A PARTIAL REPLACEMENT OF EGG SHELL POWDER FOR CEMENT IN CONCRETE

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Abstract: Construction industry depends heavily on conventional materials such as cement, granite and sand for the production of concrete. Cement is the most economical constituents used in the production of concrete and also poses the problem of acute shortage in many areas, which poses serious problems on its availability, cost and environmental impact. Approximately 1.1 tonnes of earth resources such as limestone, clay etc., are needed for the production of one tone of Ordinary Portland Cement also the process results in the emission of an equal amount of carbon-di-oxide into the atmosphere which may be serious threat to the environment in various forms. so there is always a need for substituent to OPC . For preventing environment and to produce a low cost concrete an attempt is being made in this project that the cement is partially replaced by locally available material such as egg shell powder. Generally egg shells were disposed as waste which comprises of 95% of $CaCO_3$ and 5% of Magnesium, Sodium, Potassium, Ironic acid and Silica acid which may be used as an alternate for the cement. Statistics shows that the huge amounts of egg shells were laid as waste and disposed as landfills in India. So it can be replaced for cement due to its chemical properties and its abundant in nature. In this work, experiments were carried out by using egg shells as a partial replacement for cement. The concrete design mix considered is M40 of ratio 1:1.5:2.3. The specimens were prepared by replacing cement by 5%, 10%, 15%, 20% and 25%. The mechanical properties of Egg shell powdered Concrete like compressive, split tensile and flexural strength were determined for 7, 14 and 28 days of curing period and results were compared with the conventional concrete.

***Index Terms* - High strength concrete, Egg Shell, Cement, Lime, Silica, Low cost concrete.**

I. INTRODUCTION

Utilization of waste products in concrete has advantage on both construction and environmental factors. Cement is the most important constituents used in concrete production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources by using alternative materials that are either recycled or discarded as a waste..

This study was aimed to use ESP in concrete. Although Egg shell is calcium rich and analogous to limestone in chemical composition, it is a waste material. Therefore, to initiate use of Egg shell waste for partial replacement of cement in concrete, there is a need to understand concrete properties made with Egg shell powder. Thus, the objective of this study was to understand the possibilities of use of ESP in concrete. Investigations were systematically conducted on performance of ESP concretes in terms of properties like compressive strength and splitting tensile strength and transport properties like water absorption. ESP was replaced concrete specimens were tested for 1, 7 and 28 days. Based on the test results, the influence of ESP replacement and the curing age on the concrete properties were discussed. The manufacturing process of one tonne of Ordinary Portland Cement requires about 1.1 tonne of earth resources like limestone, etc. Further during manufacturing of 1 tonne of Ordinary Portland Cement an equal amount of carbon-di-oxide are released into the atmosphere.

Among the many threats that affect the environment are the wastes which are generated in the production process or discarded after a specific material ends its life time or the intended use. The wastages are divided as solid waste, liquid waste and gaseous wastes. There are many disposal ways for liquid and gaseous waste materials. Some solid waste materials such as plastic bottles, papers, steel, etc can be recycled without affecting the environment.

However, studies on how to dispose some solid wastes such as egg shells in the most beneficial ways are not yet fully exhausted.

1.1 Egg Shells

Egg shells are agricultural throw away objects produced from chick hatcheries, bakeries, fast food restaurants among others which can damage the surroundings and as a result comprising ecological issues/contamination which would need appropriate treatment. Egg shell consists of several mutually growing layers of $CaCO_3$.

The top layer is a vertical layer covered by the organic cuticle. The Egg shell primarily contains calcium, magnesium carbonate (lime) and protein. The quality of lime in Egg shell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. It is the fine grained powder with suitable proportion which is sieved to the required size before use with concrete/mortar. The ESP had to be fine grained and it has to be sieved for the suitable size before adding into concrete.

Fig 1 Egg Shell

1.2 Need for the study

- Identifying the types, quantity and useful components present in the Waste Egg shells (ESP) materials.
- Replacing cement with ESP to various percentages in concrete, and identifying the strength comparing with conventional concrete.
- Working out relative cost of using the ESP concrete mixes in Construction works.

II. MATERIALS USED

A step by step process of conducting trail run of the experiments to be conducted as discussed in the previous chapters has been discussed in detailed in the following.

