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Partial Replacement of Cement and Coarse Aggregate by Egg Shell Powder and Coconut Shells

Ayyappa R A, Sandeep Reddy B, G. Swamy Yadav, Dara SwethaSudarshan

Abstract: ***The issues of sustainability are of prime concern these days as we use a large number of natural resources for producing materials such as construction materials. The recent trend in the construction industry is to use the alternative source of construction materials which can substitute the use of natural materials to reduce environmental impact in terms of energy consumption, pollution, waste disposal, and global warming. Aiming at characterizing the behavior of concrete structures made with eggshell powder and coconut shells are replaced in the proportions of the concrete mixture.***

In the present work, the experimental program was designed to study the properties like strength and workability of concrete by casting the cube of size 150 mm x 150mm x 150 mm and cylinder of size 30 cm height and 15 cm diameter by using M20 grade. This experimental study consists of testing compressive strength of three cubes and split tensile strength of three cylinders of conventional concrete and the comparative cubes and cylinders are made by using different proportions of coconut shells (i.e., 2%, 4%, and 6%) replacement in coarse aggregate and replacement of eggshell powder (i.e., 5%, 10%, and 15%) in place of cement at optimum strength obtained by proportions of coconut shells replaced in coarse aggregate.

Keywords: Coconut Shells, Egg Shell Powder, Compressive Strength, Split Tensile Strength, Workability.

I. INTRODUCTION

Concrete has high compressive strength and low tensile strength capacity and which is formed by mixing of cement, CA and fine aggregate. In the present situation of the construction industry, materials are hugely not available and which can't remain for future generations and when production of materials like cement, industries emitting gases like greenhouse gases, it causes global warming and climate change[12][13]. For reducing these problems, replacing the concrete materials with the waste products generated from households, industries, etc. and is also decreasing the cost of the material. This is also one of the methods for efficient usage of waste material from regular usage. CS (CS) and Eggshells are the waste materials that are producing from households, markets, etc.

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***** Correspondence Author
Ayyappa R A*, Assistant Professor, S R Enginering College, Warangal, Telangana, India.
Sandeep Reddy B, PG Scholar, JNTU Kakinada, Kakinada.
G. Swamy Yadav, Assistant Professor, S R Enginering College, Warangal, Telangana, India.
Dara SwethaSudarshan, Assistant Professor, S R Enginering College, Warangal, Telangana, India.

CS are a good material, which is flaky in shape and it has a good compressive strength value and it is replaced as CA[4][5][14] while preparing the concrete at a percentage of 0, 2, 4 and 6. This will save a lot of weight of CA material in construction.

Eggshells are also one of the waste materials which is recently used in construction purposes and it consists of calcium material which has a cementitious material and it is used as cement[1][2][6]. In this work, replacing the cement by ESP with 0%, 5%, 10% and 15% at optimum condition obtained while the CS are replaced as aggregates. Here the optimum condition is considered for the strength parameters of the concrete specimens after curing of 28 days.

II. MATERIALS

A. Cement:

Cement is one of the most important materials required for construction purposes. One of the ordinary cement used in the world which is Portland cement and it is often used in concrete and mortar respectively. Ordinary Portland Cement (OPC) is specified according to Indian Standard IS 269. The mixed proportions of aggregates, sand, water, cement form the concrete which is used in construction development of buildings, bridges, roads, and other structures. The hydration process OPC 43 results in hardening and increase strength gain when mixed with water. In this work, used the OPC cement 43 grade and replaced by ESP 5%, 10%, 15%.

B. Eggshell Powder (ESP)

ESP is generated from the eggshells which are the waste products and naturally available from poultries. ESP is a smooth surface and it is grainded by the machines. From the good quality of eggshells 2.2 grams of calcium carbonate is generated and which is used as cement[3][9][16]. In the every drt eggshell, 95 percentage of calcium content is available[7][10][15].Eggshells are waste products from bakeries, fast food restaurants, and chick hatcheries. These eggshells are stored and powdered in the flour mill and sieved in 75-micron sieve size. This ESP is replaced as cement in this work. The specific gravity of the ESP is approximately 2.5 to 2.7.

