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TITLE: TO STUDY THE PARTIAL REPLACEMENT OF CEMENT BY GGBS IN CONCRETE

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Abstract

Concrete is most probably, the extensively used construction material in the world. About Six billion tonnes of concrete is being produced every year. Its per-capita consumption is only next to per-capita consumption of water. Thus, environmental sustainability is at stake both in terms of CO_2 emission during cement manufacturing and damage caused by the extraction of raw material. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials.Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays important role in the infrastructure like- buildings, bridges, structures, and highways etc. leading to utilization of large quantity of concrete. On the other side, ingredients ofconcrete are scarce and expensive, thus leading to usage of economically alternative materials in its production. This has drawn the attention to explore new replacements of ingredients of concrete. This report focuses on investigating characteristics of concrete with partial replacement of cement with Ground Granulated Blast furnace Slag (GGBS). This topic consists of the usage of GGBS and advantages as well as disadvantages in using it in concrete. This usage of GGBS serves as replacement to already depleting conventional building materials and the recent years and also as being a by-product it is an Eco Friendly way of utilizing the product without dumping it on ground as waste material.

Index Terms: *Concrete, Blast Furnace Slag Powder, Compressive Strength, Optimum Replacement.*

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1. INTRODUCTION

Blast furnace slag is a solid waste which is discharged in large quantities by the iron and steel industry in India. The re-cycling of these slags will become an important measure for the environmental protection. After many years of research the slag that is generated as a by-product in iron and steel production is now in use as a useful material. Slag enjoys stable quality and proper-ties that are difficult to obtain from natural materials and in the 21st century is gaining increasing attention as an environmentally friendly material from the perspectives of resource saving, energy conservation and CO_2 reduction. The primary constituents of slag are lime (CaO) and silica (SiO_2).

Ground Granulated Blast furnace Slag (GGBS) is a by-product from the blast furnaces used to make iron. These furnaces operate at a temperature of about 1500 degrees centigrade 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 removed 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 optimises the cementitious properties and produces granules similar to coarse sand. This granulated slag is then dried and ground to a fine powder. Although normally designated as “GGBS”, it can also be referred to as “GGBFS” or “Slag cement”. The main problem is the original conventional materials are depleting and we are in search of alternate building materials. This makes GGBS an efficient material. Since GGBS is a waste material, making use of it serves as a step for a greener environment.

This report deals with the use of the blast furnace slag powder as a partial replacement of OPC and its effect on strength of cement concrete mix.

2. LITERATURE SURVEY

2.1 Chemical and Physical Composition of GGBS

The chemical composition of a GGBS varies considerably depending on the composition of the raw materials present in the production of iron process.The flux mostlyconsists of a mixture of limestone and forsterite or in some cases dolomite,for in the case of pig iron production. In the blast furnace the slag floats on top of the iron.

The typical chemical composition of GGBS is:
Calcium oxide = 40%
Silica = 35%
Alumina = 13%
Magnesia = 8%

The glass content of slag's suitable for mixing with Portland cement typically varies between 90-100% and depends on the cooling method and the temperature at which cooling is initiated. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like Portland cement.

Typical physical properties:-
Colour: off white
Specific gravity: 2.9
Bulk density: 1200 Kg/m3
Fineness: 350 m^2/kg

2.2Production and Composition

To obtain good slag reactivity, the slag melt is needed to be cooled rapidlyor quenched below 800 °C in order to prevent the crystallization of merwinite and melilite. To cool and fragment the slag a granulation process is applied. In this granulation process, molten slag is subjected to jet streams of water or air under pressure.

The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%). If we go on increasing the CaO content in the slag, it results in increased slag basicity and an increase in compressive strength. The MgO and Al_2O_3 content show the same trend up to 10-12% and 14% respectively, beyond which no further improvement can be obtained.

The content of glasssuitable for blending with Portland cement typically varies between 90-100% and depends on the temperature and cooling methodcooling. The glass structure of the quenched glass depends largely on the proportions of network-forming elements such as Si and Al over network-modifiers such as Ca, Mg and to a lesser extent Al. If theamount of network-modifiers are high then it leads to higher degrees of network de-polymerization and reactivity.

Common constituents of blast-furnace slags are merwinite and melilite. Other minor components which can form during progressive crystallization are belite, monticellite, rankinite, wollastonite and forsterite. Minor amounts of reduced sulphur are commonly encountered as oldhamite.

