Experimental Study on Properties of Concrete with Partial Replacement of Cement Using Egg Shell Powder And GGBS

Mr. Sheikh Ovais Ahmed[1], Mr. Sourabh Lalotra[2]

[1]Student, Dept. of Civil Engineering, Sri Sai College of Engineering & Technology
[2] Assistant Professor, Dept. of Civil Engineering, Sri Sai College of Engineering & Technology

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Abstract - *The production of Portland cement results in emission of pollutants that ultimately causes environmental pollution. The carbon dioxide delivered by concrete enterprises causes natural contamination and an unnatural weather change. In production of 1000Kg of concrete, roughly 900Kg of CO_2 is discharged into atmosphere. To diminish the effect of concrete production on climate, some wastes and by-products can be are utilized as admixture, so ecological contamination and depletion of natural resources is decreased. We used eggshell powder and GGBS in our research as partial replacement of cement. The reason behind this is the chemical behavior and abundant availability. Eggshell is made almost entirely of calcium carbonate ($CaCO_3$) crystals. The chemical composition of cement and eggshell are almost similar. GGBS as we know is a pozzolanic material which is being used as partial cement replacement since ages. It has good cementing action which can be taken as advantage. Since we are utilizing waste products to get concrete with desired properties, we are actually transforming waste into wealth. In our study, replacement of Egg shell powder was varied from 0% up to 20% (0, 4, 8, 12, 16, 20 respectively) and replacement of GGBS was added at varying percentages from 0% to 40% (0, 8, 16, 24, 32, 40 respectively). The above-mentioned waste products were utilized as partial replacement of cement and different properties of concrete were determined.*

Key Words: Eggshell Powder, GGBS, Compressive Strength, Flexural Strength, Split Tensile Strength.

1.INTRODUCTION
1.1 General

Concrete being the main construction material in construction industry. Production of Portland cement causes release of greenhouse gases like CO_2 which leads to environmental pollution and global warming. Main emphasis is put on the use of wastes and by-products in concrete as partial replacements. It is estimated that concrete consumption on earth is of the order of 10 billion tonne per year. To meet the sustainable development and environmental goals while maintaining the strength requirements, responsiveness to environmental regulations and waste management practices should be a part of daily operations in the concrete industry. The concrete industry must consume a wider range of by-products from other industries. Waste materials in cement concrete not only reduce the emission of greenhouse gases, but also provide a sustainable management of waste in countries like India, where infrastructure projects such as irrigation, roads and buildings are being constructed or are near completion of the planning and design stages

1.2 Eggshell Powder

Eggshell waste is generated from not only households and food industries but also hatcheries. Eggshells are a part of agricultural wastes that serves a problem for its disposal. India, as we know, is the second largest producer and consumer of eggs after China. Managing such huge quantities of eggshells emerges as a problem. There is a chance that we can convert this waste into wealth. Scientifically, eggshell comprises of Calcium. Eggshell contains of 1% magnesium carbonate, 1% calcium phosphate, 4% organic matter, and 94% calcium carbonate. Cement and eggshells have almost same primary composition in calcium compounds. Thus, it can be utilized as replacement of cement in concrete industry after reaching optimum percentage that satisfies our need.

1.3 GGBS

GGBS (Ground Granulated Blast-furnace Slag) is a cementitious material commonly used in concrete. It is a by-product of blast furnaces used to make iron. The blast furnace runs at a temperature of about 1500°C, fed by a carefully controlled mixture of iron ore, coke, and limestone. Slag forms on top of the iron as the iron ore is reduced to iron. As a molten liquid, this slag is periodically removed. In order to manufacture GGBS, it must be rapidly cooled in large volumes of water. The quenching process improves the cementitious properties, producing granules similar to coarse sand. A fine powder is then ground from the dried granulated slag.

GGBS is often referred to as "slag cement", but it can also be called "GGBFS" or "GGBS". Since GGBS hardens very slowly. it is usually mixed with Portland cement in concrete. Based on the amount of GGBS in the cementation material, concrete made from Ground Granulated Blast Furnace Slag sets more slowly than ordinary Portland cement concrete. Moreover, it takes longer for it to gain the necessary strength.

1.4 Objectives

a) To perform Compressive Strength Test, Flexural Strength Test and Split Tensile Strength Test of concrete and to compare the results with and without replacement of Eggshell Powder and GGBS.
b) To reduce the overall environmental effects of concrete production using Eggshell Powder and GGBS as partial replacement of cement.
c) Workability of concrete.

