A Study to Produce Sustainable Concrete using EGG Shell Powder and GGBS

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Abstract— Throughout the world, concrete is widely used for the construction of most of the buildings, bridges etc. To meet this rapid infrastructure development a huge quantity of concrete is required. To make the production of cement sustainable, the whole construction industry is in search of a economical, eco-friendly and effective the waste product that would minimize the use of cements. The pressure to reach sustainability favors the development of ternary composite cement some of such supplementary cementacious material (SCM) has already been identified like Fly Ash, Silica Fumes, Rice Husk Ash (RHA), Egg shell etc.The synergistic effect on mechanical behavior at 28 days between EGG SHELL POWDER and pozzolanic additives like BLAST FURNACE SLAG (BFS), has been documented. In order to better understand the synergistic effect, this article investigated the effect of egg shell powder on the microstructure of cement-slag cementitious system.

Key words: Egg Shell Powder, Blast Furnace Slag, Synergistic Effect

I. INTRODUCTION

In recent years, special attention has been devoted to industrial sectors that are sources of pollution of the environment. The industry generates large mass of solid wastes, which can end up in rivers and lakes. The disposal of these industrial wastes is a very important problem, which can cause risk to general public health. A large number of food plants are constantly accumulating substantial quantities of eggshell waste. This natural solid waste, although nonhazardous, is directly disposed in environment. As a consequence, a huge problem of pollution is generated. In addition, it can attract rats and worms by the organic protein matrix presented on egg shell surface, resulting in a problem of public health. The blending of cement clinker with other supplementary cementitious materials (SCMs), such as blast furnace slag (BFS) and egg shell powder (LP), has been the most promising route to increase the sustainability of construction engineering. Nowadays, Portland cement (PC) is still the essential component in cementitious system and blended cements are most often binary, e.g. FA-PC and BFS-PC. While at high replacement levels, the early age mechanical behavior of binary cementitious system becomes an issue. A possible approach to improve early age mechanical behavior is to generate ternary cement system, in which different SCMs can interact with each other and may enhance the performance of concrete.

II. PROPERTIES OF MATERIAL

A. Cement:

53 Grade Ordinary Portland Cement (OPC) Ultra tech Cement conforming to IS: 12269-1987 has been used.

B. Egg Shell Powder:

The shell itself is about 95% CaCO3 .The remaining includes Magnesium, Potassium, Zinc, Iron, Copper, Ironic acid Aluminum, Phosphorous, Sodium and Silica acid. Eggshell has a cellulosic structure and shell contains amino acids, thus, it is expected to be a good bio-sorbent.

Sr no	Constituents	Value %
1	CaO	53.83
2	SiO_2	1.12
3	Al_2O_3	0.11
4	MgO	0.01
5	Fe_2O_3	0.15

Table 1: Properties of ESP

C. Blast Furnace Slag:

GGBS is by-product of iron manufacture industry, is a glassy granular material which has cementitious properties. GGBS acts as pozzolans and is therefore combined with Portland cement. Resulting in a hardened cement of GGBS combined with Portland cement. Moreover, it contains less free lime, which in its presence forms ettringite or efflorescence, and makes the resulting hardened Cement more stable.

Sr no	Constituents	Value %
1	CaO	33.2
2	SiO_2	34.4
3	Al_2O_3	21.5
4	MgO	9.5
5	Fe_2O_3	0.2
6	Specific gravity	2.9
7	Bulk density	1200 kg/m^3

Table 2: Properties of GGBS

III. MICRO STRUCTURE REACTION

The hemicarboaluminate produced in cement-slag samples transformed into monocarboaluminate [$C_3A{\cdot}CaCO_3{\cdot}11H_2O$] in cement-Slag-Lime samples. This proved that lime powder did influence the chemical constitution of alumina-contained phase in cementitious system. In addition, the products of carboaluminate would fill the capillary pores and the mechanical behavior could be therefore enhanced.

C_3A + 1/2CH +1/2 CC+ $11.5H_2O$ → C3A ·1/2CC·1/2CH·$11.5H_2O$ (Hc) (I)

C_3A ·1/2CC·1/2CH·$11.5H_2O$ + 1/2CC → C_3A ·CC·$11H_2O$ + 1/2CH + 1/2H (II)

C_3A + CC+ $11H_2O$ → C_3A ·CC·$11H_2O$ (Mc) (III)

IV. CONCRETE BATCH MIX PROPORTION

For identifying effect of egg shell powder and GGBS on concrete various batches has been casted. However cement is replaced by egg shell powder by 5%,10% ,15% and 20%. And to check combination effect cement is replaced by GGBS by 10%,15% and 20%.Total 10 batch has been casted and harden as well durability test has been performed.

