Environmental Sustainability And Suitability of GGBS As A Replacement Material For Cement And Pond Ash As A Replacement Material For Fine Aggregate In Concrete

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Abstract- *The production of the Portland cement as a main constituent of concrete has basically led to the dangerous impacts on our environment by releasing substantive amount of CO_2. Production of one ton of Portland cement emits one ton of CO_2 and other greenhouse gases. Hence the cement must be effectively replaced by some other cementitious materials without compromising the desired properties of concrete.The coal based power plant generates a huge amount of fly ash which is collected from electrostatic precipitator and the bottom ashes are disposed in a slurry form in large ponds and dykes. Pond Ash requires huge area, water and energy to dispose off, so recycling of the pond ash is indeed required.*

The purpose of this study is to find the suitability of GGBS as a replacement material for cement and pond ash as a replacement material for fine aggregate without compromising the strength & durability of conventional concrete. Replacement of cement partially by GGBS also reduces the supply demand on cement and may also reduce the emission of CO_2 into atmosphere. The physical and chemical properties of GGBS and pond ash has been studied and both the industrial wastes are used to replace the cement and fine aggregate up to 40% and 20% respectively in concrete. The specimens were tested for its mechanical properties such as compressive strength, split tensile strength and flexural strength on 7, 28, 56 days and durability properties like water permeability and chloride permeability.

Keywords- CA- Coarse Aggregate, CC- Conventional Concrete, C-S-H- Calcium Silicate Hydrate, GGBS- Ground Granulated Blast furnace Slag, BFC- Blast Furnace Slag

I. INTRODUCTION

1.1 GENERAL

Concrete is considered to be very durable material that requires little maintenance. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a leading role in the development of structures of Sheltering, Housing, Infrastructuring etc., leading to utilization of large quantity of cement and fine aggregate. Wang Ling et al (2004) analyzed the performance of GGBS and the effect of GGBS on fresh concrete and hardened concrete. GGBS concrete witnesses development in compressive, Chemical attack and durability behaviour of concrete. GlicerioTriches et al (2006) presented a laboratory research of RCC mixtures with addition of bottom ash for composite pavements. Results revealed that an increase in flexural strength levels at increasing levels of fine aggregate replacement by bottom ash. An important process in the concrete mixing is the formation of C-S-H gel which is primarily due to the addition of cement. The hydration of the Portland cement results from the production of Portlandite crystal [Ca(0H)2] and amorphous calcium silicate hydrate gel[C3S2H3] (C-S-H) in large amounts. Hydrated cement paste contains approximately70% C-S-H, 20% $Ca(0H)_2$; 7% sulpho-aluminates and 3% secondary phases. GlicerioTriches et al (2006) presented a laboratory research of RCC mixtures with addition of bottom ash for composite pavements. Results revealed that an increase in flexural strength levels at increasing levels of fine aggregate replacement by bottom ash.
The use of Ground Granulated Blast-Furnace Slag has a positive effect on binding the $Ca(0H)_2$ compound, which decreases the quality of the concrete. At the end of the reaction of the slag and $Ca(0H)_2$, hydration products, such as C-S-H gel is formed.

1.2 GGBS

The normal ratios of aggregates and water to cementitious material in the mix remain unchanged. GGBS ican effectively replaces the role of portlant pozzolona by weight. Replacement levels for GGBS vary from 25% to up to 80%.GGBS cement is slightly less expensive than Portland cement, concrete made with GGBS cement will be similarly priced to that made with ordinary Portland cement. Shariq et al (2008) studied the effect of curing procedure on the compressive strength phenomenon of cement mortar and concrete incorporating GGBS.

1.3 POND ASH

Pond Ash, a waste product of Thermal Power Plants, is one such material, that can be adopted as a suitable material as fine aggregate in concrete, replacing natural Sand. Encouraging the usage of such a waste material is a social responsibility of researchers to promote & contribute to 3Rs – Reduce, Reuse and Recycle & there by promoting sustainable construction. Abdulhameed et al (2012) investigated the properties of concrete using tanjung bin power plant coal bottom ash and fly ash. Coal bottom ash and fly ash were utilized in partial replacement for fine aggregates and cement respectively in the range of 0, 5, 10, 15 & 20%. Pathan et al (2012) concluded in their paper that ground granulated blast furnace slag is better replacement of cement than various other alternatives.

