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Experimental study on strength characteristics on M_{25} concrete with partial replacement of cement with fly ash and coarse aggregate with coconut shell

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Abstract- An attempt has been made to examine the suitability of replacing the 20% of fly ash obtained from V.T.P.S; Vijayawada is common for all mixes with cement and simultaneously by replacing 10%, 20% and 30% of coconut shell as coarse aggregate for concrete of grade M25. Examine strength characteristics such as compressive strength, split tensile strength and flexural strength of concrete mix are found for 7 days, 14 days, 28 days, 56 days of curing period and results are analysed and compared with the regular (conventional) mix. Test for grade as per specified procedure of IS codes. The materials are proportioned by their weight. The water cement ratio is obtained by conducting workability tests. The results found were comparable with that of conventional mix.

Index Terms- Coarse aggregate, coconut shell, compressive strength, concrete, fly ash, split tensile strength, flexural strength.

1 INTRODUCTION

The word “sustainable” is becoming very common worldwide. The trend goes beyond the practice of design and construction, since the awareness of the current population is a crucial factor for the success of this tendency. Sustainable building systems can have a direct implication on the betterment of livelihood conditions of communities. Unfortunately, the extraction of natural aggregates has led to establishing human-made quarries that have drastic environmental impact on the nature and surroundings.

Sustainable materials are currently widely considered and investigated in construction engineering research. Some examples of sustainable research worldwide are the use of recycled concrete aggregates, coal fly ash, ground clay brick and pervious paver block system. Further, substantial research work has been conducted on fiber-reinforced concrete which is a concrete primarily made of a mix of hydraulic cement, aggregates, water and reinforcing fibers.

The high demand for concrete in the construction using normal weight aggregates such as gravel and granite drastically reduces the natural stone deposits and this has damaged the environment thereby causing ecological imbalance. Therefore, there is a need to explore and to find out suitable replacement material to substitute the natural stone. In developed countries, the construction industries have identified many artificial and natural lightweight aggregates (LWA) that have replaced conventional aggregates thereby reducing the size of structural members. However, in Asia the construction industry is yet to utilize the advantage of LWC in the construction of high rise structures. Coconut Shell (CS) are not commonly used in the construction industry but are often dumped as agricultural wastes. The aim of this review is to spread awareness of coconut fibres as a construction material.

Typical concrete is a mixture of fine aggregates, coarse aggregates, cement and water. Because of its convenient use, it is not only used in building construction but also in other areas roads, harbors, bridges and many more. The usage of concrete is very wide. It is one of the most important constituent materials. It is comparatively economical, easy to make offers continuity solidity and indeed it lays the role of developing and improving our modern society. Coarse aggregates not only constitute the bulk of concrete but also contribute the most towards its compressive strength through high particle strength and close particle interlock. But, the construction industry worldwide is facing a shortage of this natural resource. The recycling of demolished masonry rubble as coarse aggregate in concrete is an interesting possibility due to its environmental benefits. It is not only a viable alternative to natural coarse aggregate but also solves the major problem of disposal of demolition of waste. Recycling construction and demolition waste into aggregate would ultimately lead to fewer quarries and landfills.

2 DESCRIPTIONS OF MATERIALS

2.1 Cement

Cement must develop the appropriate strength. It must represent the appropriate rheological behaviour. Generally same types of cements have quite different rheological and strength characteristics, particularly when used in combination with admixtures and supplementary cementing materials.

S.no.	Parameter	Test results
1	Normal Consistency	28%
2	Fineness of cement (%)	6
3	Specific Gravity	3.148
4	Initial setting time	70mins
	Final setting time	300mins
5	Compressive strength of cement at	
	7days -	17N/mm^2
	28days -	22.8N/mm^2

2.2 Fly ash

Fly ash has been used extensively in concrete for many years. Fly ash much more variable than silica fumes in both their physical and chemical characteristics. In general, fly ash is used at about 15-25% of the cement content.