C. Coarse Aggregate(CA)

CA is one of the most important materials in the construction industry and it influences the strength and workability of concrete. Without aggregate, large castings of neat cement,the paste would essentially self-destruct upon drying. CAs are particles greater than 4.75 mm. They can be from primary, either secondary or recycled. The specific gravity of the CA approximately 2.5 to 2.7.

D.Fine Aggregate

The finer aggregate has a better positive effect on the properties of fresh concrete and hardened in high-performance concrete. Thus, the fine aggregate is playing an important role in the concrete mixture. The fine aggregate, CA, and cement will give the cohesive mix of concrete by adding water. Generally, we preferred rived sand for construction purposes.

E. Coconut Shell (CS)

CSare the waste products from temples, hotels, and markets. These are hard and not effectively degrade material is crushed to the size of aggregate can be a potential material to substitute CA and sand. The chemical composition of the CS is similar to wood. It contains 33.61% cellulose, 36.51% lignin, 29.27% and ash at 0.61%[8]. These shells are crushed and sieved in 4.75mm and 12mm sieve. This sieved material is taken as replaced as CA

III. METHODOLOGY

The below methodology describes the comparison of the strength parameter of conventional concrete with partial replacement of coconut shells as coarse aggregate and partial replacement of eggshell powder as cement at optimum coconut shell percentage.

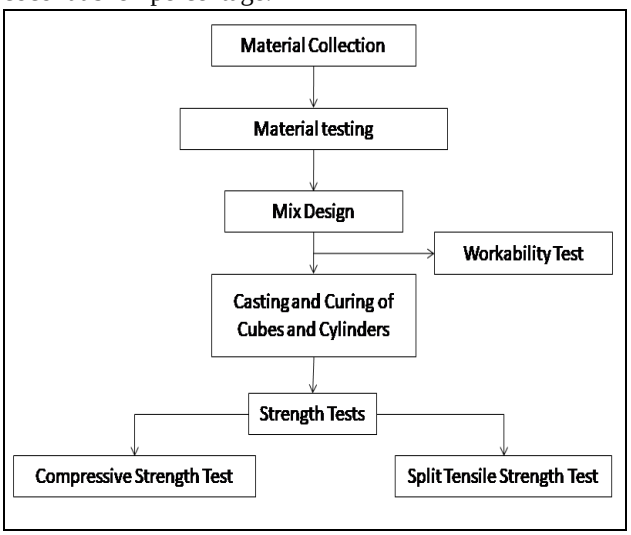

Fig.1. Methodology

A.Material Collection:

Collecting the materials such as cement, coarse aggregate, fine aggregate, coconut shells and eggshell powder and performs tests on materials to maintain the standards indicated by ASTM.

B. Material Testing

Before casting, the specimens need to know the characteristics of the concrete material such as cement, coarse aggregate, fine aggregate, coconut shells and eggshell powder. In this work, specific gravity, absorption test and sieving analysis performed on materials.

C.Mix Design:

Mix design is the process of determining the weight of suitable ingredients such as cement and aggregate to producing the minimum strength and durability for satisfying the requisite conditions. In this work, the proportion of ingredients is calculated and designed based on IS 10262. According to the code for M20 concrete, cement, fine aggregate, coarse aggregate, and water are mixed in the proportion of 1:1.5:3:0.5 for the conventional plain mix and while replacing the coconut shells as aggregate, replacing the percentage of coarse aggregate by the equal weight of coconut shells.