% Replacement	Compressive strength test(7,28 days)	Split tensile(28 days)	Sulphate attack Test	Acid attack Test	Sorptivity	RCPT
ESP0%	6	3	3	3	3	3
ESP5%	6	3	3	3	3	3
ESP10%	6	3	3	3	3	3
ESP15%	6	3	3	3	3	3

% Replacement	Compressive strength test(7,28 days)	Split Tensile(28 days)	Sulphate attack Test	Acid attack Test	Sorptivity	RCPT
5%ESP+10%GGBS	6	3	3	3	3	3
5%ESP+15%GGBS	6	3	3	3	3	3
5%ESP+20%GGBS	6	3	3	3	3	3
10%ESP+10%GGBS	6	3	3	3	3	3
10%ESP+15%GGBS	6	3	3	3	3	3
10% ESP+ 20% GGBS	6	3	3	3	3	3

Table 3: Casting Schedule

Fig. 1: Concrete cubes casting and curing

V. TESTING AND RESULTS

A. *Compressive Strength Test (IS 516 (1959)*

Compressive strength of concrete is important characteristic of concrete, which is measured by engineers in designing structures. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days. Determination of compressive strength using by cube where size of cube specimen is 150 ×150 ×150 mm and this test was performed on a 2000 kN capacity compression testing machine. The compressive strength of cube specimen is calculated using the following Formula:

Compressive Strength = P/A N/mm^2

P = peak load

A = cross sectional area in mm

BATCH NAME	Replacement %	7 day strength (N/mm^2)	% change	28 day strength (N/mm^2)	% change
ESP0	NORMAL CONCRETE	17.75		29.53333	
ESP5	5% ESP	17.80	+0.28	31.34	+6.12
ESP10	10% ESP	17.10	-3.66	28.19333	-4.53
ESP15	15% ESP	13.26	-25.29	22.01333	-25.46
A_1	5%ESP+10%GGBS	20.69333	+16.56	31.22333	+5.72
A_2	5%ESP+15%GGBS	21.74	+22.47	33.28667	+12.66
A_3	5%ESP+20%GGBS	20.17667	+13.60	30.67	+3.82
B_1	10%ESP+10%GGBS	18.66	+5.12	29.35	-0.66
B_2	10%ESP+15%GGBS	16.36	-7.83	27.47	-7.12
B_3	10%ESP+20%GGBS	16.35	-7.84	26.38	-10.66

Table 4: Compressive strength results

B. *Split Tensile Strength Test*

The most commonly used tests for estimating the tensile strength of concrete are the split tensile test and the third-point flexural loading test. In the splitting tension test a 150 mm x 300 mm concrete cylinder is subjected to compression loads along the two axial lines which are diametrically opposite. The load is applied continuously at a constant rate within the splitting tension stress until the specimen fails in

two halves. The compressive stress produces a transverse tensile stress, which is uniform along the vertical diameter. Split tensile strength of concrete cylinder is measured in N/mm^2.The tensile strength of the cylinder specimen is calculated using the following formula:

Split Tensile Strength = $2P/\Pi LD$ in N/mm^2

Where, P = Load at failure in N

L = Length of the Specimen in mm (300 mm)

D = Diameter of the Specimen in mm (150mm)

BATCH NAME	Replacement %	28 day SPLIT strength (N/mm^2)	% change
ESP0	NORMAL CONCRETE	3.542344893	
ESP5	5% ESP	3.749469214	+5.64
ESP10	10% ESP	3.245104978	-8.47
ESP15	15% ESP	2.317055909	-34.7
A_1	5%ESP+10%GGBS	3.611983958	+1.97
A_2	5%ESP+15%GGBS	3.442604388	-2.82
A_3	5%ESP+20%GGBS	2.942038217	-16.94
B_1	10%ESP+10%GGBS	2.843972635	-19.77
B_2	10%ESP+15%GGBS	2.651497995	-25.14
B_3	10%ESP+20%GGBS	2.63116301	-25.70

Table 4: Split tensile strength results

C. Acid Attack Test (ASTM C 267)

Acid attack is one of the most important aspects for consideration when we deal with the durability of concrete. Acid attack is particularly important because it primarily responsible for corrosion of reinforcement. The cubes were cast and kept at a temperature of 27°C ± 2°C for 24 hours. After 24 hours the cubes were removed from the mould and immersed in clean water until they were taken out for testing. After 28 days of curing, the Cubes were immersed in a 5% concentrated sulphuric acid (H_2SO_4) & 5% hydrochloric acid (HCl) by weight of water. After 56 days of curing weight difference and the compressive strength of cube were measured.