Because of the variability of the fly ash produced even from the single plant, quality control is very important. This involves determination of the blain specific surface area, as well as the chemical composition. It is also very important to check the degree of crystallinity.

S.no.	Parameter	Test results	Specifications As per IS: 3812 – 1981
1	Bulk density(Kg/M^3)	1010	1120
2	Specific gravity	2.22	2.14 to 2.42

2.3 Fine aggregate

Fine aggregate normally consists of natural, crushed, or manufactured sand. Natural sand is the usual component for normal weight concrete. In some cases, manufactured light weight particles used for lightweight concrete and mortar. The maximum grain size and size distribution of the fine aggregate depends on the type of product being made.

S.no.	Parameter	Test results
1	Specific gravity	2.605
2	Fineness modulus	2.465
3	Bulk density(Kg/M^3)	
	Loose	1488.89
	Compacted	1600

2.4 Coarse aggregate

As coarse aggregates in concrete occupy 35 to 70% of the volume of the concrete. It may be proper to categories the properties into two groups: exterior features (maximum size, particle shape, textures) and interior quality (strength, density, porosity, hardness, elastic modulus, chemical mineral composition etc.). Smaller sized aggregates produce higher concrete strength. Particle shape and texture affect the workability of fresh concrete. The transition zone between cement paste and coarse aggregates, rather than the properties of the coarse aggregates itself.

Usually an aggregate with specific gravity more than 2.55 and absorption less than 1.5% (except for light weight aggregates) can be regarded as being of good quality. Where aggregates strength is higher, concrete strength is also higher.

S.no.	Parameter	Test results
1	Specific gravity	2.75
2	Fineness modulus	8.625
3	Water absorption (%)	0.15
4	Bulk density(Kg/M^3)	
	Loose	1525.92
	Compacted	1659.25

2.5 Coconut shell

The physical properties of coconut shell are shown below table.

S.no.	Parameter	Test results
1	Specific gravity	1.33
2	Water absorption (%)	25
3	Bulk density(Kg/M^3)	
	Loose	592.59
	Compacted	800

3 WORKABILITY TESTS

3.1 Slump cone test

The slump test is the most commonly used method. Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It is used for the determination of the consistency of freshly mixed concrete, where the maximum size of the aggregate does not exceed 38 mm. The slump test is suitable for slumps of medium to high workability, slump in the range of 25 – 125 mm; the test fails to determine the difference in workability in stiff mixes which have zero slumps, or for wet mixes that give a collapse slump. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It is also used to determine consistency between individual batches. The apparatus used for conducting the slump test consists of slump cone or Abrams cone with handles and foot pieces. The size of the slump cone is 20-cm diameter base, 10 cm diameter top and 30 cm height. Foot pieces can be fixed to the clamps on the base plate. The base plate has lifting handle for easy transportation. One graduated steel tamping rod 16 mm diameter x 600 mm long rounded at one end graduated in mm. The internal surface of the mould is thoroughly cleaned and free from moisture and adherence of any old set concrete before commencing the test. The mould should be placed on smooth surface. Oil is applying on internal surface of the mould and applies the smooth surface where the mould is placed. The types of slump are as follows.

Collapse: In a collapse slumps the concrete collapses completely.

Shear: In a shear slump the top portion of the concrete shears off and slips sideways.

True: In a true slump the concrete simply subsides, keeping more or less to shape

3.2 Compaction factor test

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. This test gives behaviour of concrete under the action of external forces. If measures the compactability of concrete, by measuring the amount of compaction. This test is suitable for mixes having medium and low workabilities i.e. compaction factor in between 0.91 to 0.81, but is not suitable for concretes with very low workabilities, the compaction factor below 0.71.