II. NEED FOR THIS RESEARCH

One of the main ingredients used for the production of concrete is the Ordinary Portland Cement (OPC).Carbon-dioxide (CO_2) gas which is a major contributor in greenhouse effect and the global warming, is produced in the production of cement, hence it is needed either to search for another material or partially replacement by some other material. And also natural sand confirming to Indian Standards is becoming scarcer and costlier due to its non-availability in time, because of government laws and acts of Land, illegal dredging done by sand mafia, non-accessibility to the river source during rainy season and non-confirming with IS requirements. GGBS is an effective alternative for cement, adopting GGBS instead of cement enhances the environmental Sustainability of cement by reducing heat of hydration of the cement which in return is one of the serious concern as in the fact of global warming.

III. MATERIAL COLLECTION AND TESTING

3.0 Cement

Ordinary Portland cement of 53 grade confirming IS 12269 was used in the experimental work and properties as mentioned in table 3.1.

3.1 GGBS

Table 3.2 Physical Properties of GGBS

Chemical properties of GGBS bought from GGBS manufacturing company are given below.Table 3.3 shows the Chemical Properties of GGBS.

Table 3.3 Comparison of Physical Properties of Cement and GGBS

S.NO	PROPERTY	CEMENT	GGBS
1	Specific gravity	3.134	2.98
2	Bulk unit weight	1400 kg/m^3	1454.5 kg/m^3
3	Fineness	4.2 %	2.33 %
4	Consistency	24 %	31 %
5	Initial setting time	33 mins	32 mins
6	Final setting time	600 mins	580 mins

3.2 Pond Ash

In the present investigation work, the pond ash used is obtained from Thermal Power Station, Ennore. Thepond Ash is available at free of cost so it results in more than 25% savings in construction if it can replace the fine aggregate. Fig. 3.3 shows the Pond Ash used in concrete.

Table 3.4 Comparison of Physical Properties of Fine aggregate and Pond Ash

S NO	PROPERTY	FINE AGGREGATE	POND ASH
1	Specific gravity	2.64	1.972
2	Bulk unit weight	1800 kg/m^3	879 kg/m^3
3	Fineness modulus	2.278	2.39

IV. MIX DESIGN

Mix design were developed for M 35 grade as per the Indian Standard, IS 10262: 2009

I) Mix Proportions:
Water : Cement : Fine aggregate : Coarse aggregate
0.40 : 1 :1.910 : 3.89

Correction for Water Absorption
Therefore, Design mix ratio after correction
Water : Cement : Fine aggregate : Coarse aggregate
0.45 : 1:1.89 : 3.86

Table 4.1 Mix proportions for various Mixes

MIX NAME	GGBS (%)	CEMENT (%)	POND ASH (%)	F.A (%)
Conv.mix	0	100	0	100
Mix 1	10	90	10	90
Mix 2	20	80	10	90
Mix 3	30	70	10	90
Mix 4	40	60	10	90
Mix 5	10	90	20	80
Mix 6	20	80	20	80
Mix 7	30	70	20	80
Mix 8	40	60	20	80

V. RESULTS AND DISCUSSIONS

5.1 .Slump Test

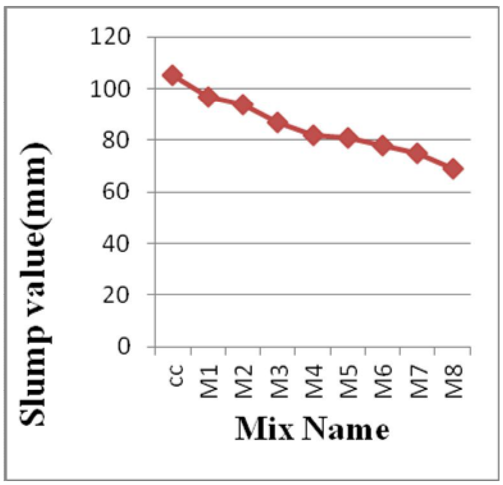

Fig 5.1 Slump values of Fresh Concrete

Mix Name	GGBS (%)	Pond Ash (%)	Slump Value	Degree of workability
C.C	0	0	105 mm	High
M-1	10	10	97 mm	Medium
M-2	20	10	94 mm	Medium
M-3	30	10	87 mm	Medium
M-4	40	10	82 mm	Medium
M-5	10	20	81 mm	Medium
M-6	20	20	78 mm	Medium
M-7	30	20	75 mm	Low
M-8	40	20	69 mm	Low

Fig.5.2 Slump values for various mix

5.2 Compressive Strength Test

The test specimens are casted in steel cube moulds of size 150mm, cylinder mould of size 150x300mm. The test cube specimens are made as soon as practicable after mixing and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete is filled into the mould in layers approximately 5 cm deep. Each layer is compacted either by hand or by vibration. After the top layer has been compacted the surface of the concrete is brought to the finished level with the top of the mould, using a trowel. After proper curing concrete cubes are tested in compression testing machine