2. MATERIALS
2.1 Cement

OPC 43 Grade conforming to IS: 8112 was used. All concerned test results of cement were performed at the concerned laboratory. Various tests were performed on cement to know its physical properties. The test results are shown in Table 1.

Table -1: Test results of Cement

S. No.	Properties	Exp Value	IS:8112-1989 limits
1.	Fineness (Sieving method)	5.71%	< 10%
2	Normal Consistency	29%	--
2	Initial Setting Time [minutes]	61	>30
3	Final Setting Time [minutes]	289	<600
4	Specific Gravity	3.13	3 to 3.25
5	Specific Surface Area (cm^2/g)	2781	>2250
6	Soundness Test (Le-Chatelier Apparatus)	0.7	10 mm (max.)
7	Compressive Strength (MPa) 1. 3 days 2. 7 days 3. 28 days	 26.12 MPa 38.19 MPa 47.11 MPa	Minimum 16 MPa 22 MPa 43 MPa

2.2 Fine Aggregate

Crushed Sand was used as fine aggregates. Physical Properties of sands like fineness modulus, specific gravity was determined at the laboratory as shown in Table 2.

Table -2: Test results of Fine Aggregate

Test	Values obtained
Specific Gravity	2.68
Fineness modulus	2.8
Silt content	4.48%
Water absorption	1.1%
Bulk density (poured)	1376 kg/m³
Bulk density (tamped)	1611 kg/m³

2.3 Coarse Aggregate

Angular crushed aggregates have been used in this research. The physical properties of coarse aggregate were determined and are tabulated in Table 3. Grading of coarse aggregates was done according to IS:383-1970. Aggregates of nominal sizes 20mm and 10 mm were combined. Water absorption and specific gravity of coarse aggregate was determined as per IS 2386-Part-III (1963).

Table -3: Test results of Coarse Aggregate

Test	Result
Aggregate Crushing Value (ACV)	17.14 %
Aggregate Impact Value (AIV)	11.31 %
Nominal Size	20 mm
Specific Gravity	2.67
Water absorption	0.75%
Grading ratio of 20mm to 10mm	2:1
Bulk Density (poured)	1701 kg/m³
Bulk Density (tamped)	1938 kg/m³

2.4 Water

Potable water available in a laboratory as per specifications conforming to BIS:456-2000 was used for this project in mixing and curing.

2.5 Eggshell Powder

ESA is a waste substance that is difficult to come by. It is created by incineration or controlled combustion of ESP at extreme temperatures. Calcium carbonate makes up the majority of ESP. The carbonate of lime decomposes into calcium oxide with the production of carbon dioxide when exposed to high temperatures. Egg Shells for this research were collected from different Bakers and Restaurants in Jammu City. The material was brought in one place and spread out to dry for 72 hours before burning. Then the shells were burnt in Oven at 1200-degree Celsius. Finally, the ashes of the burnt shell were taken to Laboratory for testing. It was sieved using 90µm Sieve. Chemical composition of Egg Shell Powder shows that it has CaO content even greater than industrial grade lime. Thus, it may lay a very important role in augmenting the calcium supply of the primary stabilizer, i.e., lime.

The physical and chemical properties of eggshell powder are given as under in Table 4 and Table 5 respectively.

Table -4: Physical Properties of Eggshell Powder

S. No	Property	Value
1	Shape	Spherical/Irregular
2	Specific Gravity	2.07 – 2.50
3	Average Particle Size	1-155 micron
4	Bulk Density	1081 kg/m^3
5	Surface Area (BET)	307-1400 m^2/kg

Table -5: Chemical Properties of Eggshell Powder

S. No	Property	Value
1	Iron Oxide (Fe_2O_3)	2.60 %
2	Silicon Dioxide (SiO_2)	0.11 %
3	Calcium Oxide (CaO)	50.7 %
4	Aluminium Oxide (Al_2O_3)	0.05 %
5	Sodium Oxide (Na_2O)	0.14 %
6	Potassium Oxide	1.88 %
7	Loss on Ignition	6.00 %

2.6 GGBS

GGBS was procured from seller "Kashmir Ispat" via online Store namely "India Mart". It has off-white colour. The physical and chemical properties of GGBS are given as under in Table 6 and Table 7 respectively.