The apparatus, which is commercially available, consist of a rigid frame that supports two conical hoppers vertically aligned above each other and mounted above a cylinder. The top hopper is slightly larger than the bottom hopper, while the cylinder is smaller in volume than both hoppers. To perform the test, the top hopper is filled with concrete but not compacted. The door on the bottom of the top hopper is opened and the concrete is allowed to drop into the lower hopper. Once all of the concrete has fallen from the top hopper, the door on the lower hopper is opened to allow the concrete to fall to the bottom cylinder. A tamping rod can be used to force especially cohesive concretes through the hoppers. The excess concrete is carefully struck off the top of the cylinder and the mass of the concrete in the cylinder is recorded. This mass is compared to the mass of fully compacted concrete in the same cylinder achieved with hand rodding or vibration. The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of the fully compacted concrete. The standard test apparatus, described above, is appropriate for maximum aggregate sizes of up to 20 mm. A larger apparatus is available for concretes with maximum aggregate sizes of up to 40 mm. The compaction factor test gives more information (that is, about compactability) than the slump test. The test is a dynamic test and thus is more appropriate than static tests for highly thixotropic concrete mixtures.

4 CASTING OF CONCRETE CUBES, CYLINDERS AND BEAMS

The test moulds are kept ready before preparing the mix. Tighten the bolts of the moulds carefully because if bolts of the moulds are not kept tight the concrete slurry coming out of the mould when vibration takes place. Then moulds are cleaned and oiled on all contact surfaces of the moulds and place the moulds on vibrating table. The concrete is filled into moulds in layers and then vibrated. The top surface of concrete is struck off level with a trowel. The number and date of casting are put on the top surface of the cubes, cylinders and moulds.

5 TESTS FOR CONCRETE

5.1 Test for Compressive strength of concrete cubes

To calculate the compressive strength of concrete cubes the universal testing machine (UTM) having capacity of 300tonne was used. In this test the strength obtained in tonne. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest N/mm^2.

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days curing, 14 days curing, 28 days curing and 56 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Calculations:

Compressive strength = Maximum load/ Area

= **P/A**

5.2 Test for Split tensile strength of concrete cylinders

As we know that the concrete is weak in tension. Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The usefulness of the splitting cube test for assessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen takes place shall then be recorded. The universal testing machine (UTM) having capacity of 150tonne was used for the splitting tensile strength of the concrete cylinders.

Calculations:

The split tensile strength of the specimen calculated from the following formula

$$T_{sp} = (2P/ (\pi dL))$$

Where

P= maximum load in tonne

L= length of the specimen

d= diameter of width of the specimen

Final values are adopted from using standard deviation.

5.3 Test for Flexural strength of concrete beams

For this test the beams of dimension 100mmX100mmX500mm were casted. Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, [dubious – discuss] a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The beam tests are found to be dependable to measure flexural strength.

The value of the modulus of rupture depends on the dimensions of the beam and manner of loading. In this investigation, to find the flexural strength by using third point loading. In symmetrical two points loading the critical crack may appear at any section not strong enough to resist the stress with in the middle third, where the banding moment is maximum. Flexural modulus of rupture is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used.

Compressive Strength (N/mm^2)				
	7days	**14days**	**28days**	**56days**
Conventional	25.04	28.74	33.33	35.41
10%CS and 20% fly ash	23.11	26.78	30.78	32.11
20%CS and 20%fly ash	21.74	24.78	28.11	30.33
30%CS and 20%fly ash	19.74	23.03	26.59	28.78

Calculations:

$$F_b = PL/ bd^2$$

Where

b= width in cm of specimen

d= depth in cm of specimen at point of failure

L= length in cm of specimen on which specimen was supported

S.no.	Slump(mm)	
1	Conventional mix	80
2	Mix 1	35
3	Mix 2	42
4	Mix 3	48
	Compaction factor	
1	Conventional mix	0.920
2	Mix 1	0.924
3	Mix 2	0.927
4	Mix 3	0.931

P= maximum load in kg applied to specimen

Final values are adopted using standard deviations.