3.1 Methodology

The methodology adopted for the study is shown in the below figure. This consists of characterizing the materials used, various mix proportions with respect to the mix design results, casting of cubes, cylinders, beams specimens and testing the same.

3.2 Materials Used

The materials used for the study is briefly explained below. The sources of the materials, the tests carried out for their properties and the usage method is also mentioned.

3.2.1 Egg Shell Powder

Broken egg shells collected from the local sources. The shells cleaned in normal water and air dried for five days approximately at a temperature range of 25 – 30 °C. The shells then hand crushed, grinded and sieved through 90 µm. Material passed through 90 µm sieve was used for cement replacement and the retained material was discarded.

Fig 2 Egg shell Powder used in Concrete

Table 1 Physical Properties of Egg shell Powder

Physical Properties	Egg shell Powder
Specific gravity	1.89
Fineness modulus (%)	41

Bulk density kg/m^3	1081
Surface area m^2	290

Table 2 Chemical Composition of Egg shell Powder

Oxide contents	Percentage (%)
CaO	96.35
SiO_2	0.01
P_2O_5	0.27
K_2O	0.02
MgO	0.1
SO_3	0.16

3.2.2 CEMENT

Cement is a well-known building material has occupied an indispensable place in construction works. It is obtained by burning together, in a definite proportion, a mixture of naturally occurring argillaceous and calcareous materials to a partial fusion at high temperature. Generally Cement is a binding material used in the preparation of concrete. It binds the coarse aggregates and fine aggregates with help of water to a monolithic matter and also it fills the voids in the concrete. The cement used in this study is OPC 53 grade confining to IS 8112 is used throughout the work.

III. **TESTS AND MIX DESIGN**

The following tests are conducted to find the physical properties of materials.

4.1 Tests on fine aggregate

In this project, the river sand, which was available in saturated surface dry Condition was used as fine aggregate and the following tests were carried out on sand as per IS: 2386 - 1968

- Sieve analysis
- Density
- Specific Gravity
- Water absorption

4.2 Tests on coarse aggregate

- Impact value
- Sieve analysis
- Density
- Specific gravity
- Water absorption.

4.2.1 Sieve analysis test

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I)-1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

4.2.2 Sieve analysis test on Fine Aggregate

The experiment is carried out to find and check the gradation of the fine aggregate i.e., sand. The sand is differentiated on the basis of its gradation, such type sand will possess the capability to form a compact structure thus will have more strength.

Table 3 Sieve Analysis Test on Fine Aggregate

Is sieve size	Weight Retained(gm)	% of Weight Retained	Cumulative % Retained	% of Passing
4.75mm	94	4.7	4.7	95.3

2.36mm	158	7.6	12.6	87.4
1.18mm	708	35.4	48	52
600	812	40.6	88.6	11.4
300	180	9	97.6	2.4
150	4	0.2	99.6	0.4
75	2	0.1	99.7	0.3
pan	6	0.3	100	0

4.2.3 Sieve Analysis Test on Coarse Aggregate

The sieve analysis of coarse aggregate is to find the average size of the particles in coarse aggregate by an index number. The cumulative percentage retained on each sieve is added and subtracted by 100 gives the value of fine aggregate.

Table 4 Sieve analysis Test on coarse aggregate

Is sieve size	Weight Retained(gm)	% of Weight Retained	Cumulative % Retained	% of Passing
20mm	290	5.8	5.8	94.2
16mm	2768	55.36	61.16	38.84
12.5mm	1454	29.08	90.24	9.76
10	430	8.6	98.84	1.16
6.3	58	1.16	100	0
4.75	0	0	0	0
pan	0	0	0	0

4.3 DENSITY TEST

4.3.1 Density Test on Fine Aggregate

This method is used to determine the bulk density of the fine aggregate. If we know the bulk density of fine aggregate then we can easily calculate the mass required to fill a unit volume container. The bulk density indicates the percentage of voids present in the aggregate material. The percentage of voids effects the grading of the aggregate which is important in higher strength concrete. We will get the percentage of voids by comparing loose state and compacted state.