Table -6: Physical Properties of GGBS

S. No	Property	Value
1	Colour	Off-white
2	Specific Gravity	2.78
3	Specific Surface Area	400 – 600 m2/kg
4	Bulk Density (Loose)	1000 - 1100 kg/m3
5	Bulk Density (Vibrated)	1200 - 1300 kg/m3

Table -7: Chemical Properties of GGBS

S. No	Chemical Properties	Value
1	CaO	33.20 %
2	SiO2	34.40 %
3	Al2O3	21.50 %
4	MgO	09.50 %
5	Fe2O3	00.20 %
6	SO3	00.66 %
7	Na2O	00.34 %

3. METHODOLOGY
3.1 Casting

Workability of concrete in terms of slump was measured before moulding was done. For compressive strength test, specimens of standard of size i.e., 150 x 150 x 150 (all dimensions in mm) were casted having different percentages of Egg shell powder and GGBS. For flexural strength test, specimens of size 150 x 150 x 700 were prepared. The moulds are well lubricated before filling in the concrete mix to allow easy demoulding after gaining strength. Similarly, for split tensile strength test, specimens of size 300 x 150 were prepared. After filling moulds with concrete, compaction was done using manual tamping rod to achieve desired compaction. Then a trowel was used to finish the surface well and date of casting with mix designation number was marked on it.

3.2 Curing

After 24 hours of moulding, the specimens were taken out from moulds and placed in curing tanks for curing process for 28 days at normal room temperature.

3.3 Tests on Concrete

3.3.1 Slump Cone Test

This test consists of a mould known as Slump Cone having standard dimensions. This test was used to determine fluidity. Note that the concrete should be free form bleeding and segregation. The apparatus consists of a tamping rod of dia 16 mm and length 600mm, a truncated cone of height 300 mm, bottom dia 200mm and top diameter 100 mm.

3.3.2 Compressive Strength Test

Concrete specimens of size 150 x 150 x 150 were tested for compressive strength at three different curing periods.

Note that specimens of size 100 x 100 x 100 mm can also be used for aggregate size less than 20 mm. If specimen size is 150 mm, tamping is done 35 times for each layer and if the specimen size is 100 mm, then tamping is done 25 times on each layer. Specimens were placed in CTM and a gradual load was applied @ 14N/mm² upto failure and the load corresponding to failure was noted.

3.3.3 Flexural Strength Test

Ability of concrete structure to resist flexural failure in bending is called flexural strength. This test gives directly the modulus of rupture. The specimen is generally prismatic section of size 150 x 150 x 700 mm. If aggregate size is less than 19 mm, then specimen of size 100 x 100 x 500 mm can be used. In our study, the specimens of size 150 x 150 x 700 mm were used which is as per IS:516-1959. The gradual loading was applied without shock at the rate of 180 kg/min for 100mm and 400 kg/min for 150mm until cracks appeared on the surface of the specimen. Reading was noted at failure.

3.3.4 Split Tensile Strength Test

This test gives indirect tensile test of concrete and is generally used to determine the tensile strength. In our research, cylindrical specimens of standard dimensions 150 mm diameter and 300 mm long were used. This test was conducted as per IS 5816 (1999). Gradual loading was applied ranging from 1.2 N/mm²/min to 2.4 N/mm²/min at uniform rate until the specimen failed.

3.4 Mix Design

Concrete mix design was based on compressive cube strength of trial mixes arrived at as per IS 10262-2009.

Table -8: Mix Design parameters

i.	Mix Grade	:	M35
ii.	43 Grade Cement strength At 7 days At 28 days		 33 MPa 43 MPa
iii)	Maximum aggregate size (Coarse)	:	20 mm (angular size), graded.
iv)	Sp. Gravity of C.A (Saturated Surface Dry condition)	:	2.67
v)	Sp. Gravity of F.A (Saturated Surface Dry condition)	:	2.68
vi)	Bulk density of C.A. (loose) (Rodded)	:	1.70 kg/L 1.94 kg/L
vii)	Bulk density of F.A. (loose) (Rodded)	:	1.376 kg/L 1.611 kg/L
viii)	Workability	:	100-120 slump
ix)	Fine Aggregate	:	Zone II
x)	Quality Control at site	:	Good
xi)	Exposure conditions	:	Severe

The mix design ratio as calculated is as under:
Cement: FA: CA = ***1 : 1.9 : 3***