6 RESULTS

The mix proportion for M25 is 1: 1.18: 2.86 and W/C ratio of 0.44 was casted. Slump and compaction factor tests were tested when the concrete in fresh state. The cubes, cylinders and beams were tested for compressive strength, split tensile strength and flexural strength. These tests were carried out at the age of 7 days, 14 days, 28 days and 56 days.

6.1 Workability test results

6.2 Strength Results

6.2.1 Compressive strength test results

Observations

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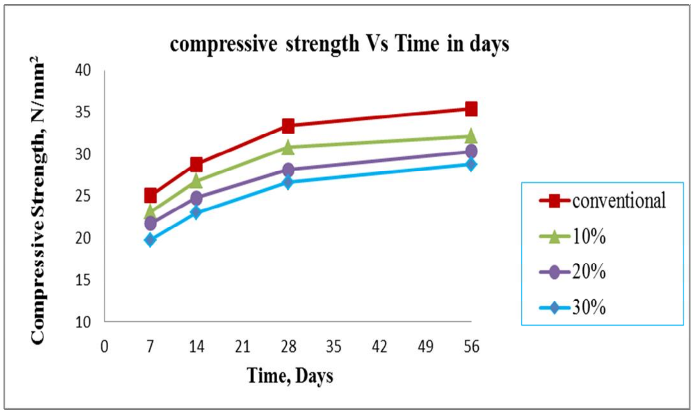
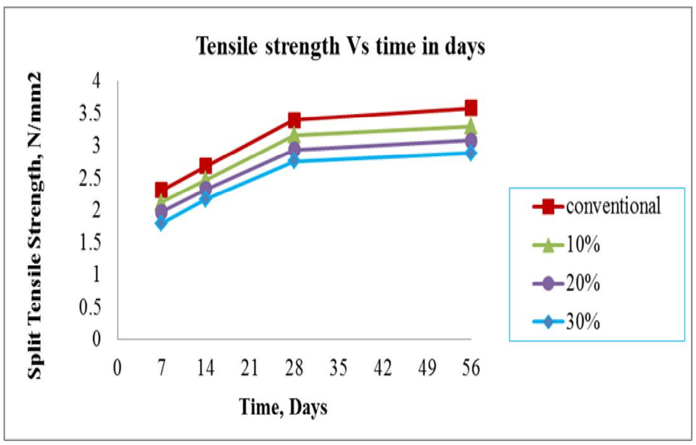


