Efficacy of Partial Replacement of Cement with Hypo Sludge and Egg Shell Powder in Concrete

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Abstract

The concrete is an important material in construction. The major element in concrete is cement. The production process of cement from its raw material produces a lot of CO2 which causes environmental pollution and global warming. To reduce the emission of CO2 during cement manufacturing process, alternatives like fly ash, GGBS, Rice husk ash, hypo sludge, Egg shell powder, coconut shell ash, silica fume, etc. are used. In this project we prefer Hypo sludge and Egg shell powder as a partial replacement of cement in concrete. Egg shell is rich in calcium and has nearly same composition of cement. The utilization of Egg shell as cementitious material has benefits like utilizing waste material, minimizing the usage of cement and eco-friendly. Hypo sludge consists of magnesium and silica particles which would increase the strength of concrete and also hypo sludge contains large percentage of silicon dioxide which will give extra strength to concrete. Cement is replaced with Hypo sludge and Egg Shell powder with varying percentages of 0%, 5%, 10%, 15% and 20% (in the ratio of 1:3) by weight of cement. This experimental study demonstrates the strength features such as compressive strength, split tensile strength and flexural strength of M30 concrete mix which are investigated at 7 and 28 days and the results were compared with the conventional concrete.

Keywords: *Concrete, Cement replacement, Hypo Sludge, Egg Shell Powder, Development of Strength*

1. Introduction

A nation's development not only depends upon the new emerging trends and technologies but also the infrastructure of that particular nation. The present situation in our country mainly focusses on the infrastructure development thus leading to a wealthy nation [17]. Hence construction industry is the key route for the success of infrastructure development. Without concrete, the infrastructure is not a possible thing. Concrete, this is an essential element that plays a vital role in the construction industry [17]. Concrete is the combination mixture of various materials like cement, Fine Aggregate, Coarse Aggregate and water [03]. The Fine Aggregate and the Coarse Aggregate are naturally occurring sources. Cement is also a material whose raw materials are naturally occurring. Therefore abundant use of these materials in the construction industries lead to the exploitation of natural resources [16]. Thus many researches have been under progress for utilizing waste materials and various minerals as replacement for cement and aggregates [02]. Since the production of cement not only costs high but also it is highly energy intensive. The production of one ton of Ordinary Portland cement nearly emits one ton of carbon dioxide into the atmosphere [03, 10, 11]. Hence the production process of cement involves 5% of carbon dioxide emissions of the world [04]. Hence currently the entire construction industry is in search of suitable and effective products that should considerably minimize the use of cement and also should be economical. Therefore the replacement of cement in concrete should be a needful one. Since cement is the principal binder in concrete, we may not completely replace it in the concrete. We can partially replace the cement with various mineral admixtures and some of the waste products. Several minerals, wastes and waste byproducts from domestic and industries are available for such replacements. Some of them are Fly ash, metakaolin, copper slag, quarry dust, GGBS, micro silica, egg shell powder, hypo sludge, coconut shell ash, waste glass powder, rice husk ash, saw dust, etc., can be used as partial replacement of cement. This study involves the utilization of Hypo sludge and Egg Shell Powder as a partial replacement of cement in concrete and its efficacy its efficacy is discussed in this paper.

II. Study Area

A. Materials Used

a) Hypo Sludge

Hypo sludge is nothing but the wastes or waste byproducts that are discharged out from paper mills

or paper industries [12]. Since the paper fibers can be recycled only for a limited number of times to produce high quality paper, the low quality paper pulp or fibers are thrown away as wastes [15]. These wastes are simply called as Hypo sludge. These wastes are washed up to separate inks, dyes, pigments, staples, etc., and the waste solids are dumped as wastes [1, 26]. Hence it consumes a large percentage in landfill affects both water and soil [11]. In worst cases they are burnt up and therefore it causes environmental pollution and causes serious air pollution problems. Nearly 300 kg of Hypo sludge is disposed for each ton of recycled paper [13, 15]. Hence the utilization of these wastes is an essential one in construction materials to develop as profitable building materials from them. The Hypo sludge was originally introduced as an artificial pozzolana [01, 13]. When pozzolanic materials are incorporated in concrete, the silica present in the materials reacts with the calcium hydroxide released during the hydration process, thus forms additional calcium silicate hydrate and improves its mechanical properties [13]. Since Hypo sludge possess low calcium, maximum calcium chloride and minimum silica, it behaves like cement and thus it improves the setting time of concrete [01].