Table - I: Mix proportion values for preparation of 3 cubes when coconut shell replaced as coarse aggregate

S. No	% of coconut shell replaced in coarse aggregate	Weight of the material used in Kg(for 3 cubes)				
		Cement	*Fine aggregate*	*CA*	*Water*	*CS*
1	0	4.86.	7.29	14.58	2.43	0
2	2	4.86.	7.29	14.3	2.43	0.29
3	4	4.86.	7.29	14.0	2.43	0.585
4	6	4.86	7.29	13.7	2.43	0.88

Table -II: Mix proportion values for preparation of 3 cylinders when coconut shell replaced as coarse aggregate

S. No	% of coconut shell replaced in coarse aggregate	Weight of the material used in Kg(for 3 cylinders)				
		Cement	Fine aggregate	CA	Water	CS
1	0	7.63	11.45	22.9	3.82	0
2	2	7.63	11.45	22.48	3.82	0.46
3	4	7.63	11.45	22.02	3.82	0.92
4	6	7.63	11.45	21.56	3.82	1.38

After performing the tests, replacing the equal weight of eggshell powder in place of the percentage of cement where the optimum strength value obtained from coconut shells and preparing the mix according to the mix design.

Preparing three cubes and three cylinders for each percentage replacement of coconut shells and eggshell powder and calculating the mix design according to the number of specimens casting.

D.Workability test

To assess the workability of the fresh concrete the slump test was conducted based on ASTM C143. A concrete mix should be workable enough to be placed, compacted and finished. The ingredients in concrete should be in such a proportion as to allow good workability of the concrete and sufficient strength to support the required load after hardening.

E. Casting and Curing

The specimens are casting to conduct the compressive strength test and split tensile strength test on conventional concrete and partial replacement of coconut shells and eggshell powder. For conducting the compressive strength test, preparing the cube molds to a size of 150*150*150 mm and preparing the cylindrical molds to a size of 150 mm diameter and 300 mm height for conducting Split Tensile Strength test.

For each percentage of coconut, shell and eggshell powder prepared three cubes and three cylinders,

stored the specimens in the open air at a temperature of 27°C to dry the specimens, and placed in vibration-free places for one day. After that curing these specimens for 28 days and to maintain the stable temperature, prevent loss of moisture content in a specimen and to achieve strength.

F. Strength Tests:

i. Compressive Strength Test

After curing the specimens of size 150*150*150mm for 28 days, placing and testing the specimens under a loading rate of 2.5 KN/s by using Universal Testing Machine (UTM) which has a capacity of 2000 KN as per IS 516-1959. Performing the test until the specimen will fail under the constant loading and measuring the stress, strain and deformation parameters. From these parameters, the compressive strength of each specimen calculated by using the following formula:

$$CompressiveStrength = \frac{Load\ at\ point of failure of the specimen}{Initial\ Cross-Sectional\ area of the\ specimen}$$

These tests can be used to determine the yield strength of the specimens and in this work, it is used for comparing the strength parameters of the concrete when replacing the aggregate by coconut shells and cement by eggshell powder when the optimum condition of coconut shells.

ii. Split Tensile Strength Test

After curing the specimens of size 150mm diameter and 300 lengths for 28 days, placing and testing the specimens along thelong side of the specimen under a loading rate of 2.5 KN/s by using Universal Testing Machine (UTM) which has a capacity of 2000 KN as per IS 516-1959. Materials can carry the compressive strength but sometimes these materials are failing under tensile load. Split Tensile Strength test performing on specimens to know about, how the material behaving while applying tensile load. While testing the specimens place the plywood on top and bottom of the cylinders. Split tensile strength of each specimen calculated by using the below formula:

$$SplitTensileStrength = \frac{2 * Maximum\ applied\ load\ on\ specimen}{\prod * length of the specimen * Diameter of the specimen}$$

The maximum applied load on the specimen is obtained from the UTM machine.

These tests can be used to determine the yield strength of the specimens and in this work, it is used for comparing the strength parameters of the concrete when replacing the aggregate by coconut shells and cement by eggshell powder when the optimum condition of coconut shells.

IV. RESULTS AND DISCUSSIONS

After performing the compressive strength and split tensile strength test on specimens on the UTM machine, calculated the strength from the measured parameters such as stress, strain, and deformation and the strength values are noted in Table – III.