Fig. 2: Concrete cubes in acid curing

BATCH NAME	Replacement %	28 day strength (N/mm^2)	56 day strength (N/mm^2)	28 day weight (kg)	56 day weight (kg)
ESP0	NORMAL CONCRETE	29.53333	28.56	9.33	9.11
ESP5	5% ESP	31.34	27.97	9.12	9.10
ESP10	10% ESP	28.193	26.18	8.77	8.40
ESP15	15% ESP	22.01333	20.19	8.70	8.40
A_1	5%ESP+10%GGBS	31.22333	28.84	9.10	8.90
A_2	5%ESP+15%GGBS	33.28667	32.20	9.19	8.80
A_3	5%ESP+20%GGBS	30.67	28.60	9.30	9.12
B_1	10%ESP+10%GGBS	29.35	24.82	8.60	8.40
B_2	10%ESP+15%GGBS	27.47	23.90	8.79	8.40
B_3	10%ESP+20%GGBS	26.38	22.50	9.06	8.58

Table 5: Acid attack test results

D. Rapid Chloride Penetration Test

Chloride diffusion is one of the major reasons for causing corrosion to steel reinforcement inside concrete. Therefore it is necessary to study concrete for its chloride ion permeability. This test performs as per the ASTM C 1202. The size specimen is 50 mm thickness and 102 mm diameter. Cover exposed face of specimen with an impermeable material such as rubber or plastic sheeting. Place rubber stopper in cell filling hole to restrict Moisture movement. Allow sealant to cure per manufacturer's instructions. The diffusion cell consists of two chambers.3% NaCl and 0.3N NaOH solutions are prepared. 3% NaCl solution is filled in one chamber and in another chamber 0.3 N NaOH solution is filled. Apply the 60 Volts DC for 6 hours. The current is measuring at every 30 min intervals by using voltmeter.The current is measuring at 30 min intervals, the following formula, based on the trapezoidal rule.

$$Q = 900 (I_0 + 2I_{30} + 2I_{60} + \ldots + 2I_{300} + 2I_{330} + I_{360})$$

Where: Q = charge passed (coulombs),

Io = current immediately after voltage is applied, and

It = current at t min after voltage is applied

Fig. 3: RCPT apparatus

BATCH NAME	Replacement %	CHARGE PASSED	CL PENETRIBLITY
ESP0	NORMAL CONCRETE	576.4149	VERY LOW
ESP5	5% ESP	1160.842	LOW
ESP10	10% ESP	1383.461	LOW
ESP15	15% ESP	1688.092	LOW
A_1	5%ESP+10%GG	1286.342	LOW

	BS		
A_2	5%ESP+15%GGBS	1439.167	LOW
A_3	5%ESP+20%GGBS	1563.924	LOW
B_1	10%ESP+10%GGBS	1006.686	LOW
B_2	10%ESP+15%GGBS	3289.008	MODERATE
B_3	10%ESP+20%GGBS	3634.596	MODERATE

Table 6: RCPT results

VI. CONCLUSION

1) It was noticed a cost of normal concrete is around 3500 rs per 1M3, however that is for sure by increasing cement replacement percent cost of concrete will decrease.
2) Though B3 batch has highest replacement percent and so cost per 1 m3 concrete is 2920 that is 16% lower than normal concrete. A batch A2 is observed to be best compressive strength batch and it has 12% lesser cost than normal concrete
3) According to results of harden concrete and durability test batch A2 (5%ESP+10%GGBS) is noticed most promising combination batch. Furthermore according to rate analysis A2 batch gives 11.14% money saving hence, practically by using such combination industrial by product can be utilize without decrease in mechanical properties.
4) Out of several batches, B3 batch have maximum replacement percent though such concrete has found good resistances against durability. Concrete batches A3, B2, B3 can be practically used where higher strength is not required and money saving is prime concern.
5) A batch A2 has found optimum combination dosage. As 5% ESP+15% GGBS.Reason of such improved mechanical behavior is reaction between aluminum in cement paste and lime of egg shell powder. Such combination generates mono carboaluminate at micro level and imparted in improved behavior
6) Finally, these conclusions are of test conditions described here above and for the materials that have been tested. Other types of fillers or granulated blast furnace slag could show other behaviors and effects on mechanical and durability properties. Before field implementation pilot study are necessary in actual site condition.

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