or crude iron production. Lower grade ores have optimum volume of slag contain. [5] [6]

The blast furnace slag which floats on the molten pig iron (hot metal) is collected in slag pot and sent to slag crushing plant or to cooling pits. Depending on the cooling process, three type of slag are produced namely air-cooled slag, granulated slag, expanded slag. Air-cooled slag is produced because of atmospheric conditions in pit. Granulated slag is produced with use of high pressure water jet. Expanded slag is formed by controlling the cooling with water or water synthesis with steam and compressed air. This Granulated slag is dried and crushed to fine powder. [7]

Table -1 consist the chemical composition of Ground granulated blast furnace slag[8].

Chemical Constituent	Percentage
Sio_2	34.4
Al_2O_3	21.5
Fe_2O_3	0.2
Cao	33.2
MgO	9.5
P_2O_5	0.54
SO_3	0.66
Passing from 90 micron	80%
Specific Gravity	3.15

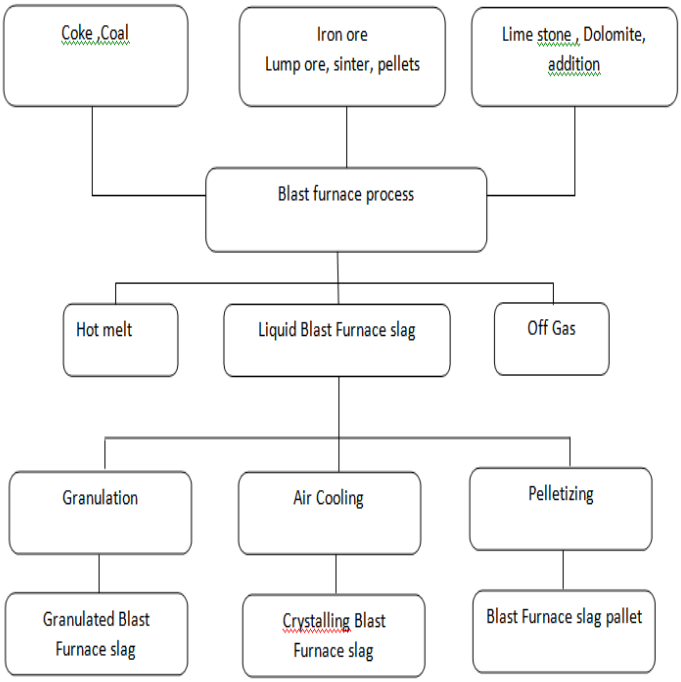

Fig.1 Manufacturing Process of GGBF

IV. CHEMICAL AND PHYSICAL PROPERTIES OF GGBF

The composition of GGBF depends on the ore, pure lime stone and adulterant in coke. Normally silicon, calcium aluminum ,magnesium and oxygen remains 95 % or more in GGBF.

To increase hydraulic or cementitious properties, melt slag must be chilled quickly as it leave the blast furnace slag. Quick chilling reduce crystallization and change the melted slag in fine aggregate of particle size less than 4.75 mm sieve. The cementitous action of a GGBF depends on the volume of glass contains compare to other ingredient. The slower cooling leads to crystalline nature of slag making its devoid of cementicious properties.

The various factor affecting the cementicious properties of the GGBF are

- Chemical composition of GGBF.
- Responding system of alkali concentration.
- Percentage of glass contain in GGBF.
- Fineness of GGBF and Portland cement.
- Temperature during beginning of hydration process. [5].

Table -2 Consist the Physical & Chemical Properties of GGBF [9]

Physical & Chemical Properties of GGBF	
Fineness	3.12
Soundness	1.00mm
Initial setting time	260 Mintues
Insoluble residues	0.15% of mass
Magnesia content	0.47% of mass
Sulphide content	0.63% of mass
Sulphid content	0.23% of mass
Loss on ignition	0.30% of mass
Magnesia content	0.30% of mass
Glass content%	90% of mass

V. APPLICATION OF GGBF

Ground Granulated Blast Furnace Slag is additive material used in wide variety of commercial and architectural concrete construction application. Ground granulated blast furnace slag is used as a replacement of portland cement in concrete mixture. GGBF is having pH value ranging from 8 to 10, which helps to improve resistance against corrosion in reinforced concrete element. The GGBF could applicable for the cementicious raw material, as roadbed ,as admixture and as aggregate in concrete and mortar. It could be use as soli stabilizer and filler material in grout.[9-10]