Table III: Compressive Strength and Split Tensile Strength of concrete after curing of 28 days when aggregate replaced by Coconut shells

S. No	% of Coconut Shells Replaced in Aggregate	Compressive Strength of Concrete in N/mm^2	Split Tensile Strength of Concrete in N/mm^2
1	0	29.1	2.92
2	2	25.8	2.65
3	4	24.6	2.44
4	6	23.11	2.21

Table – IV represents that, the weight of the specimens after curing of 28days which is replaced by coarse aggregate as coconut shells.

Table IV: Weight of cubes and cylinder concrete after curing of 28 days when aggregate replaced by Coconut shells

S. NO	% Replacement of coconut shell in coarse aggregate	Weight of cubes in Kg	Weight of cylinders in Kg
1	0	9.15	13.89
2	2	8.8	13.51
3	4	8.5	13.16
4	6	8.25	12.8

Table – V represents the workability of concrete which is replaced by coarse aggregate as coconut shells.

Table V: Workability of Concrete in the replacement of Coconut shells as aggregates

S. NO	% Replacement of coconut shell in coarse aggregate	Slump value in mm
1	0	65
2	2	61
3	4	58
4	6	56

From Table – III, IV and V, optimum strength value, workability and self-weight occurred at coconut shells replaced as 6% of the coarse aggregate weight. After that, replacing the eggshell powder as cement at the optimum condition of coconut shells and designing the mix proportions for cubes and cylinders at 0%, 5%, 10%, and 15%.

Table - VI: Mix proportion values for preparation of 3 cubes when Eggshell powder replaced as cement

S. No	% of eggshell powder replaced in cement	Weight of the materialused in Kg(for 3 cubes)					
		Cement	*Fine aggregate*	*CA*	*Water*	*CS*	*ESP*
1	0	4.86	7.29	13.7	2.43	0.88	0
2	5	4.62	7.29	13.7	2.31	0.88	0.243
3	10	4.44	7.29	13.7	2.22	0.88	0.486
4	15	4.14	7.29	13.7	2.07	0.88	0.729

After performing the compressive strength and split tensile strength test on specimens on the UTM machine, calculated the strength from the measured parameters such as stress, strain, and deformation and the strength values are noted in Table – VIII.

Table - VII: Mix proportion values for preparation of 3 cylinders when Eggshell powder replaced as cement

S. No	% of eggshell powder replaced in cement	Weight of the material used in Kg(for 3 cylinders)					
		Cement	*Fine aggregate*	*CA*	*Water*	*CS*	*ESP*
1	0	7.63	11.45	21.56	3.82	1.38	0
2	5	7.25	11.45	21.56	3.62	1.38	0.38
3	10	6.87	11.45	21.56	3.44	1.38	0.76
4	15	6.5	11.45	21.56	3.25	1.38	1.15

Table - VIII: Compressive Strength and Split Tensile Strength of concrete after curing of 28 days when Cement replaced by Eggshell powder

S. No	% of Eggshell Powder Replaced in Cement	Compressive Strength of Concrete in N/mm^2	Split Tensile Strength of Concrete in N/mm^2
1	0	23.11	2.21
2	5	22.49	2.09
3	10	20.95	1.98
4	15	20.11	1.91

From Table – VIII, observing the strength parameters of the specimens which are prepared by replacing the eggshell powder as 0, 5, 10 and 15 percentage and getting the optimum strength value at 15% of eggshell powder.

Table – IX represents that, the weight of the specimens after curing of 28days which as replaced by coarse aggregate as coconut shells.

Table -IX: Weight of cubes and cylinder concrete after curing of 28 days Cement replaced by Eggshell powder

S. NO	% Replacement of coconut shell in coarse aggregate	Weight of cubes in Kg	Weight of cylinders in Kg
1	0	8.25	12.8
2	5	8.01	12.46
3	10	7.79	12.14
4	15	7.54	11.8

Table – X represents the workability of concrete which is replaced by eggshell powder as cement and the workability of concrete is continuously reducing.