Volume of Cylinder = 9.81×10^{-3}

Table 5 Density test on fine aggregate

Weight of Compacted Aggregate		Weight of Loose Aggregate	
Trial I	17.36 kg	Trial I	16.12 kg
Trial II	17.46 kg	Trial II	16.60 kg
Average	17.41 kg	Average	16.36 kg

4.3.2 Density Test on Coarse Aggregate

This method is used to determine the bulk density of the coarse aggregate. If we know the bulk density of coarse aggregate then we can easily calculate the mass required to fill a unit volume container. The bulk density indicates the percentage of voids present in the aggregate material. The percentage of voids effects the grading of the aggregate which is important in higher strength concrete. We will get the percentage of voids by comparing loose state and compacted state. For coarse aggregate a higher bulk density means that there are few voids which are to be filled by the aggregate and cement thus the bulk density also depends upon the degree of packed.

Table 6 Density test on Coarse aggregate

Weight of Compacted Aggregate		Weight of Loose Aggregate	
Trial I	16.64 kg	Trial I	15.78 kg
Trial II	16.45 kg	Trial II	15.67 kg
Average	16.55 kg	Average	15.73 kg

4.4 Specific Gravity Test

Following were the test results of specific gravity of materials,

Table 7 Test results for specific gravity of materials

S.No	Material	Specific Gravity
1	Fine Aggregate	2.65
2	Coarse Aggregate	2.80
3	Cement	3.14

4.5 Mix Design

The mix calculation arrived per unit volume of concrete shall be as follows,

Table 8 Design Mix Value

S.No	Material	Quantity (kg/m³)
1	Cement	465
2	Water	186
3	Fine Aggregate	742.37
4	Coarse Aggregate	1083.21
5	Water Cement Ratio	0.40

So the design mix ratio is 1:1.5:2.3

IV. **EXPERIMENTAL INVESTIGATION**

The Egg shell powder concrete specimens of various mixes has to be tested for Compressive, Split and Flexural strength at 7, 14 and 28 days of age in the laboratory.

4.1 Compressive Strength Test

Compressive test are made at recognized ages of the test specimens. Least three specimens, preferably from different batches shall be made for testing at each selected age. The cubes are placed in the compression testing machine in such manner that the load is applied to the opposite sides of the cube as cast. The load is applied at the rate of 140 kg/cm^2/min (approximately) until the failure of the specimen. Compression test was carried out on the specimens after 7, 14 and 28 days of curing of concrete.

Fig 3 Compressive Strength Test

4.2 Split Tensile Test

The tensile strength of concrete is determined by splitting the cylinder across the vertical diameter. Split tensile strength is an indirect method of finding out the tensile strength of concrete. As per ASTM, the test was carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine. The load was applied until the specimen fails.

Fig 4 Split Tensile Strength Test

4.3 Flexural Strength Test

Flexural strength test was conducted in accordance with IS: 516-1959. Beam of 100 x 100 x 500 mm size were used for this test. The flexural strength test was conducted on the same machine on which the compressive strength test was performed.

Fig 5 Flexural Strength Test

V. RESULTS AND DISCUSSIONS

The result of the investigations carried out for finding out compressive strength, and workability using Egg shell powder partially replaced for cement.

5.1 Compressive Strength

From each concrete mixture, cubes of size 150mmx150mmx150mm have been casted for the determination of compressive strength and. The concrete specimens were cured under normal conditions as per IS 516-1959 and tested at 7, 14 and 28 days for determining Compressive strength as per IS 516-1959 .

Experimental results for cube compressive strength for M_{40} grade of concrete for mix proportions 0%, 5%, 10%, 15%, 20% and 25% for 7,14and 28 days are tabulated in the below table.