b) Egg Shell Powder

Egg shell is one the most important agricultural and domestic waste which is disposed abundantly is accumulative concentration. The wastes that can be of any type of source when its concentration is excess on disposal or dumping or discharging leads to a critical situation to humans, animals, vegetation and to environment. The egg shell wastes which receives a kind attention now a days as its recyclable applications are majorly carried out in massive disposal of Egg shells. Whereas in domestic areas including houses, restaurants and agricultural areas such as poultry farms the egg shells are just disposed in landfills [7]. Since it is a purely organic material, when it decomposes it leads to various discomfort to the environment as well as to the public. The major problem associated with the disposal of these egg shell wastes is that these wastes attracts vermin due to its attached membrane on it and causes several health related issues and environmental hazards [09]. Hence these types of wastes must be utilized in a particular manner. Nearly 1.61 million tons of egg shells are disposed as wastes annually [23]. India ranks second in the world annual egg production and also a large contributor in the disposal of the egg shell wastes [04, 09]. Since egg shells are rich in calcium, it has the composition nearly same that of limestone which is the basic raw material for cement production [04, 24]. Thus usage of egg shell powder as a partial replacement in cement can incorporate some benefits like minimizing the usage of cement, considering natural lime and also utilization of waste materials [03, 10, 24]. Since the chemical composition of cement and the egg shell powder were found to be similar, it can be used as a suitable partial alternative for cement in concrete.

c) Cement

Cement is the constituent binder in the concrete which possess adhesive and cohesive properties [20]. It is a fine powdered substance that is greenish grey in color that can be mixed with Fine aggregate, Coarse aggregate and water to form a paste like substance and then on curing forms to a hard rock like structure. Usually Portland cement is manufactured that depends upon the application where it is used. This research uses the Ordinary Portland cement of 53 grade with brand name Ultratech that confirms to IS 8112:1989.

d) Aggregates

Fine aggregates and coarse aggregates are two major constituents in concrete. Fine aggregate generally consists of natural river sand or crushed stone whose particles passing through a 4.75 mm sieve. The Coarse aggregates are particles greater than 4.75 mm sieve but they generally lie between the ranges of 9.5 mm to 3.75 mm in diameter. Based on sizes, Coarse aggregates are available in sizes such as 40 mm, 20 mm, 16 mm, 12.5 mm, etc., This research utilizes River sand and 20 mm Coarse Aggregate for the experimental analysis which confirms to IS 383:1970.

III. Methodology

The methodology of this research is shown in the flowchart (Figure.1) below. The research initiates with the survey of various literatures and the discussions from it are collected and reviewed. After the reviewing of literature is done, the material collection is the key process of the research. The Hypo sludge is collected from 'Shri Pariyur Amman Kraft Papers Pvt. Ltd.' in Perundurai. The Hypo sludge is brought free of cost from that industry. Then the next additive Egg Shells was collected from various restaurants, cake shops and houses in Perundurai locality. Then they are washed and sun dried for 5-6 days till they loses their moisture content completely and then the Hypo sludge and Egg shells were powdered using Ball Mill apparatus. Then they are sieved through 90 micron sieve and the chemical composition of these materials is shown in the following Table1.

Table 1. Chemical Composition [06, 10, 20, 29]

Composition	Percentage		
	Cement	Hypo sludge	Egg Shell powder
Lime	63.1%	14.94%	55.85%
Silica	20.6%	60.57%	0.09%
Alumina	6.3%	2.06%	0.03%
Iron Oxide	3.6%	0.92%	0.04%
Magnesia	2.1%	3.59%	0.01%
Sulphur Trioxide	2.65%	1.07%	0.38%

The River sand is used as Fine Aggregate and the 20 mm Coarse Aggregates are used for the experimental work. After the materials are collected, then they are undergone into basic tests for determining the basic properties of these materials. The Cement, Hypo sludge and Egg Shell powder are undergone into Fineness test, Specific Gravity test, Standard Consistency test and Initial Setting Time test. The results of these tests are shown in the following Table 2.