6.2.2 Split tensile strength results

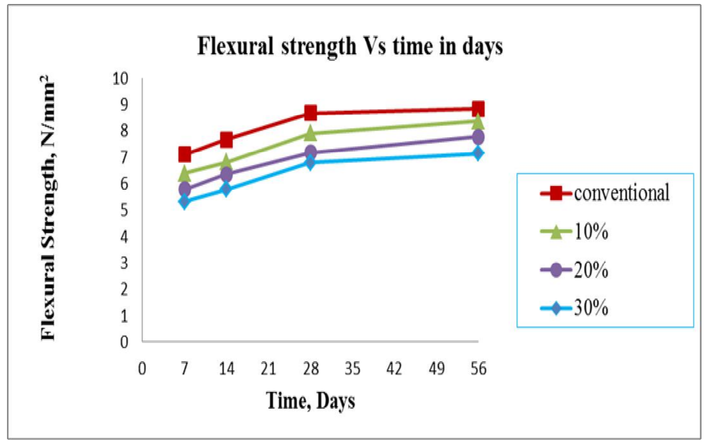
Observations



6.2.3 Beam flexural strength results

Observations

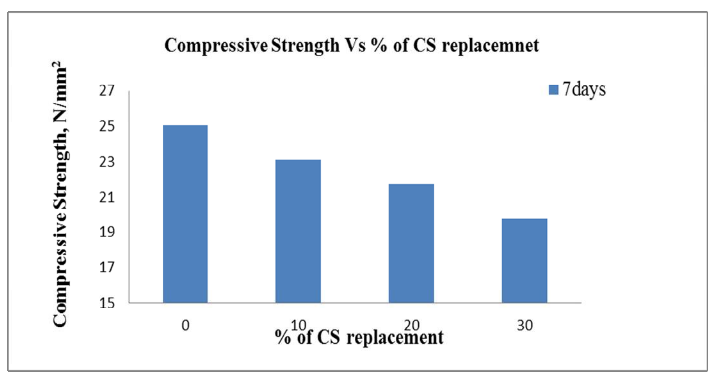
Split Tensile Strength (N/mm²)				
	7days	14days	28days	56days
Conventional	2.310	2.68	3.39	3.58
10%CS and 20% fly ash	2.130	2.48	3.16	3.30
20%CS and 20%fly ash	1.98	2.33	2.94	3.08
30%CS and 20%fly ash	1.80	2.17	2.76	2.89

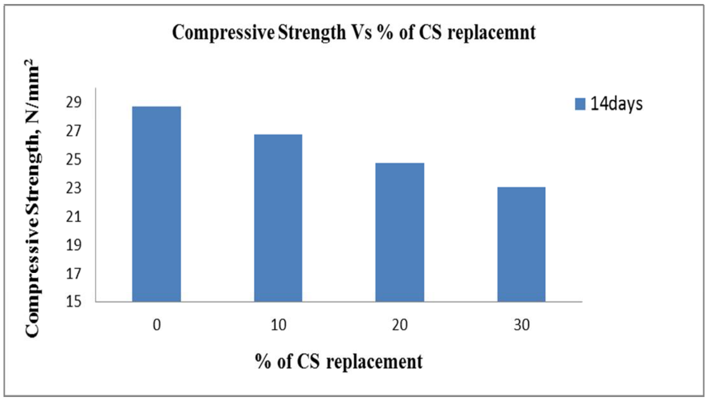


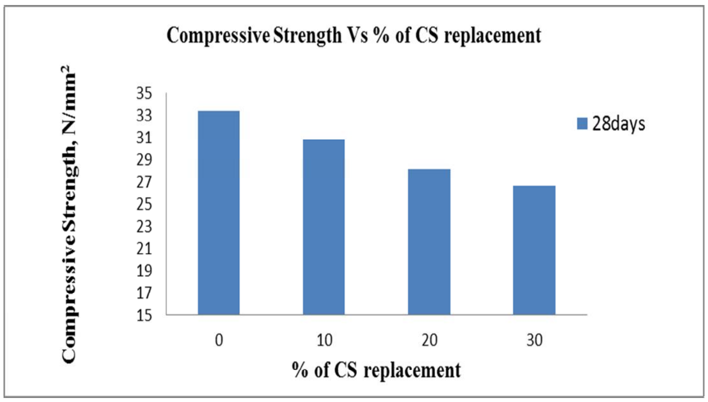
6.3 Bar Charts

The bar charts are drawn for compressive strength, split tensile strength and flexural strength results. These are drawn between strength and percentage replacement of coconut shell at 7 days, 14 days, 28 days and 56 days to observe the variation of strength.

Flexural Strength (N/mm²)				
	7days	**14days**	**28days**	**56days**
Conventional	7.1	7.67	8.67	8.83
10%CS and 20% fly ash	6.38	6.8	7.9	8.36
20%CS and 20%fly ash	5.78	6.35	7.17	7.78
30%CS and 20%fly ash	5.33	5.78	6.78	7.13




Compressive Strength Vs % of CS replacemnt
Compressive Strength, N/mm²
29
27
25
23
21
19
17
15
0
10
20
30
% of CS replacement
14days