Table 5.2 Compressive Strength

Mix Name	GGBS (%)	Pond Ash (%)	14days Compressive Strength N/mm²	28 days Compressive Strength N/mm²	56 days Compressive Strength N/mm²
Conventional Mix	0	0	33.96	44.04	47.16
M 1	10	10	26.54	39.20	43.45
M 2	20	10	26.30	38.84	42.29
M 3	30	10	29.65	42.35	46.41
M 4	40	10	25.28	36.12	41.56
M 5	10	20	22.38	32.93	44.78
M 6	20	20	24.38	32.92	39.80
M 7	30	20	30.72	43.18	48.91
M 8	40	20	22.79	34.02	38.10

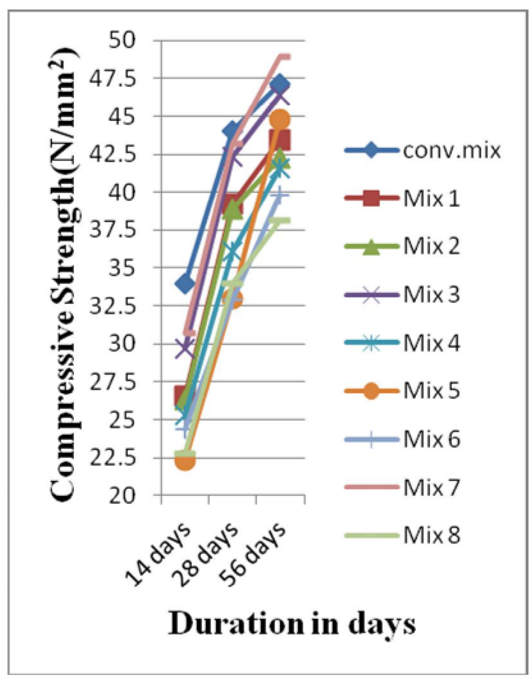

Fig.5.3 Compressive strength values for various mix proportions

All replaced specimens show a decrease in strength at 14 days, 28 days and 56 days when compared to conventional mix. But at 56 days the mix M7 reaches strength higher than that of conventional mix. The decrease is strength is Among various mixes M 7 (GGBS -30 % and Pond ash –20 %) gives the optimum compressive strength.

5.3 Split Tensile Strength

Cylindrical test specimens of size 150 mm dia and height were cast and after 28 days of water curing, tension in the concrete was measured indirectly by conducting split tensile strength as per standard procedure. Fig. 6.5 shows the specimen under Split Tensile Strength test.

Table 5.3 Split Tensile Strength

S.NO	Mix Name	Pond Ash (%)	GGBS (%)	Split Tensile Strength (N/mm^2)
1	C.C	0	0	3.08
2	M1	10	10	3.78
3	M2	10	20	3.31
4	M3	10	30	3.65
5	M4	10	40	2.60
6	M5	20	10	3.98
7	M6	20	20	3.83
8	M7	20	30	4.28
9	M8	20	40	3.24

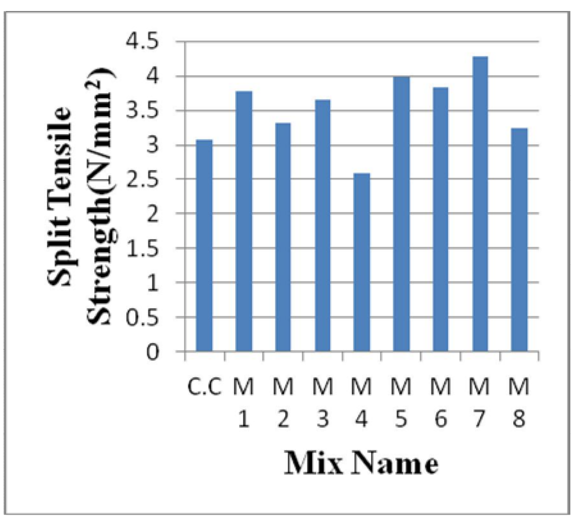

Fig. 5.5 Split tensile strength values for various mix proportions

Among various mixes M 7 (GGBS - 30 % and Pond ash – 20 %) gives the optimum split tensile strength.

5.4 Flexural Strength

Concrete prism of size 100 mm x 100 mm x 500 mm were casted and after 28 days of water curing, the flexural strength will be determined. Fig. 6.7 shows the specimen under flexural strength test.