Table 2. Basic Properties of Cement, Hypo sludge and Egg Shell powder

Composition	Percentage		
	Cement	Hypo sludge	Egg Shell powder
Fineness	3%	2.5%	3%
Specific Gravity	3.15	2.75	2.15
Standard Consistency	32%	44%	40%
Initial Setting Time	35 minutes	95 minutes	70 minutes

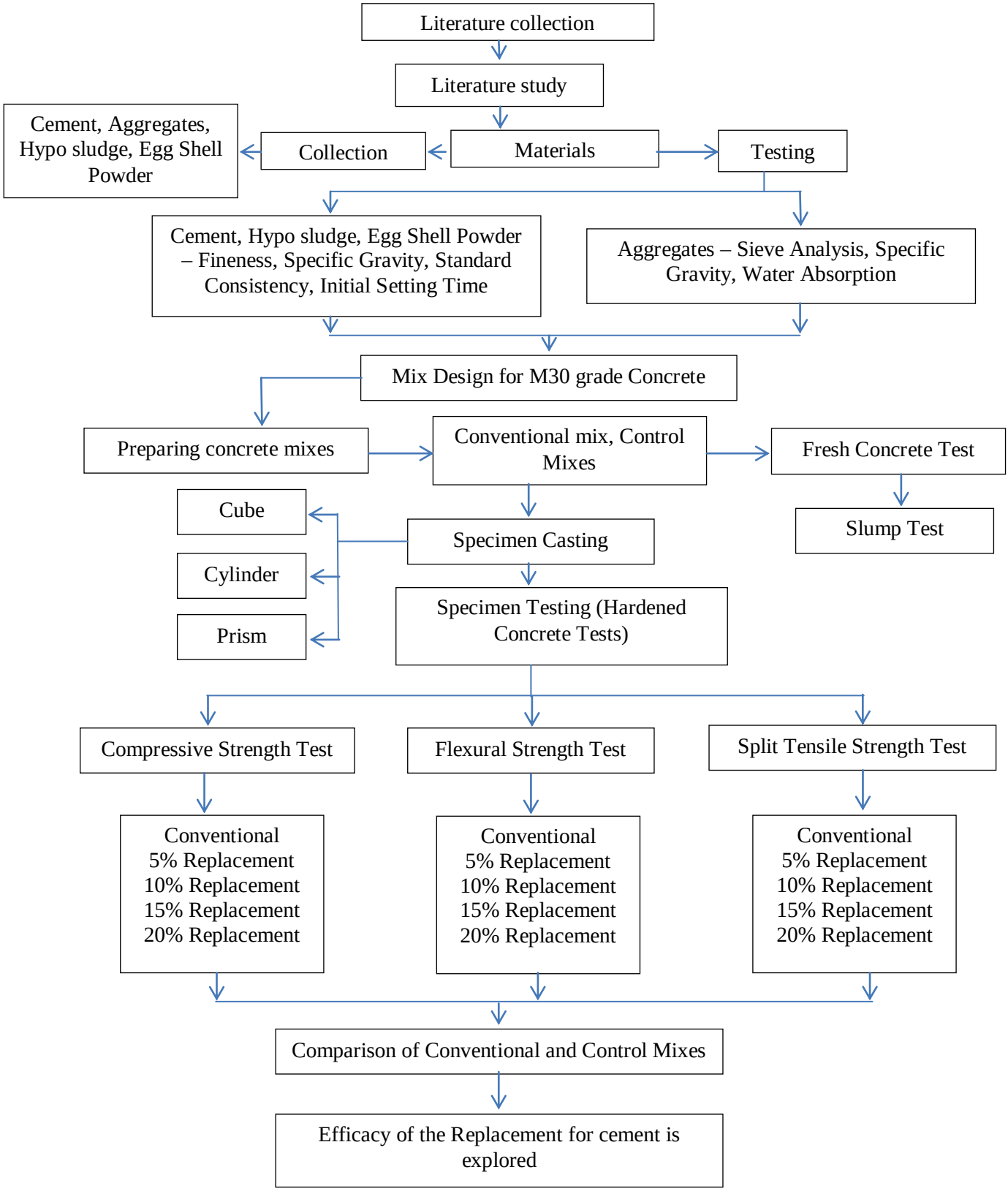

Figure 1. Methodology Chart of the Research

The Fine Aggregates and Coarse Aggregates are made into Sieve Analysis test, Specific Gravity test and Water Absorption test. The results of these tests are shown in the following Table 3.