Compressive Strength Vs % of CS replacement
Compressive Strength, N/mm²
35
33
31
29
27
25
23
21
19
17
15
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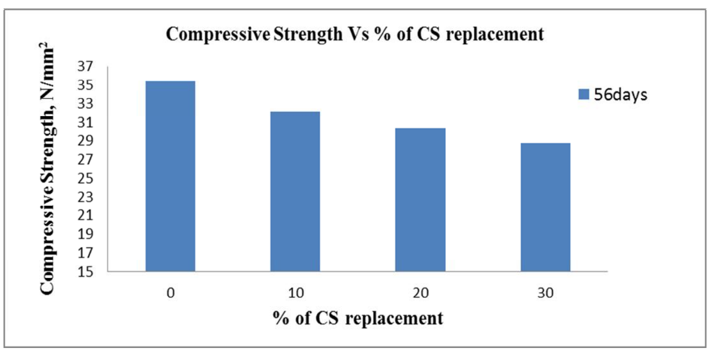
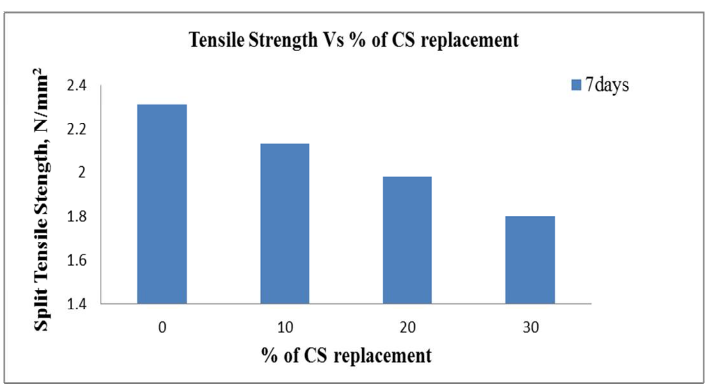
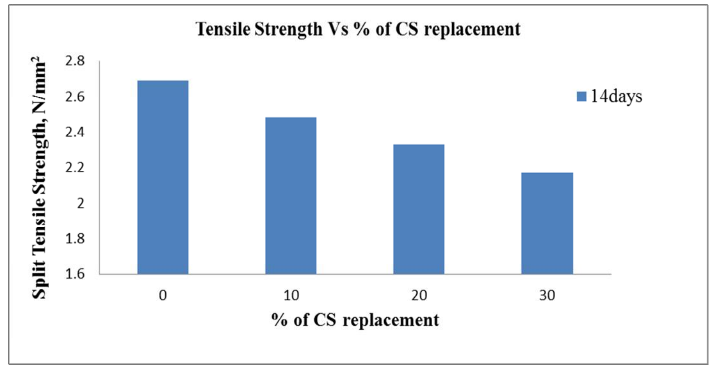
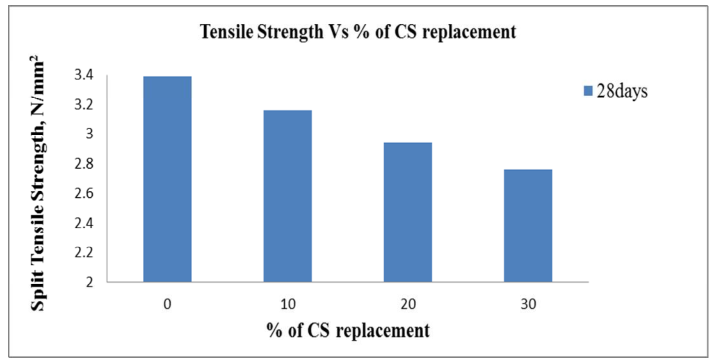
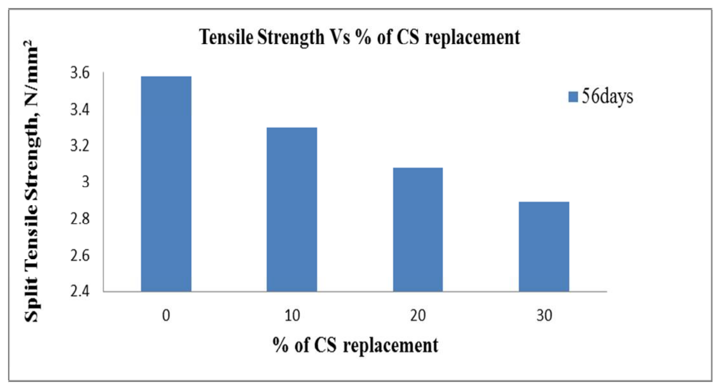
10
20
30
% of CS replacement
28days