Table 9 Compressive Strength of (M40) for various mix proportions at 7, 14 and 28 days

Mix	Specimen no	Compressive Strength at 7 days(N/mm^2)			Compressive Strength at 14 days(N/mm^2)			Compressive Strength at 28 days(N/mm^2)		
		Load KN	Stress N/mm^2	Avg	Load KN	Stress N/mm^2	Avg	Load KN	Stress N/mm^2	Avg
	1	663	29.5	29.5	767	34.1	34.2	900	40.0	41.0
0%	2	648	28.8		756	33.6		922	41.0	

	3	682	30.3		783	34.8		945	42.0	
	1	660	29.6		816	36.3		925	41.1	
5%	2	686	30.5	30.2	767	34.1	35.1	938	41.7	41.5
	3	688	30.6		790	35.1		945	42	
	1	695	30.9		790	35.1		943	41.9	
10%	2	718	31.9	31.0	785	34.9	35.6	950	42.2	41.8
	3	682	30.3		828	36.8		931	41.4	
	1	706	31.4		834	36.0		950	42.2	
15%	2	725	32.2	31.2	828	36.8	36.3	960	42.7	42.5
	3	675	30.0		816	36.3		958	42.6	
	1	697	31.0		819	36.4		943	41.9	
20%	2	690	30.7	30.8	810	36.2	36.0	940	41.8	41.1
	3	690	30.7		820	36.4		958	42.6	
	1	679	30.2		804	35.8		895	39.8	
25%	2	684	30.4	30.2	810	36.2	35.6	900	40.0	40.2
	3	675	30.0		790	35.6		909	40.4	

In the above table shown that the compressive strength of concrete (M_{40}) values. This is compared with normal concrete and various mix proportions with its fresh weight and hardened concrete.

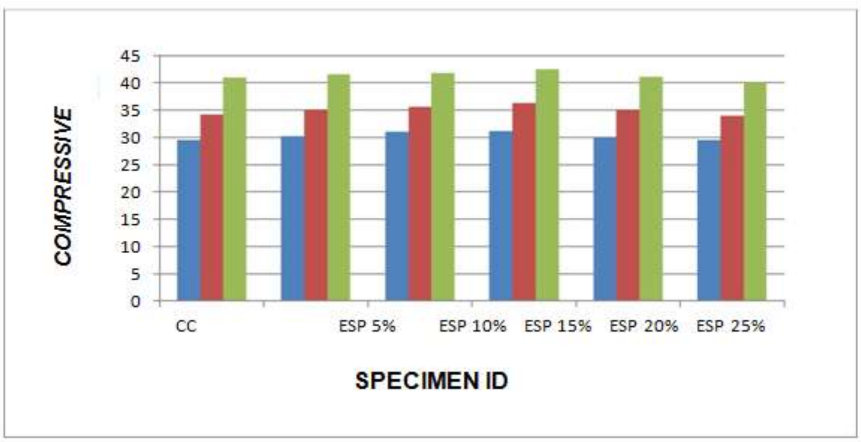

Fig 6 Compressive Strength for 7, 14 & 28 days

5.2 Split Tensile Strength

From each concrete mixture, cylinders of size 150mmx300mm have been casted for the determination of splitting tensile strength. The concrete specimens were cured under normal conditions as per IS 516-1959 and tested at 7, 14 and 28 days.

Experimental results for cylinders split tensile strength for M_{40}. For mix 0%, 5%, 10%, 15%, 20% and 25% for 7, 14 and 28 days are tabulated in below table. The graphical representation of split tensile strength for various mixes are shown in the below figure. As per IS456-2000, split tensile strength of concrete= $0.7F_{ck}$.The splitting tensile strength is calculated using the formula,

$$Tsp = 2P/ \pi DL$$

Where P = applied load D = diameter of the specimen L = length of the specimen

Mix	Specimen No	Split tensile strength at 7 days (N/mm²)		Split tensile strength at 14 days (N/mm²)		Split tensile strength at 28 days (N/mm²)	
		Stress N/mm²	Avg	Stress N/mm²	Avg	Stress N/mm²	Avg

0%	1	2.95	2.95	3.41	3.42	4	4.10
	2	2.88		3.36		4.1	
	3	3.03		3.48		4.2	
5%	1	2.96	3.02	3.63	3.52	4.11	4.16
	2	3.05		3.41		4.17	
	3	3.06		3.51		4.2	
10%	1	3.09	3.10	3.51	3.56	4.19	4.18
	2	3.19		3.49		4.22	
	3	3.03		3.68		4.14	
15%	1	3.14	3.12	3.6	3.64	4.22	4.25
	2	3.22		3.68		4.27	
	3	3		3.63		4.26	
20%	1	3.1	3.08	3.64	3.63	4.19	4.21
	2	3.07		3.62		4.18	
	3	3.07		3.64		4.26	
25%	1	3.02	3.02	3.58	3.59	3.98	4.01
	2	3.04		3.62		4	
	3	3		3.56		4.04	