Table X: Workability of Concrete in the replacement of Eggshell powder as cement

S. NO	% Replacement of Eggshell powder in Cement	Slump value in mm
1	0	56
2	5	52
3	10	49
4	15	47

From Table – VIII, IX and X, strength, workability and self weight of the specimens is continuously reducing with the increasing of eggshell powder in cement at optimum coconut shell condition. The compressive strength and split tensile strength of specimens which are replaced by coconut shells as aggregates are graphically represented in the fig -2.

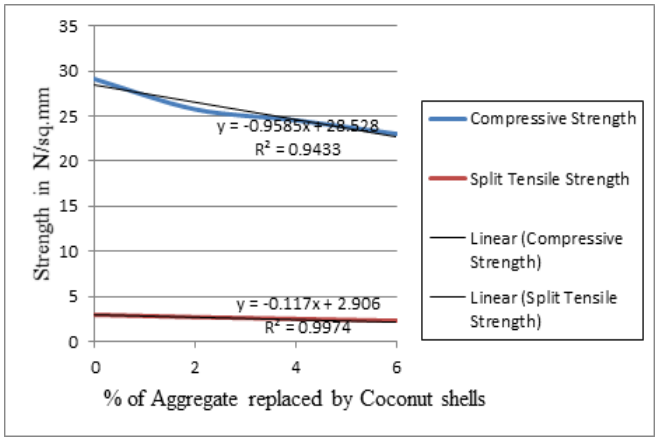

Fig.2. Compressive Strength and Split Tensile Strength of concrete after curing of 28 days when aggregate replaced by Coconut shells

From the fig – 2, regression values are calculated from the obtained strength values and the regression value is 0.9433 for compressive strength and 0.9974 for split tensile strength.

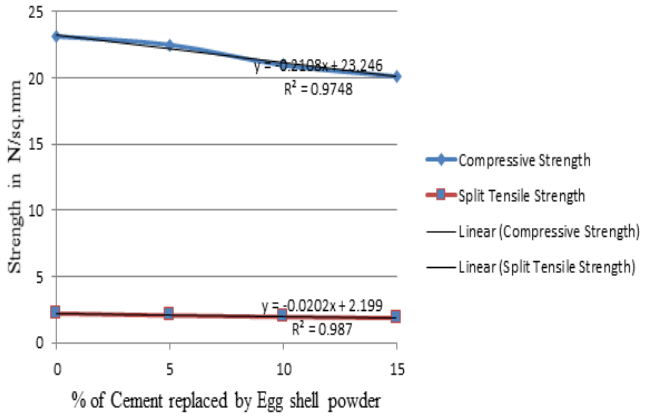

Fig.3. Compressive Strength and Split Tensile Strength of concrete after curing of 28 days when Cement replaced by Eggshell powder at the optimum coconut shell content

Fig – 3 represents the compressive strength and split tensile strength values of specimens which are replaced by eggshell powder as cement at optimum strength value of concrete which are replaced by coconut shells as coarse aggregates and the graph represents the regression value of strengths such as 0.9748 for compressive strength and 0.987 for split tensile strength.

IV. CONCLUSION

Based on the above results, the strength and workability of the concrete iscontinuously decreaseswith increasing the partial replacement of Coconut shells in place of coarse aggregateand got the optimum strength value at 6% and strength and workability of the concrete again decreasing with replacement of eggshell powder at optimum strength of coconut shell (6%).The weight of cubes decreased with increasing the percentage of eggshell powder and coconut shells, it means that the density of the concrete is decreasing. Strength and density parameters indicting that the material is used for the construction the compound walls not for the massive construction works.

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AUTHORS PROFILE

Ayyappa R A, Assistant Professor, S R Enginering College, Warangal, Telangana – 506004.
Email: ayyappa_reddy_a@srecwarangal.ac.in.

Sandeep Reddy B, PG Scholar, JNTU Kakinada, Kakinada.

Swamy Yadav, Assistant Professor, S R Enginering College, Warangal, Telangana – 506004.

Dara SwethaSudarshan, Assistant Professor, S R Enginering College, Warangal, Telangana – 506004.