Table 3. Basic Properties of Fine Aggregates and Coarse Aggregates

Properties	Result	
	Fine Aggregates	Coarse Aggregates
Specific Gravity	2.39	2.85
Sieve Analysis	Confirming to Zone II of IS 383:1970	Confirming to Table 2 of IS 383:1970
Water Absorption	6.19%	2.02%

From the results of the basic properties of the materials, the mix design of concrete which is of grade M30 is made with the water cement ratio of 0.45. From the results of the mix design, the quantities of materials required per m3, per cube, per cylinder and per prism are calculated. The above mix design is made for conventional concrete initially. Then a trial mix is made by using 0% HS&ESP, 5% HS, 5% ESP and 2.5%HS+2.5%ESP in four different cube moulds and they are tested initially. From the trial mix results, it clearly states that the addition of Hypo sludge gives more strength when compared to Egg Shell powder but addition of these both additives gives strength more than the conventional concrete. Therefore Hypo sludge and Egg Shell powder are taken in the ratio 3:1 as a replacement of cement in concrete. After the quantities of materials are calculated, then the specimens are casted by replacing the cement in the percentages of 0%, 5%, 10%, 15% and 20% by weight with Hypo sludge and Egg Shell powder. The specimens are casted in cube moulds, cylinder moulds and prism moulds for determining compressive strength, split tensile strength and flexural strength respectively. The casted specimens are demoulded after 24 hours and they are placed in the curing tank. The curing process is carried out for 7 days and 28 days. Then the specimens are tested at 7 days and 28 days and the results are interpreted.

IV. Results and Discussions

A. Fresh Concrete Test

There are various tests that are available to determine the workability of fresh concrete. This research focusses on the Slump test in order to determine the workability of the fresh concrete for the different mixes. The slump test is carried out by filling the concrete in the slump cone by 4 layers with 25 strokes for each layer using the tamping rod of rounded end. Then the cone is removed vertically and slowly and the slump value is measured from its top and also its nature of slump is interpreted. The following Table 4 shows the slump test results of different mixes of this experimental work.

Table 4. Slump Test Results

% Replacement	Slump value (mm)	Nature of Slump
0% (Conventional)	40	TRUE
5%	30	TRUE
10%	30	TRUE
15%	30	TRUE
20%	20	TRUE

B. Hardened Concrete Tests

a) Compressive Strength Test

The Compressive Strength Test is carried out by casting the cube specimens of size 150 mm X 150 mm X 150 mm and then tested in the compression testing machine. This gives the characteristic compressive strength of concrete. The following Table 5 shows the Compressive Strength Test results of the concrete cubes of various mixes at 7 days and 28 days.

Table 5. Compressive Strength Test Results

% Replacement	Compressive Strength (N/mm^2)	
	7 days	28 days
0% (Conventional)	22.37	32.04
5%	26.15	33.33
10%	27.03	36.73
15%	22.96	28.81
20%	20.33	23.41

The following chart (Figure.2) pictures the Compressive Strength Test results @ 7 days and 28 days.

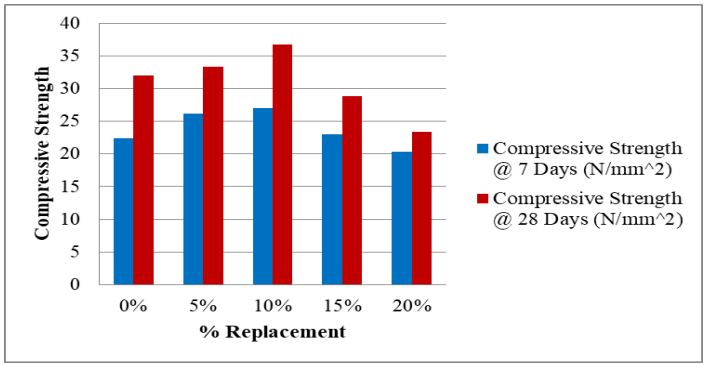

Figure 2. Compressive Strength Test Results

b) Split Tensile Strength Test

The Split Tensile Strength of concrete is one of the most basic and important property of concrete which incorporates the extent and size of cracking in concrete. Since concrete is weak in tension and also brittle in nature, it can't resist the direct tension. Therefore cracks are developed when the tensile force exceeds its tensile strength. The specimens are of cylindrical type of diameter 150 mm and height of 300 mm is casted and tested in the compression testing machine. The following Table 6 shows the Split Tensile Strength test results of the cylindrical specimens tested at 7 days and 28 days.

