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Experimental Study on Concrete by Partial Replacement of Fine Aggregate with Fly Ash and Egg Shell Powder

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Abstract:

This experimental study aims to investigate the suitability of fly ash and egg shell powder as partial replacement for fine aggregate in the production of low-cost and light weight concrete. In this experimental study is an attempt to find the optimum usage of fly ash and egg shell powder in normal concrete by replacing the river sand (7%,14%,21%,28% & 35%) by weight at various proportions.

Tests are conducted on concrete cubes, cylinders and flexural beams to study compressive strength, split tensile strength and flexural strength. Tests are conducted for finding the strength of the concrete in 7 days and 28 days strength. Finally the results are compared with the normal conventional concrete. The weight reduction is also calculated. The suitability of the fly ash and egg shell powder concrete is evaluated.

Keywords:
Concrete, Fly ash(FA), Egg shell powder(ESP), Fine aggregate(F.A) .

1. Introduction:

In India, the most widely used fine aggregate for construction is the natural river sand mined from the riverbeds. However, the availability of river sand for the preparation of concrete is becoming scarce, due to the excessive non scientific methods of mining from the riverbeds, lowering of water table, sinking of the bridge piers, etc.

Due to the depletion of river bed it has also become expensive. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing countries.

The present scenario demands identification of cheaper and locally available substitute materials for the river sand for making concrete which is environment friendly solution for the fast depleting and excessively mined river sand and lead to an overall reduction in construction cost for sustainable development.The quantity of fly ash produced from thermal power plants in India is approximately 80 million tons each year, and its percentage utilization is less than 10%. Majority of fly ash produced is of Class F type.

Fly ash is generally used as replacement of cement, as an admixture in concrete, and in manufacturing of cement. Whereas concrete containing fly ash as partial replacement of cement poses problems of delayed early strength development, concrete containing fly ash as partial replacement of fine aggregate will have no delayed early strength development, but rather will enhance its strength on long-term basis.

This study explores the possibility of replacing part of fine aggregate with fly ash as a means of incorporating significant amounts of fly ash.Eggshell is generally thrown away as a waste. The egg shell also creates some allergies when kept for a longer time in garbage. Disposal is a problem. If the waste cannot be disposed properly it will lead to social and environmental problem. This experimental study aims to investigate the suitability of fly ash and egg shell powder as partial replacement for fine aggregate at equal proportion. The objectives and scope of present study are

a)To study the physical properties of fresh & hardened concrete with fly ash and egg shell powder as partial replacement for fine aggregate.

b)To relate mechanical properties between control specimens and specimens fly ash and egg shell powder.

c)To study the effect of fly ash and egg shell powder for various mix proportions.

d)To provide economical construction material.

e)Use of fly ash and egg shell powder by partially sand replacement in normal concrete for real time projects thereby reducing the overall cost of construction.

f)Reduction in mining river sand helps protecting the ground water table.

g)The effective way of utilizing waste material leads to clean environment.

2. Theoretical Background of the study:

Rafat Siddique had a study and determining the effect of fine aggregate partial replacement with Class F fly ash on the mechanical properties of concrete. River sand was replaced with five percentage mixes (10%, 20%, 30%, 40%, and 50%) of Class F fly ash by weight. Tests were performed for properties of fresh concrete. Compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity were determined at 7, 14, 28, 56, 91, and 365 days. Test results indicate significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement of fine aggregate. The strength differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28 days and it can be effectively used in structural concrete.

Amarnath Yerramala studied the Properties of concrete with eggshell powder as cement replacement.This paper describes research into use of poultry waste in concrete through the development of concrete incorporating eggshell powder (ESP). Different ESP concretes were developed by replacing 5-15% of ESP for cement. The results indicated that ESP can successfully be used as partial replacement of cement in concrete production. The data presented cover strength development and transport properties. With respect to the results, at 5% ESP replacement the strengths were higher than control concrete and indicate that 5% ESP is an optimum content for maximum strength. In addition, the performance of ESP concretes was comparable up to 10% ESP replacement in terms of transport properties with control concrete.