Table -9: Quantity of Cement, Eggshell powder & GGBS

S. No	MIX	% ESP	% GGBS	ESP Content (kg/m³)	GGBS Content (kg/m³)	Cement (OPC) (kg/m³)
1	CC	0	0	0.00	0.00	385.00
2	X1	4	8	15.40	30.80	338.80
3	X2	8	16	30.80	61.60	292.60
4	X3	8	24	30.80	92.40	261.80
5	X4	12	24	46.20	92.40	246.40
6	X5	12	32	46.20	123.20	215.60
7	X6	16	32	61.60	123.20	200.20
8	X7	20	40	77.00	154.00	154.00

4. RESULTS AND DISCUSSIONS

4.1 Slump Cone Test

Table -10: Slump variation with cement, ESP & GGBS

S. No	Mix Name	ESP	GGBS	Slump (mm)
1	CC	0%	0%	76
2	X1	4%	8%	79
3	X2	8%	16%	81
4	X3	8%	24%	89
5	X4	12%	24%	97
6	X5	12%	32%	101
7	X6	16%	32%	98
8	X7	20%	40%	99

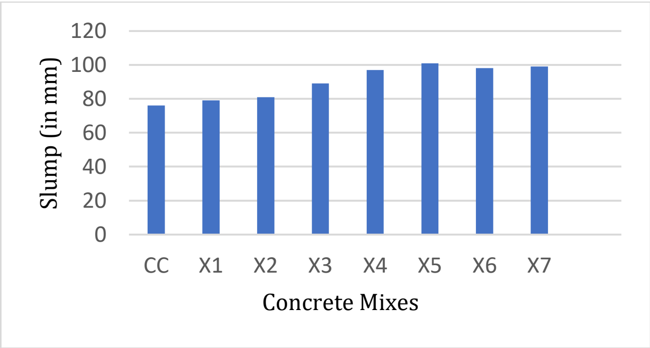

Fig -1: Slump variation with cement, ESP & GGBS

4.2 Compressive Strength Test

In this test, we used the specimen size of 150 x 150 x 150 (All dimensions in mm). The specimens were casted and after 24 hours, they were placed in curing tank at required temperature and relative humidity. Compressive Strength was performed on specimens at three stages (7 days, 14 days and 28 days.

Table -11: Compressive Strength variation

S. No	MIX	% ESP+GGBS	Compressive Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	CC	0+0	26.89	35.13	40.34
2	X1	4+8	27.48	37.05	41.22
3	X2	8+16	27.87	37.58	41.81
4	X3	8+24	29.08	37.98	43.62
5	X4	12+24	25.25	32.78	37.87
6	X5	12+32	24.77	31.90	37.15
7	X6	16+32	24.54	33.41	36.81
8	X7	20+40	22.16	28.69	33.24

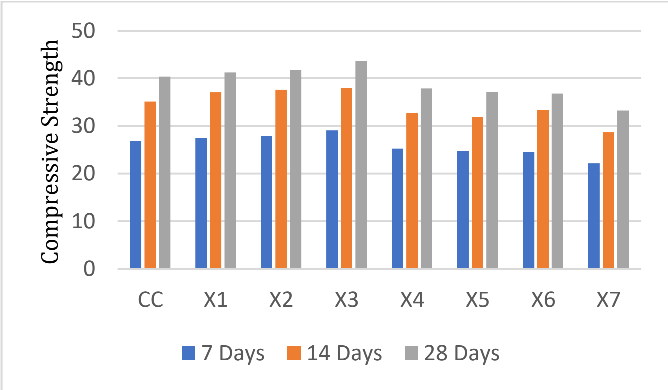

Fig -2: 28 Day Compressive Strength Variation

4.3 Flexural Strength Test

Ability of a concrete structure to resist bending failure is measured in terms of flexural strength. Tests were conducted at 7 days, 14 days and 28 days curing ages.