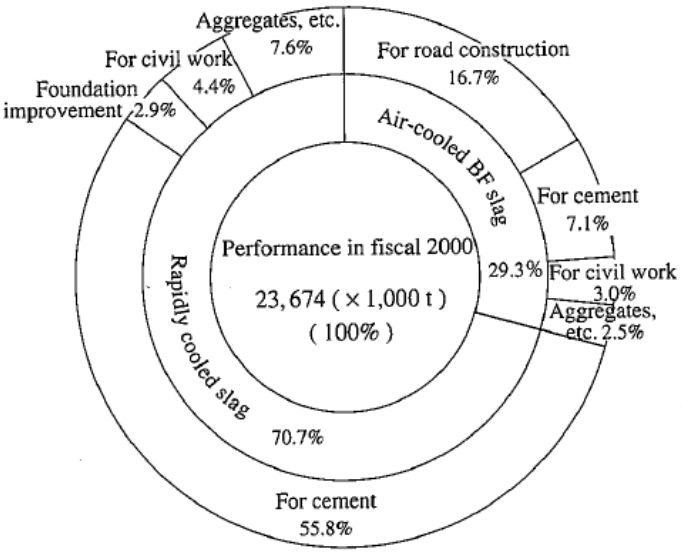

Fig.2 Consumption of Blast Furnace slag .[11]

A. Cement

The Production of one tonne cement required approximately 1.5 tonne of mineral extraction and use 5000 MJ energy and would produce 0.95 tonne carbon dioxide gas equivalent .The production of one tonne GGBF require 1300 MJ energy and produce 0.07 tonne of carbon dioxide gas equivalent. [5] Ground granulated blast furnace slag is mainly used in the production of Portland Blast Furnace Slag Cement and High-Slag Blast Furnace Cement. In production of blast furnace slag cement the contains the GGBF of about 30 to 70%. .The application of portland blast-furnace slag cement is growing in several countries due to is economical aspect and hydration rate of cement is slower where ordinary portland cement. GGBF cement had higher chloride penetration resistance compare with to other types of cement. Cement with GGBF have specific importance for the construction exposed to severe marine environment. 70% is of slag in cement is give highest resistance to chloride penetration compare to lower performance to normal portland cement .[9- 13] Setting time of concrete increases with the increase of GGBF in concrete. 35 to 65% of GGBF by mass increases the setting time by 60 minutes.

B. Concrete

The use of GGBF in concrete as additive material increase the setting times at the same time contributes to gain the strength over long production period. Due to this lower heat of hydration and lower temperature raising avoids cold joints. 70% replacement of GGBF against cement reduces 40% cracks in the reinforced concrete element. In concrete, 50 % replacement of cement by GGBF optimizes the 7 days compressive strength compare to the normal concrete without GGBF. Setting time of concrete with the increase of GGBF in concrete. 35 to 65% of GGBF by mass increase the setting times by 60 minutes. Concrete containing slag or slag cement usually increases workability and reduces the water demand in concrete due to lower density of GGBF. Low electrical conductivity is resulted due to use of GGBF as additive material in concrete or slag cement. concrete blended with GGBF increase chloride and corrosion resistance. [14-16]

GGBF is not reactive in highly alkali environment. Use of GGBF in place of ordinary portland cement achieve greater long term strength, lower chloride ion, less permeable, less creep, Higher sulfate and alkali resistance, increase durability and adequate workability decrease bleeding in concrete.[9][17].

Durability of concrete is very much affected by the chloride penetration or chloride attack in concrete. Corrosion in reinforcement affects the serviceability and safety of concrete is result of chloride attack. Almost 40% of the structural failure are due to corrosion in the structures. Two mechanisms are assumed to define relation between chloride solution and binder material which changes the micro-structural pore size distribution in concrete. First mechanism is for choride which is mixed or exposed to unhydrated concrete, the Na and Cl ions increases the hydration of cement which results in increase in C-S-H and reduces the pore size. The second mechanism is for chemical reaction between the chloride solution which takes part in process of Friedel's salt which shows the change in pore size. Second is the chemical reaction between the chloride solution take part in process of Friedel's salt which is show the change in pore size. For the range up to 0.5m chloride concentration, physical and chemical bound chloride together contributes to the total bound chloride with the use GGBF mixture up to 0 to 40% . chloride concentration between 0.5m to 1 m , 40% of GGBF chemical bound chloride controls the bound chloride .[18]

Foamed concrete and aerated concrete are classified as light weight concrete. The foamed concrete is made by adding suitable foaming agent where aerated concrete is the concrete made by adding of aluminium powder to create void in concrete. The formed concrete do have thermal insulation, sound insulation and low self weight of concrete. The foamed concrete and Aerated concrete are having that its had low compressive strength as compare to conventional concrete. Use of 50% GGBF in formed and aerated concrete will increase the properties like compressive strength , ultra sound velocity pulse and thermal insulation.[19-20]. GGBF based concrete made with 40% replacement of cement by GGBF had superior compressive strength compare to 20% and 60% GGBF based concrete. The concrete containing 60% of GGBF has lower compressive strength compare to concrete containing 40% and 20% in all ages of concrete. [21]

C. Mortar

The construction industry is the largest user of natural resources which lead to reduction in natural sand. This circumstances lead to discover alternative materials and industrial waste replacement of natural sand. The requirement of natural sand is is very high in developing countries to convince the speedy infrastructure growth. The developing country like India facing lack of good quality natural sand and in predominantly in India natural sand deposits are being used up and creating serious risk to environment and society. Rapid removal of sand from river bed causing so many problem like losing water retaining soil stratum, deepen of river beds and causing bank of rivers, disturbs the marine life as well as disturbs agriculture due to lower water table in well etc. The properties of cement mortar like durability workability and strength depends on the quality of fine aggregate.