The results further show that addition of fly ash along with ESP is beneficial for improved performance of concretes. The studies on partially replacement of fine aggregate by rice husk and egg shell powder in concrete by Sathanantham showed that effect of egg shell powder and rice husk on some mechanical properties and physical properties of concrete was investigated. The tensile strength, flexural strength was decreased with increasing egg shells and rice husk percent. The tensile strength decreased from (2.36 N/mm2) to (0.21 N/mm2) with increasing egg shell and rice husk from (0 wt %) to (50 wt %). The compressive strength of the concrete is to meet required strength with 20% of the egg shell and rice husk at the same time weight of the cubes are reduced up to 2kg to 2.8kg.

According to K. Uma Shankar J, revealed that the use of egg shell powder, GGBS and saw dust ash as concrete. Egg shell plays a major role, as it is used in all the combination of the concrete cubes. The tests revealed encouraging results for the study. The sample of blended cement consists of 20% of egg shell powder, 50% of GGBS and 10% of saw dust ash. The proportion of the mineral admixtures is applied in testing cubes for their compressive strength. The results of the works can be concluded that egg shell powder, GGBS and saw dust ash mixed concrete cubes had maximum strength at 5%, 10% replacement. The 28 days compressive strengths of the ESP & GGBS mix concrete cubes shows maximum strength at 10% replacement with cement.

3. Experimental Program:

3.1 Materials:

3.1.1 Cement:

The cement used for the present experimental investigation was ordinary Portland cement of 53 grade, conforming to IS: 12269–1987. The various characteristics of cement were tested as per the Indian Standards IS: 4031 – 1988. Specific Gravity of the cement was 3.15.

3.1.2 Fly Ash:

Class F fly ash obtained from thermal power plant at Kadapa in Andhra Pradesh was used in this investigation. It was sieved through 90 micron sieve for the purpose of concreting samples. Specific Gravity of FA was 2.10. Fineness of FA was 310m3/kg. Bulk Density of FA was 0.749 gm/cm3 conforming to IS: 3812-1981.

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Table 1 Chemical Analysis for Fly Ash:

Loss on ignition	4.5
$S_1 O_2$	56.65
$Al_2 O_3$	27.35
$Fe_2 O_3$	4.79
Ca O	2.19
Mg O	0.57
Soluble $S_1 O_2$	3.95

3.1.3 Egg shell powder:

The egg shell powder was sourced from Gayatri Chemicals, Hyderabad, Telangana, India. It was sun dried and kept in waterproof bags. Specific Gravity of ESP was 0.84. Bulk Density of ESP was 0.80gm/cm3. Moisture content of ESP was 1.17%.

Table 2 Chemical Analysis for Egg Shell Powder:

Ca O	50.7
$S_1 O_2$	0.09
$Al_2 O_3$	0.03
Mg O	0.01
$Fe_2 O_3$	0.02
$Na_2 O$	0.19
$P_2 O_5$	0.24
Sr O	0.13
Ni O	0.0001
SO_3	0.57
Cl	0.219

3.1.4 Fine aggregate :

Natural river sand confirming to Zone 2 grading as per IS: 383 – 1987 was used. The sand was thoroughly flushed with water to reduce the level of impurities and organic matter and later sun dried. Its physical properties are shown in Table 3.

3.1.5 Coarse Aggregate:

The natural broken stone (coarse aggregate) used for the study was of 20mm size maximum. It is conforming to IS: 383-1970. It was retrieved from a local quarry near Chengalpattu, Kanchipuram District, Tamil Nadu. The shape and quality of aggregate was uniform throughout the project work. It was free from any impurities. Its physical properties are shown in Table 4.