2.3Architectural and Engineering Benefits

2.3.1 Durability

GGBS cement is routinely used in concrete to provide protection against both sulphate attack and chloride attack. GGBS has now effectively replaced sulphate-resisting Portland cement (SRPC) on the market for sulphate resistance because of its superior performance and greatly reduced cost compared to SRPC. Most projects inDublin's Docklands, including Spencer Dock, are using GGBS in subsurface concrete for sulphate resistance.

To protect against chloride attack, GGBS is used at a replacement level of 50% in concrete. Instances of chloride attack occur in reinforced concrete in marine environments and in road bridges where the concrete is exposed to splashing.. The use of GGBS in such instances will increase the life of the structure by up to 50% had only Portland cement been used, and precludes the need for more expensive stainless steel reinforcing.

GGBS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBS cement generates both lower peak and less total overall heat than Portland cement.

2.3.2. Appearance

The near-white color of GGBS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost as compared to grey colour of Portland cement. To achieve a lighter colour finish, GGBS can be used in range between 50% to 70% replacement levels, although levels as high as 85% can also be used. GGBS cement also gives a smoother, &more defect free surface, due to the fineness of the GGBS particles. Dirt particles do not adhere to GGBS concrete, as easily as dirt adhere to concrete made with Portland cement. This leads to reduction in maintenance costs. The occurrence of efflorescence is prevented by GGBS, also the staining of concrete surfaces by calcium carbonate deposits.

2.3.3. Strength

As compared to concrete made with Portland cement, concrete made with GGBFS has higher Ultimate strength. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBS continues to gain strength over time, it has been seen that the strength is double the value of its 28-day strength over periods of 10 to 12 years.

2.4.4. Sustainability

Since GGBS is a by-product of steel manufacturing process, its use in concrete help in reducing environment related problems, thus is recognized by LEED etc. It also helps in improving the sustainability of the project and will therefore add points towards LEED certification. In this respect, GGBS can also be used for superstructure in addition to the cases where the concrete is in contact with chlorides and sulphates. This is provided that the slower setting time for casting of the superstructure is justified.

2.5 Applications

GGBS is used with other pozzolanic materials to make durable concrete structures. GGBS is being widely used in Europe, and increasingly in the Asia (particularly in Japan and Singapore) and in United States for its good concrete durability, increasing the lifespan of buildings from 50 years to 100 years.

Two main uses of GGBS are in the production of Portland Blastfurnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), in which GGBS content varies typically from 30 to 70%. It is also used in the production of ready-mixed or site-batched durable concrete.

As compared to concrete made with Portland cement concrete made with Ground Granulated Blast Furnace slag sets more slowly. Concrete made with GGBFS continues to gain strength over a longer period of time. This results in lower heat of hydration and lower temperature rises, and thus helps in avoiding cold joints, but this affects the construction schedule where quick setting is required.

The risk of damage caused by Alkali-Silica-reaction (ASR) is reduced by use of GGBFS. Also provides higher resistance to chloride ingress-reducing the risk of reinforcement corrosion -and provides higher resistance to attacks by sulphate and other chemicals.

2.6 Uses of GGBS

The main use of GGBS is in ready mixed concrete. The various technical benefits, which GGBS imparts to concrete, are as follows:

1. GGBS give better workability, thus making placing and compaction easier.
2. GGBFS lowers early age temperature rise, thus reducing the risk of thermal cracking in large pours.
3. It eliminates the risk of damaging internal reactions such as ASR
4. High resistance to chloride ingress, reducing the risk of reinforcement corrosion
5. Use of GGBFS provides high resistance to attack by sulphate or any other chemicals
6. Considerable sustainability benefits.

In the production of ready mixed concrete, GGBS replaces a substantial portion of the normal Portland cement concrete, generally about 50 %, but sometimes up to 70%. The higher the portion, the better is the durability. The disadvantage of the higher replacement level is that early age strength development is somewhat slower. GGBS is also used in other forms of concrete, including site-batched and precast. Unfortunately, it is not available for smaller-scale concrete production because it can only be economically supplied in bulk. GGBS is not only used in concrete and other applications include the in-situ stabilisation of soil.

GGBS is used as a direct replacement for Portland cement, on a one-to-one basis by weight. Replacement levels for GGBS vary from 30% to up to 85%. Typically 40 to 50% is used in most instances. For on the ground concrete structures with higher early-age strength requirement, the replacement ratio would usually be 20 to 30%. For underground concrete structures with average strength requirement, the replacement ratio would usually be 30 to 50%. For mass concrete or concrete structures with strict temperature rise requirement, the replacement ratio would usually be 50 to 65%. For the special concrete structures with higher requirement on durability i.e., corrosion resistance for marine structures, sewerage treatment plants etc., and the replacement ratio would usually be 50 to 70%.