Table 10 Split Tensile Strength of (M40) for various mix proportions at 7, 14 and 28 days

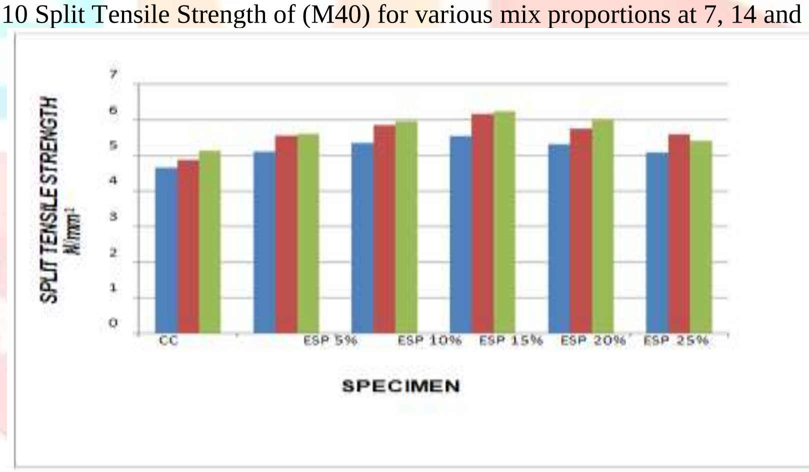

Fig 7 Split Tensile strength for 7, 14 & 28 days

5.3 Flexural Strength

From each concrete mixture, beams of size 100mmx100mmx500mm have been casted for the determination of flexural strength. The concrete specimens were cured under normal conditions as per IS 516-1959 and tested at 7, 14 and 28 days. Experimental results for beams flexural strength for $_{40}$. For mix 0%, 5%, 10%, 15%, 20% and 25% for 7, 14 and 28 days are tabulated in below table. The graphical representation of flexural strength for various mixes are shown in the below figure.

Table 11 Flexural strength of (M40) for various proportions at 7, 14 and 28 days

Mix	Specimen No.	Flexural strength at 7th day (N/mm²)			Flexural strength at 14th day (N/mm²)			Flexural strength at 28th day (N/mm²)		
		Load (KN)	Stress N/mm²	Avg	Load (KN)	Stress N/mm²	Avg	Load (KN)	Stress N/mm²	Avg
0%	1	6.29	3.10	3.37	6.73	3.32	3.43	7.38	3.64	3.76

	2	6.33	3.12		6.88	3.39		7.63	3.76	
	3	6.49	3.20		7.85	3.87		7.85	3.87	
5%	1	6.59	3.25	3.27	6.09	3.40	3.45	7.63	3.76	3.81
	2	6.78	3.34		7.16	3.53		7.73	3.81	
	3	6.55	3.23		6.94	3.42		7.87	3.88	
10%	1	6.94	3.42	3.43	7.30	3.60	3.60	7.87	3.88	3.91
	2	6.86	3.38		7.16	3.53		7.93	3.91	
	3	7.10	3.50		7.45	3.67		7.99	3.94	
15%	1	6.94	3.42	3.47	7.51	3.70	3.70	8.07	3.98	4.04
	2	7.08	3.49		7.49	3.69		8.16	4.02	
	3	6.19	3.50		7.49	3.69		8.36	4.12	
20%	1	6.43	3.17	`3.20	6.86	3.38	3.42	7.28	3.59	3.60
	2	6.59	3.25		7.08	3.49		7.18	3.54	
	3	6.45	3.18		3.90	3.40		7.45	3.67	
25%	1	6.11	3.01	3.02	6.39	3.15	3.18	6.88	3.39	3.42
	2	6.31	3.11		6.53	3.22		7.10	3.50	
	3	6.09	3.00		6.43	3.17		6.84	3.37	

5.5 Results and Comparison

In the above compressive strength, split tensile strength and flexural strength results have been discussed below detailed.