Table 3 Physical properties of fine aggregate

Sl. No	Parameters	Values
1	Specific gravity	2.9
2	Fineness modulus	3.2
3	Bulk Density	1560Kg/m^3
4	Moisture content	1.50%

Table 4 Physical properties of coarse aggregate:

Sl. No	Parameters	Value
1	Specific gravity	2.77
2	Water absorption	1.21
3	Crushing value%	15.8
4	Impact value%	17.6
5	Moisture content	1.20%

3.2 Mix Proportions:

In order to study the mechanical properties of fly ash and egg shell powder concrete. Six mix proportions were made. The percentage replacements of aggregates by fly ash and egg shell powder were 0%, 7%, 14%, 21% ,28% and 35%.This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other sample which is finally used for the comparison. The mix proportions studied for the fly ash and egg shell powder concrete are totally 5 proportions as shown in Table 5. The mix proportion was done as per the IS: 10262-1982. The target mean strength was 39.9 and 50.89 N/mm2 for M30 and M40. The final mix that is used 1:1.13:2.36 and 1:1.07:2.20 is obtained for water cement ratio is 0.38 and 0.31.

Table 5 Mix proportions (M30 & M40):

Sl. No.	Mix	Fly Ash	Egg Shell Powder	Combined Replacement
1	M0	0%	0%	0%
2	M1	3.5%	3.5%	7%
3	M2	7%	7%	14%
4	M3	10.5%	10.5%	21%
5	M4	14%	14%	28%
6	M5	17.5%	17.5%	35%

3.3 Mixing, compaction, preparation of specimen and curing:

For each mix, the required quantities of the constituents were batched by weight. The mix design is produced for maximum size of aggregate is 20mm conventional aggregate FA and ESP with replacement of fine aggregate. The replacement of FA and ESP respectively and combinely with fine aggregate by 7%, 14%, 21% ,28% and 35% is studied by casting cubes, cylinders and beams.

The concrete is prepared in laboratory. The concrete is poured into the mould in 3 layers by poking with tamping rod. The cast specimens are removed after 24 hours and these are immersed in a water tank. After curing 7 & 28 days the specimens are removed and these are tested for Compression, Split and Flexural strength as shown in fig.1, fig.2 and fig. 3 respectively, and the results compared with conventional concrete.

Fig. 1 Compressive Strength test

Fig. 2 Spilt tensile strength test.

Fig. 3 Flexural strength test.

Table 6 Preparation & casting of specimens:

% of Replacement	No of Cubes, Cylinders and Beams			
	FA and ESP (50:50) for M30		FA and ESP (50:50) for M40	
	7 days	28 days	7 days	28 days
0	3	3	3	3
7	3	3	3	3
14	3	3	3	3
21	3	3	3	3
28	3	3	3	3
35	3	3	3	3

3.4 Test Program:

The cubes of 150X150X150 mm size and cylinders of 150mm diaX300mm and beams of 100X100X500mm, were tested for Compression, Split Tensile and Flexural Strength. Tests were done as per following codes of Bureau of Indian Standards. The test for Compressive Strength on cubes were measured at 7 and 28 days of

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curing as per IS:516-1959, test for Flexural Strength on beam was measured at 7 and 28 days of curing as per IS:516-1959 and test for Split Tensile Strength on cylinder was measured at 7 and 28 days of curing as per IS:5816-1999.

4. Results and Discussion:

Table 7 Avg. Test Results in N/mm2 for M30:

Mix %	Compressive Strength at 7 days	Split Tensile Strength at 7 days	Flexural Strength at 7 days	Compressive Strength at 28 days	Split Tensile Strength at 28 days	Flexural Strength at 28 days
0	26.85	2.80	3.13	38.69	3.60	4.30
7	31.47	3.04	3.46	45.86	3.82	4.61
14	29.19	2.91	3.30	42.23	3.70	4.29
21	28.28	2.86	2.64	41.51	3.58	3.46
28	26.85	2.75	2.31	40.63	3.50	3.30
35	21.94	2.57	1.64	31.15	3.24	2.97