3. STUDY EXPERIMENTAL PROGRAM

In the study investigation GGBS marketed by GajapathiCements is used. The results furnished by the manufacturer are presented in Table 1

3.1 Mix Design (As Per IS 10262: 2009)

The following specifications were considered for Mix design.

Table 1: The specifications for Mix design

Type of cement	OPC 43 grade
Maximum nominal aggregate size	20 mm
Minimum cement content	310 Kg/m3
Maximum water cement ratio	0.55
Workability	25-50 mm
Exposure condition	Mild
Degree of supervision	Good
Type of aggregate	Crushed angular aggregate
Maximum cement content	540kg/m3
Chemical admixture type	no
Type of fine aggregate	Normal river sand
Type of vibration	Mechanical

The mix proportions for 1 m3 of concrete are presented in Table 2.

Table 2: Mix Proportions for One m^3 of concrete

Grade	Cement	Fine aggregate	Course aggregate	Water	w/c ratio
Units	kg/m3	kg/m3	kg/m3	kg/m3	
M20	338.2	641.07	1226	1860.55	0.55
M40	442.85	610.54	1167.54	1860.42	0.42

The designed ratio for M20 is 1:1.9: 3.62: 0.55 and for M40 is 1:1.38: 2.64: 0.42.

Among the trail mix conducted, the above mix gave required workability and required strength.

3.3.1 Replacement of Cement with GGBS

The mix proportions with partial replacement of OPC with 0%, 30%, 40% and 50% of GGBS are calculated.

Mix Proportions for M20 grade concrete

Conventional Concrete – 1:1.9: 3.62: 0.55
30% replacement- 0.7:1.9: 3.62: 0.55
40% replacement – 0.6:1.9: 3.62: 0.55
50% replacement – 0.5:1.9: 3.62: 0.55

Mix Proportions for M40 grade concrete

Conventional Concrete – 1:1.38: 2.64: 0.42
30% replacement- 0.7:1.38: 2.64: 0.42
40% replacement – 0.6:1.38: 2.64: 0.42
50% replacement – 0.5:1.38: 2.64: 0.42

4. EXPERIMENTAL OUTCOMES

Tests for Workability

The results on tests for workability are shown in Table 3 and Table 4

Table 3: Slump and Compaction Factor Values for M20

Sr.No.	Description	Compaction Factor	Slump (mm)
1	Plain Concrete	0.87	40
2	30% GGBS	0.89	43
3	40 % GGBS	0.89	49
4	50 % GGBS	0.9	52

Table 4: Slump and Compaction Factor Values for M40

Sr.No.	Description	Compaction Factor	Slump (mm)
1	Plain Concrete	0.85	22
2	30% GGBS	0.852	34
3	40 % GGBS	0.87	41
4	50 % GGBS	0.883	44

Compressive Strength of Concrete

CTM of 2000 KN capacity was used with load rate of approximately 140 kg/cm /min until failure for Compressive strength test. The test results for compressive strength are presented in Tables 5 and Table 6 (0%, 30%, 40% and 50% of GGBS concrete) for M20 and M40 grades of concrete at room temperature for 28 and 90 days respectively.

Table 5 Compressive Strength of concrete for M20

SR. No.	% of GGBS	Compressive strength in N/mm^2	
		28 days	90 days
1	0	33.3	46.2
2	30	35	50.11
3	40	36.42	52.49
4	50	32.2	48.12

Table 6 Compressive Strength of concrete for M40

Sl. No.	% of GGBS	Compressive strength in N/mm^2	
		28 days	90 days
1	0	49.99	54.22
2	30	51.12	55.02
3	40	53.6	57.46
4	50	50.12	54.27

4.1 DISCUSSION ON RESULTS

It is observed that at about 40% replacement of cement with GGBS, concrete attains its maximum compressive strength for both M20 and M40 grade concretes, when the replacement exceeds 40%, the compressive is found to be decreasing slightly. And 30% replacement of GGBS is greater than the 50% replacement of GGBS.

5. CONCLUSION

Based on the analysis of experimental results and discussionthere upon the following conclusions can be drawn.

1. Workability of concrete increases with the increase in GGBS replacement level.
2. The compressive strength of concrete increased when cement is replaced by GGBS for both M20 and M40 grade of concrete. At 40% replacement of cement by GGBS the concrete attained maximum compressive strength for both M20 and M40 grade of concrete.
3. As we have seen GGBS is a good replacement to cement in some cases and serves effectively but it can’t replace cement completely. But even though it replaces partially it gives very good results and a greener approach in construction and sustainable development which we are engineers are keen about today.

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