Table 6. Split Tensile Strength Test Results

% Replacement	Split Tensile Strength (N/mm^2)	
	7 days	28 days
0% (Conventional)	1.95	2.84
5%	2.35	2.97
10%	2.88	3.04
15%	2.16	2.84
20%	1.86	2.75

The following chart (Figure.3) pictures the Split Tensile Strength Test results @ 7 days and 28 days.

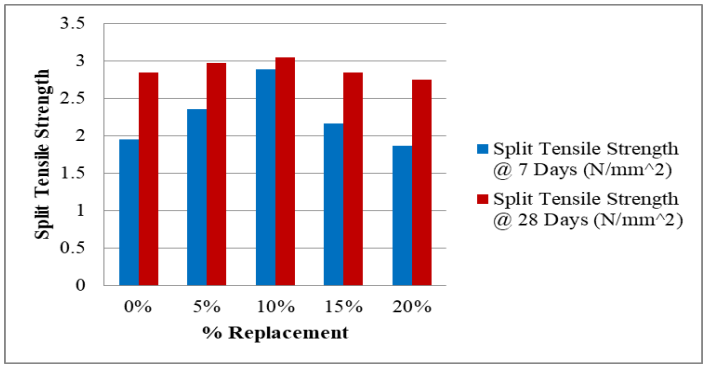

Figure 3. Split Tensile Strength Test Results

c) Flexural Strength Test

Flexural Strength is also known as the bending strength of concrete or the Modulus of Rupture of concrete. This test is carried out in order to measure the resistance to failure in bending. This test is carried out by casting the specimens that of rectangular prism type of beam of size 100 mm X 100 mm in cross section and 500 mm in length and it is tested in Flexural testing machine using two point loading. The following Table 7 illustrates the Flexural Strength Test results of the specimens tested at 7 days and 28 days.

Table 7. Flexural Strength Test Results

% Replacement	Flexural Strength (N/mm^2)	
	7 days	28 days
0% (Conventional)	4.58	6.83
5%	5.79	7.00
10%	7.13	7.25
15%	5.85	6.25
20%	5.03	5.75

The following chart (Figure.4) pictures the Flexural Strength Test results @ 7 days and 28 days.

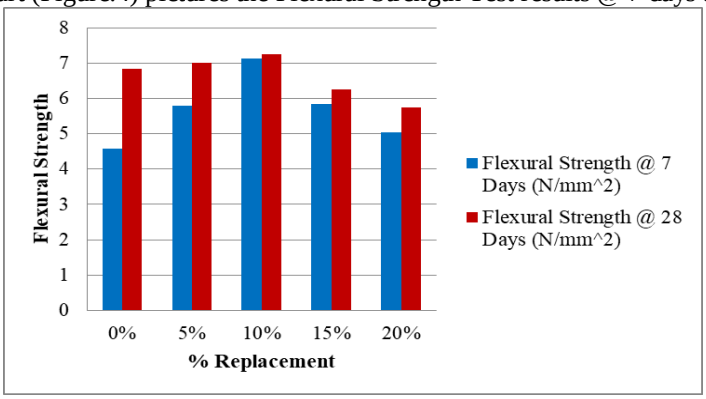

Figure 4. Flexural Strength Test Results

V. Conclusions

The possibility of utilization of Hypo Sludge and Egg Shell wastes as partial replacement of cement in concrete without using any admixtures was explored. Based on the results obtained from the experimental work the following conclusions can be drawn. There was an increase in Compressive Strength of about 14.63% at 28 days for 10% replacement of cement in concrete compared to reference mix of M30 grade. Split Tensile Strength increases about 7.04% at 28 days for 10% replacement of cement in concrete compared to reference mix of M30 grade. From the results Flexural Strength also increases upto 6.15% at 28 days for 10% replacement of cement in concrete compared to reference mix of M30 grade. In this investigation 10% replacement of Hypo sludge and Egg Shell Powder obtained optimum results. From the above results, it can be concluded that Hypo sludge and Egg Shell Powder has potential utilization as partial replacement of cement in concrete. Use of Hypo sludge and Egg Shell Powder in concrete will eradicate the disposal problem of these wastes, reduce emission of harmful pollutants by cement manufacture industry into our environment and thus prove to be environment friendly, paving way for greener concrete. Thus partially replacing the above wastes in concrete enhanced the reduction of cement usage in concrete, thereby reduces the production cost of cement. Hence it is found to be economical.

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