Table 8 Avg. Test Results in N/mm2 for M40

Mix %	Compressive Strength at 7 days	Split Tensile Strength at 7 days	Flexural Strength at 7 days	Compressive Strength at 28 days	Split Tensile Strength at 28 days	Flexural Strength at 28 days
0	31.60	2.94	3.79	46.28	3.78	5.11
7	32.04	3.08	4.12	46.85	3.95	5.44
14	31.54	3.01	3.96	46.45	3.86	5.28
21	29.74	2.83	3.30	45.86	3.65	4.61
28	26.63	2.73	2.63	40.96	3.53	3.46
35	23.77	2.62	1.81	37.33	3.38	2.80

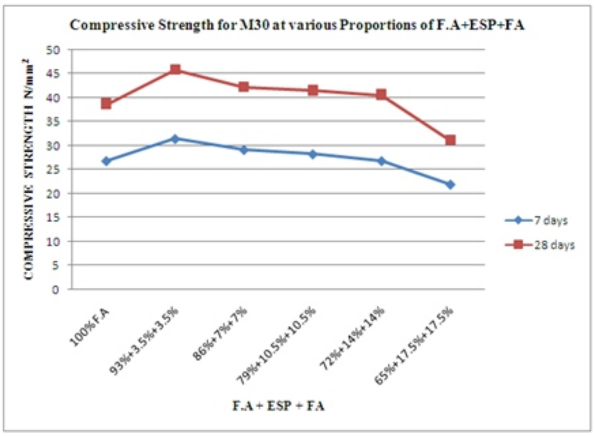

Fig. 4 Compressive strength for 7 & 28 days (M30)

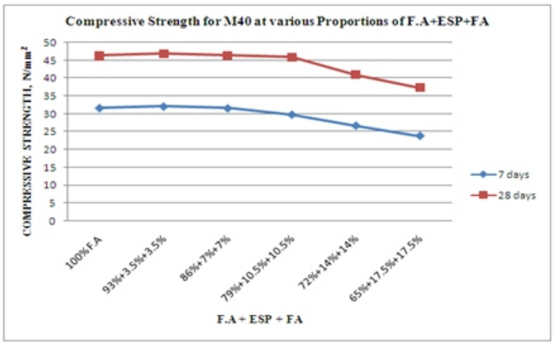

Fig. 5 Compressive strength for 7 & 28 days (M40).

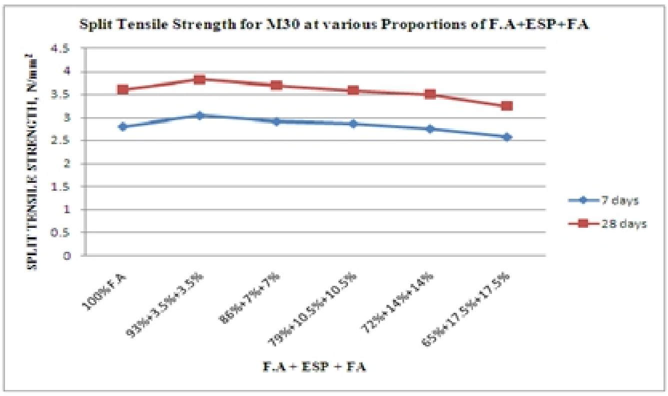

Fig. 6 Split tensile strength for 7 & 28 days (M30)

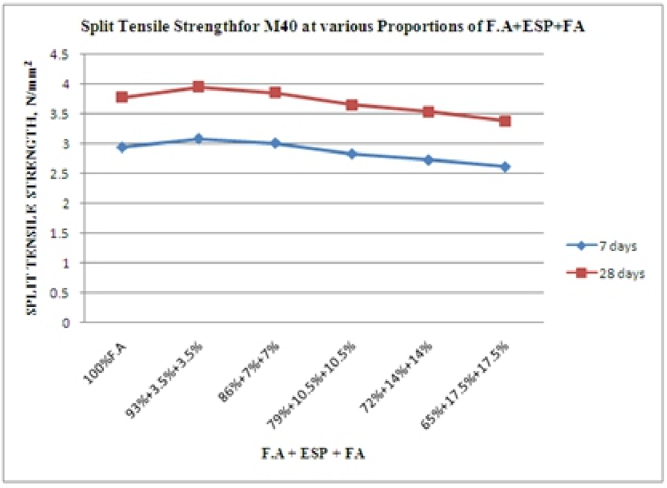

Fig. 7 Split tensile strength for 7 & 28 days (M40)