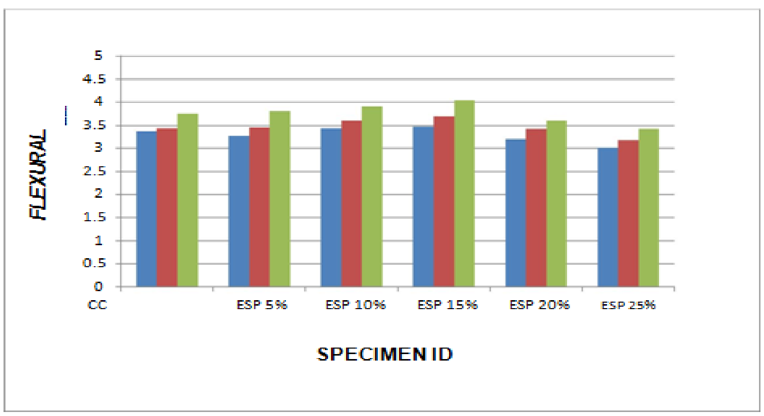

Fig 8 Flexural strength for 7, 14 & 28 days

5.5.1 Results on compression strength

The Compressive strength of concrete mixes made with Egg shell powder was determined at 7, 14 and 28 days of curing. The test results are given in table 9 and shown in fig.6 shows the variation of compressive strength (M_{40}) with age for various egg shell powder percentages and fig.5.1 shows the variation of compressive strength with egg shell powder percentages at different ages. The compressive strength of the egg shell powder concrete is compared to the conventional concrete. From fig.5.1it can be seen that there is increase in strength with the increase in egg shell powder percentages up to 15% however, the rate of increase of strength decreases with the increase in egg shell powder content. The maximum strength at all ages occurs with 15% Egg shell replacement.

5.5.2 Results on Split Tensile strength

The Split Tensile strength of concrete mixes made with Egg shell powder was determined at 7, 14 and 28 days of curing. The test results are given in table 10 and shown in fig 7 shows the variation of split tensile strength (M_{40}) with age for various egg shell powder percentages at different ages. The split tensile strength of the egg shell powder concrete is compared to the conventional concrete. From fig.5.2 it can be seen that there is increase in strength with the increase in egg shell powder percentages up to 15% however, the rate of increase of strength decreases with the increase in egg shell powder content. The maximum strength at all ages occurs with 15% Egg shell replacement. The rate of increase in strength is more prominent after 28^{th} day.

5.5.3 Results on Flexural strength

The Flexural strength of concrete mixes made with Egg shell powder was measured at the ages of 7, 14 and 28 days of curing. The test results are given in table 11 and shown in fig 8 shows the variation of flexural strength (M_{40}) with age for various egg shell powder percentages at different ages. The flexural strength of the egg shell powder concrete is compared to the conventional concrete. From fig.5.3 it can be seen that there is increase in strength with the increase in egg shell powder percentages up to 15% however, the rate of increase of strength decreases with the increase in egg shell powder content. The maximum strength at all ages occurs with 15% Egg shell replacement. The rate of increase in strength is more prominent after 28^{th} day.

VI. CONCLUSIONS

6.1 General

This study presents the effective way of utilizing egg shell powder in concrete. Presently, egg shell is available in most of the tropical countries at free of cost or at very lower price. Also from the results it is proved that the concrete obtained using egg shell powder satisfy the minimum requirements of M_{40} grade of concrete. Hence it is possible to make effectively M_{40} grade of concrete.

6.2 Conclusions

The following conclusions can be drawn from the present investigations,

- Compressive Strength, Split Tensile Strength and Flexural Strength of cement partially replaced with ESP concrete continued to increase at certain level at 7, 14 and 28 days.
- Compressive Strength was higher than normal concrete for 15% ESP replacement at 7, 14 and 28 days of curing ages.
- Split Tensile Strength of ESP concrete was comparable with normal concrete up to 25% ESP replacement. The split tensile strength of the egg shell powder concrete decreases after 15% with the addition of egg shell powder. This can be increased if the concrete is used with reinforcement.
- The flexural strength of the egg shell concrete increases with the addition of egg shell powder up to 15 percent.
- From the experimental work result it is clear that egg shell powder alone can be a good partial substituent for cement which increases the strength parameters meanwhile reduces the cement usage.

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