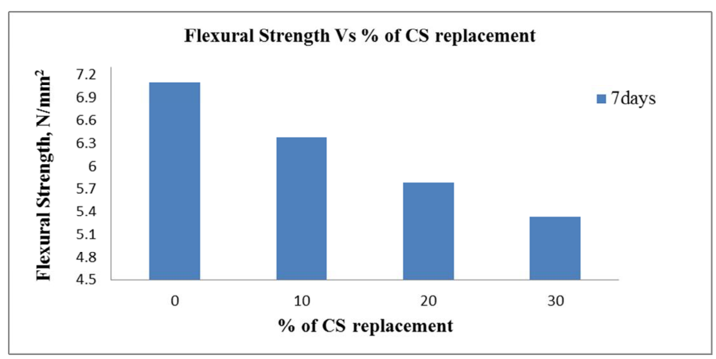

Compressive Strength Vs % of CS replacement
Compressive Strength, N/mm²
37
35
33
31
29
27
25
23
21
19
17
15
0
10
20
30
% of CS replacement
56days

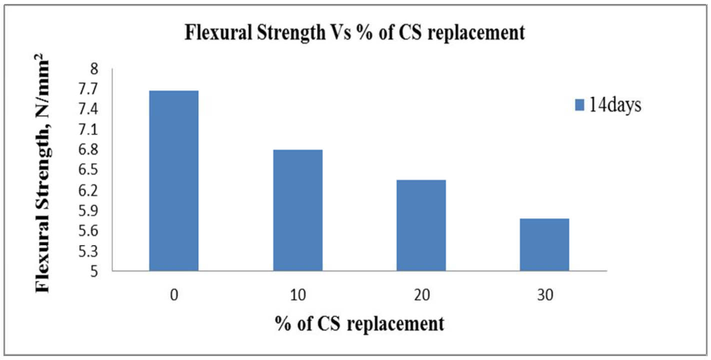

Tensile Strength Vs % of CS replacement
Split Tensile Stength, N/mm²
2.4
2.2
2
1.8
1.6
1.4
0
10
20
30
% of CS replacement
7days

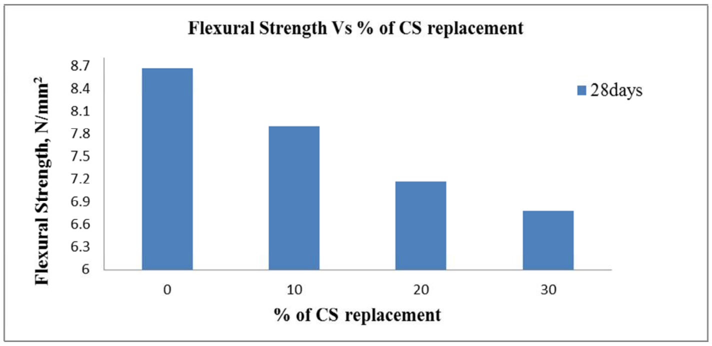

Tensile Strength Vs % of CS replacement
Split Tensile Strength, N/mm²
2.8
2.6
2.4
2.2
2
1.8
1.6
0
10
20
30
% of CS replacement
14days