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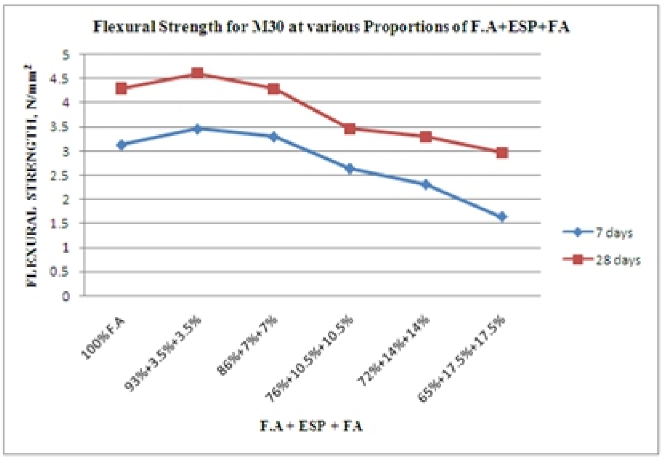

Fig. 8 Flexural strength for 7 & 28 days (M30)

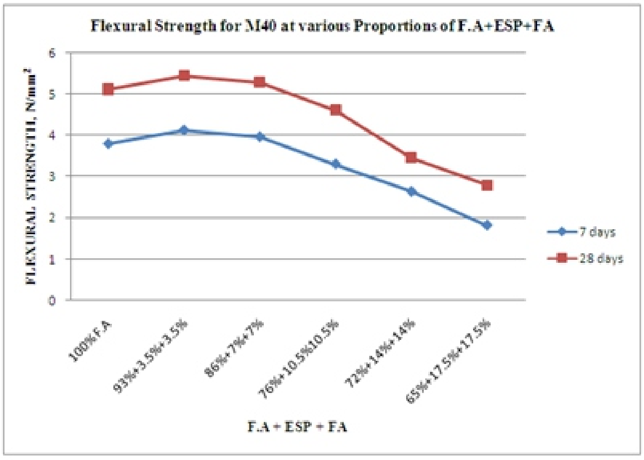

Fig. 9 Flexural strength for 7 & 28 days (M40)

5. Conclusions :

The following conclusions can be drawn from the present investigation.

1. Compressive strength, splitting tensile strength and flexural strength of fine aggregate partially replaced with FA and ESP concrete specimens were higher than the normal concrete specimens at 7 and 28 days. The strength differential between the FA and ESP concrete specimens and normal concrete specimens became more distinct after 28 days.

2. Compressive strength, splitting tensile strength and flexural strength of fine aggregate partially replaced with FA and ESP concrete continued to increase at certain level at 7 and 28 days.

3. Compressive strength was higher than normal concrete for 21% FA and ESP replacement at 7 and 28 days of curing ages. FA and ESP replacements greater than 28% (M30) and 21% (M40) had lower strength than normal concrete at the same time weight of the cubes are reduced up to 7% per cube.

4. Split tensile strength of FA and ESP concrete were comparable with normal concrete up to 35% FA and ESP replacement. However, concrete with 14% FA and ESP had lower split tensile strength than normal concrete at both the mixes.

5. Flexural strength of FA and ESP concrete were comparable with normal concrete up to 35% FA and ESP replacement. However, concrete with 14% FA and ESP had lower flexural strength than normal concrete at both the mixes.

6. Results of this investigation suggest that fly ash and egg shell powder could be very conveniently used in structural concrete.

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