Table -12: Flexural Strength variation

S. No	MIX	% ESP+GGBS	Flexural Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	CC	0+0	3.38	4.35	5.04
2	X1	4+8	3.42	4.35	5.15
3	X2	8+16	3.48	4.49	5.23
4	X3	8+24	3.63	4.68	5.45
5	X4	12+24	3.09	4.08	4.73
6	X5	12+32	3.03	4.03	4.64
7	X6	16+32	3.03	3.93	4.60
8	X7	20+40	2.72	3.55	4.16

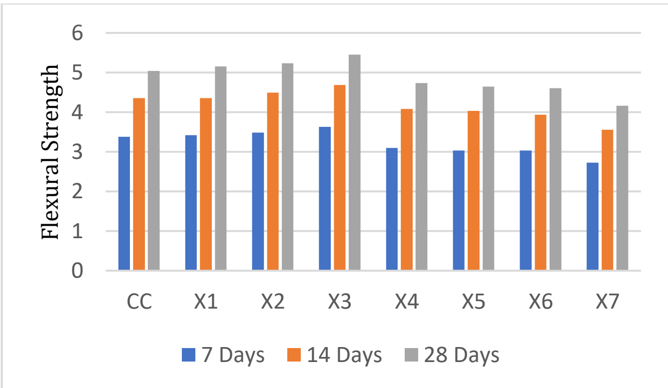

Fig -3: 28 Day Flexural Strength Variation

4.4 Split Tensile Strength Test

Direct tensile strength of concrete cannot be measured as it is very weak in tension. Tests were conduct at 7 days, 14 days and 28 days as shown in Table 13.

Table -13: Split Tensile Strength variation

S. No	MIX	% ESP+GGBS	Split Tensile Strength (N/mm^2)		
			7 days	14 Days	28 Days
1	CC	0+0	2.41	3.22	3.70
2	X1	4+8	2.43	3.25	3.75
3	X2	8+16	2.54	3.32	3.78
4	X3	8+24	2.53	3.41	3.88
5	X4	12+24	2.31	3.10	3.56
6	X5	12+32	2.30	3.08	3.52
7	X6	16+32	2.27	3.04	3.50
8	X7	20+40	2.13	2.88	3.29

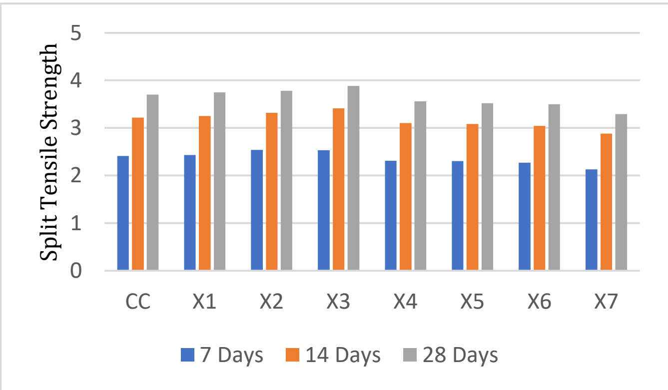

Fig -4: 28 Day Split Tensile Strength Variation

5. CONCLUSION

ESP and GGBS content both contributed to an increase in the compressive strength of partially replaced concrete. The values of compressive strength were higher than conventional concrete in most of mixes. Mix X3 showed maximum 7-day, 14-day, 28-day compressive strength having values 29.08 MPa, 37.98 MPa, 43.62 MPa respectively. Maximum increase in compressive strength with respect to conventional concrete is given in Table 14.

Table -14: Comparison of Max Compressive Strength

S. No	Curing Age	Increase in Compressive Strength (MPa)	Percentage Increase (%)
1	7 days	2.19	8.13 %
2	14 days	2.85	8.12 %
3	28 days	3.28	8.13 %

Flexural strength was higher for most of the mixes than conventional mixes. Mix X3 had the highest 7-day, 14-day and 28-day flexural strength as 3.63 MPa, 4.68 MPa and 5.45 MPa respectively. Maximum increase in flexural strength with respect to conventional concrete is given in Table 15.

Table -15: Comparison of Max Flexural Strength

S. No	Curing Age	Increase in Flexural Strength (MPa)	Percentage Increase (%)
1	7 days	0.25	7.53 %
2	14 days	0.33	7.48 %
3	28 days	0.41	8.13 %

7-Day Split Tensile Strength came out to be maximum for Mix X2 (2.54 MPa) whereas for 14-Days and 28-Days, the split tensile strength came out to be maximum for the mix X3 (3.41 and 3.88 MPa respectively). Maximum increase in split tensile with respect to conventional concrete is given in Table 16.

Table -16: Comparison of Split Tensile Flexural Strength

S. No	Curing Age	Increase in Split Tensile Strength (MPa)	Percentage Increase (%)
1	7 days	0.14	5.82 %
2	14 days	0.19	5.98 %
3	28 days	0.18	4.88 %

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