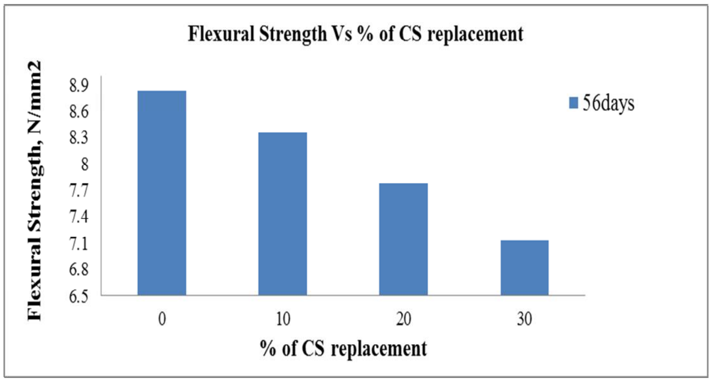

Tensile Strength Vs % of CS replacement
Split Tensile Strength, N/mm²
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0
10
20
30
% of CS replacement
28days


Tensile Strength Vs % of CS replacement
Split Tensile Strength, N/mm²
3.6
3.4
3.2
3
2.8
2.6
2.4
0
10
20
30
% of CS replacement
56days


Flexural Strength Vs % of CS replacement
Flexural Strength, N/mm²
7.2
6.9
6.6
6.3
6
5.7
5.4
5.1
4.8
4.5
0
10
20
30
% of CS replacement
7days







7 CONCLUSIONS

The following conclusions can be drawn from the experimental investigation carried out

1. The slump of the concrete increased as the percentage of coconut shell increases and decrease in comparison with the conventional concrete.
2. The compaction factor increased as the percentage of coconut shell increases and increased in comparison with the conventional concrete.
3. The specific gravity of coconut shell is low as compared to the coarse aggregate and the water absorption is high for coconut shell than coarse aggregate and hence the strength decreased in comparison with the conventional concrete.
4. The slump of the concrete increased as the percentage of coconut shell increases and decrease in comparison with the conventional concrete.
5. The compaction factor increased as the percentage of coconut shell increases and increased in comparison with the conventional concrete.
6. The specific gravity of coconut shell is low as compared to the coarse aggregate and the water absorption is high for coconut shell than coarse aggregate and hence the strength decreased in comparison with the conventional concrete.
7. 20% of cement replaced with fly ash and 10%, 20%, 30% of coarse aggregate replaced with coconut shell resulted that the compressive strength is reduced when compared with the conventional concrete.
8. The compressive strength of the concrete reduced with increasing percentage of the coconut shell replacement.
9. The cube compressive strength of concrete at the age of 7 days resulted in marginal reduction with 10% and 20% replacement of coarse aggregate with coconut shell.
10. The Split Tensile strength at 7days was reduced by 8% with 20% replacement of fly ash and the 10% replacement of coarse aggregate with coconut shell when compared with conventional concrete.
11. The strength of concrete decreased as the percentage of replacement of the conventional material increased
12. The reduction in compression strength is less in comparison with the split tensile strength with the replacement of conventional material.

13. The split tensile strength at the 7 and 14 days for all percentage replacements of conventional material is marginal.
14. The reduction in Flexural Strength of all percentage replacements at the age of 56days is less when compared with early strength of the concrete.
15. The decrease in strength percentage of compressive split tensile and flexural strengths varies from each coconut shell replacement.
16. The decrease in strength percentage of flexural strength for 10% replacement at the age of 56 days is marginal (5%) and it is less when compared to other ages and other replacements.
17. The compressive strength, split tensile strength and flexural strength decreased with the percentage replacement of coconut shell increases at the ages 7 days, 14 days, 28 days and 56 days.
18. The compressive split tensile and flexural Strength with percentage replacement of cement and coarse aggregates decreased is very less and hence can be used for less important work utilizing the waste material which is produced in large quantities.

8 FURTHER SCOPE OF WORK

1. The study can be carried out with varying percentage replacement of the material for specific low cost housing applications.
2. The engineering properties like water absorption, reduction in weight of concrete and study on economic aspects can be carried out.
3. The effect of temperature on the concrete developed can be studied.
4. The study can be extended to assess the durability aspects of the concrete with varying replacement proportions.

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