The GGBF is used as an alternative material in mortar as partially or full replacement with natural sand. The result of partially replacement of GGBF with sand will increase the compressive strength of mortar. Where 100% replacement decrease of GGBF is decrease the strength. 80 % of replacement of sand with GGBF is suggested for improved strength properties in mortar. The workability of mortar decrease with increase in amount of GGBF in mortar. The Flexural and compressive strength of GGBF replaced mortar are lower for the temperature curing and humidity curing condition. Hence , replacement GGBF in mortar is important in elevated temperature and lower relative humidity. Use of GGBF in making mortar decreases the porosity and caplillary where increases the durability against water and destructive solution. [22- 23].

D.Soil Stabilization

The basic purpose of soil stabilization is to make soil suitable for engineering purposes by employing different chemical and physical method. In road design the improved strength of soil is used in base course and sub course which is stabilized by use of additive material to effectively carry load of expected traffic and pavement loads.

Addition of GGBF for soil stabilization results in increasing density, specific gravity and strength of soil. Higher percentage of GGBF decreases the liquid limit, plastic limit , and plasticity index. High percentage of GGBF in soil will increase the compressive strength of soil which is because of soil particles are very close, and voids in the soil is reduced. Soil mixture contain high percentage of GGBF is suitable for the pavement design of road. Use of GGBF produces less cohesive, dense and resistive soil which is beneficial in pavement thickness. [24]

Table -2 Effect of GGBF on specific gravity of soil

GGBS(%)	SPECIFIC GRAVITY
0	2.56
5	2.58
10	2.59
15	2.60
20	2.61
25	2.63

The Expansion of soil cause potential natural hazard which cause damage in structure. Swelling and shrinkage is major problem in black cotton soil. Upgrading of soil by using industrial waste is cost efficient and eco friendly approach.

The soil is treated with various percentage of GGBF as 15% , 20% and 25% and conduct unconfined compressive strength test. Result of unconfined compressive strength test of 20% GGBF is compared to virgin soil is increased up to 73.79% for 21 days of curing. Shear strength of black cotton soil is increasing to 16 times with the use of 20% GGBF and 4 % lime in soil. Where by adding 40% GGBF and 4% lime in normal soil the shear strength will increasing up to 18 times. Swelling of black cotton soil is also decreasing with adding GGBF and lime in soil. The use of 40% GGBF and 4% lime in block cotton soil due to this swelling of soil is decease 60 % to 11.75 %. The result of California Bearing Ratio test by using fly and various percentage of GGBF in soil are increased up to 78.29% compare to virgin soil for the 10 days of curing period.[25].

Table 3: The USC test value for different percentage of fly ash and GGBF

SAMPLE	ADDITIVE (%)		7 DAYS CURING (KfgCM^2)	14 DAYS CURING (Kg/CM^2)	21 DAYS CURING (Kg/CM^2)
Soil sample	Flyash	5	0.87	0.95	1.04
		10	0.98	1.02	1.14
		15	0.89	0.91	1.08
		20	0.88	0.89	1.04
	GGBFS	15	1.55	1.76	1.96
		20	1.81	2.34	2.48
		25	1.73	2.26	2.34

VI. SUMMARY

In this paper, discussion has been done for use of GGBF in construction material. The GGBF contain glass silicate and aluminosilicates of calcium which have cementicious properties. The use GGBF is eco friendly and cost in effective. GGBF is waste on steel production and production of GGBF is use less energy consumption. The effective use of GGBF increase the compressive and Flexure strength of concrete. The use of GGBF in concrete is the increase the performance like durability of concrete, ability of concrete to resist to sulfate attack , alkali silica reaction and chloride attack which affect the serviceability and safety criteria of concrete. The use of GGBF improves the performance against corrosion in reinforced concrete elements. The GGBF slow down the hydration of concrete which results in lower shrinkage cracks which is useful in mass construction. GGBF is effectively used in mortar and soil stabilization. The mixture of soil and GGBF is increases the specific gravity, shear strength and bearing capacity of soil. Soil mixed with GGBF is less cohesive more resistive and densification of soil takes place which is suitable for pavement of road.

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