Table 5.4 Flexural Strength for mix proportions

S.No	Mix name	% Pond ash	% GGBS	Flexural Strength (N/mm^2)
1	C.C	0	0	7.942
2	M1	10	10	8.732
3	M2	10	20	9.312
4	M3	10	30	8.804
5	M4	10	40	8.254
6	M5	20	10	8.265
7	M6	20	20	8.442
8	M7	20	30	9.657
9	M8	20	40	8.456

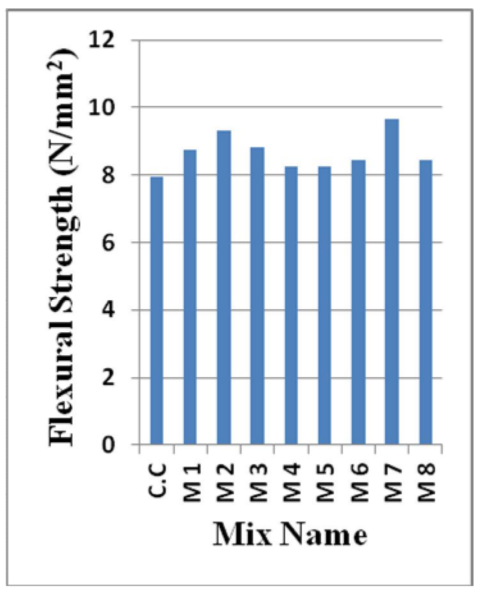

Fig. 5.6 Flexural Strength values for various Mix Proportion

It is observed that the flexural strength marginally increases when cement is replaced by GGBS and sand by Pond ash. Among various mixes M 7 (GGBS -30 % and Pond ash –20 %) gives the highest flexural strength.

5.5 Acid attack on Optimized Mix

The optimized mix with 30% GGBS and 20% Pond Ash is tested by continuous wet and dry test. In this test, the concrete cubes are placed inside the containers with 3.5% HCl & 3.5% H_2SO_4 respectively. After 24 hours the cubes are taken out and kept at outside for 24 hours. Now, the cube is weighed for one complete cycle. Similarly the cubes are tested for 14 complete cycles. Then, the cubes are tested in the CTM and loss of strength is noted when compared to the unexposed specimens.

5.6 Sulphate attack on Optimized Mix

The optimized mix with 30% GGBS and 20% Pond Ash is tested by continuous wet and dry test. In this test, the concrete cubes are placed inside the containers with 10% $MgSO_4$ respectively. After 24 hours the cubes are taken out and kept at outside for 24 hours. Now, the cube is weighed for one complete cycle. Similarly the cubes are tested for 14 complete cycles. Then, the cubes are tested in the CTM and loss of strength is noted when compared to the unexposed specimens.

VI. RESULTS AND DISCUSSIONS

6.0 RESULTS

Mix M7 (30% GGBS and 20% pond ash) reaches target compressive strength at 28 days and Flexural strength of all mixes is marginally higher than conventional mix. Mix M7 highest flexural strength. The durability of optimized concrete mix under acid (HCl) attack performed better than the control concrete. The weight of the control mix is reduced by 5.95% but the weight of the optimized mix reduces only by 2.59 % after 14 continuous cycles.The durability of optimized concrete mix under acid (H_2SO_4) attack performed better than the control concrete. The weight of the control mix is reduced by 6.95 % but the weight of the optimized mix reduces only by 5.31 % after 14 continuous cycles.The durability of optimized concrete mix under 10% MgSO solution performed better than the control concrete. The weight of the control mix is reduced by 4.60 % but the weight of the optimized mix reduces only by 3.59 % after 14 continuous wet and dry cycle.The optimum percentage of replacement level of GGBS for cement is 30% and pond ash for fine aggregate is 20% without compromising the workability and mechanical properties of concrete (compressive strength, split tensile strength and flexural strength).

Table No 6.1: Compressive strength of Concrete after HCL attack

S.No	Mix Name	Weight before Exposure	Weight after Exposure	% Change	Strength after Exposure (N/mm²)	% Change
1	C.C	8.75	8.72	0.54	41.178	6.95
2	M7	8.45	8.43	0.26	41	5.31
Compressive strength of concrete after H2SO4 attack						
S.No	**Mix Name**	**Weight before Exposure**	**Weight after Exposure**	**% Change**	**Strength after Exposure (N/mm²)**	**% Change**
1	C.C	8.62	8.56	0.85	42.103	4.60
2	M7	8.55	8.49	0.64	41.68	3.59

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