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A BRIEF STUDY ON THE STRENGTH PROPERTIES OF MODIFIED CONCRETE USING LIGHT EXPANDABLE CLAY AGGREGATE (LECA)

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ABSTRACT: One of the disadvantages of the conventional concrete is the high self weight of concrete. Many attempts have been made in the past to reduce the self weight of concrete along with increase the efficiency of concrete as a structural material. In this investigation an attempt is made to study the strength properties of modified M_{20} grade concrete with replacement of natural coarse aggregates with varying percentages of Light expandable clay aggregates (LECA) i.e, 25, 50, 75 and 100%. After 28 days various tests are carried out on the modified concrete i.e., compressive strength test, split tensile strength, flexural strength test, modulus of elasticity, in-plane shear strength through mode-II fracture test, and those results are compared. The results are observed to be quite satisfactory.

Keywords: LECA(light weight Expandable Clay Aggregate), , compressive strength, split tensile strength, modulus of elasticity, flexure, In-plane shear strength

1. INTRODUCTION:

Generally the concrete prepared with natural aggregates has more density and it increases the dead weight acting on the structures which becomes critical when structures are built in weak soils and there are considerable advantages in reducing the density of concrete. In recent years more attention has been paid to the development of light weight artificial aggregates whose properties are comparable with those of natural aggregates. The use of lightweight aggregate in concrete has many advantages. These include: (a) Reduction of dead load that may result in reduced footing sizes and lighter and smaller upper structure. This may result in reduction in cement quantity and possible reduction in reinforcement. (b) Lighter and smaller pre-cast elements needing smaller and less expensive handling and transporting equipment. (c) Reductions in the sizes of columns, slabs and beam dimension that result in larger space availability. (d) High thermal insulation. (e) Enhanced fire resistance.

LECA is light weight expandable clay aggregate which is obtained by heating clay particles to a temperature of 1200°c in a rotary kiln. Lightness of LECA is because of multi-separated air spaces which exist inside and among the aggregates. Density of aggregates ranges from 380-710Kg/m^3 depending on the size of particles. It has good thermal insulation with coefficient in the range of 0.09-0.101. It also has good sound insulation, fire resistance and even resists against acidic and alkaline substances. LECA is used for many purposes like road construction, floor and roof sloping, sewage system, water purification system, prefabricated panels and slabs, etc. Usage of LECA reduces the demand for natural aggregates which is going to become scarce in future. Also low weight of LECA makes it easy for transportation when compared to natural aggregates.

2. REVIEW OF LITERATURE

T. Parhizkar, et.al (2011) [1] presented an experimental investigation on the properties of volcanic pumice lightweight aggregates concretes. To this end, two groups of lightweight concretes (lightweight coarse with natural fine aggregates concrete and lightweight coarse and fine aggregates concrete) were built and the physical/mechanical and durability aspects of them were studied. The results of compressive strength, tensile strength and drying shrinkage showed that these lightweight concretes meet the requirements of the structural lightweight concrete.
Sivakumar & B. Kameshwari (2014) [2] presented a report which deals with the results of a real-time work carried out to form light weight concrete made with fly ash, bottom ash, and light expanded clay aggregate as mineral admixtures. Experimental investigation on concrete mix M_{20} was done by replacement of cement with fly ash, fine aggregate with bottom ash, and coarse aggregate with light expanded clay aggregate at the rates of 5%, 10%, 15%, 20%, 25%, 30%, and 35% in each mix and their compressive strength, flexural strength and split tensile strength of concrete were evaluated for 7, 28, and 56 days depending on the optimum dosage of replacement of mineral admixtures.

V. Swamynath & K. Muthumani (2017) [3] made a critical review on structural light weight concrete. Selection of lightweight aggregates depends on the selection of construction. Light weight aggregate can be used for structural, non structural and infill purposes.

Prakash Desai, et.al [4] arrived at double central notched specimen geometry which fails in predominant Mode-II failure; they also made finite element analysis to arrive at stress intensity factor. Using this DCN geometry lot of experimental investigation using cement paste, mortar, and plain concrete was done. Details of the geometry are presented as below.

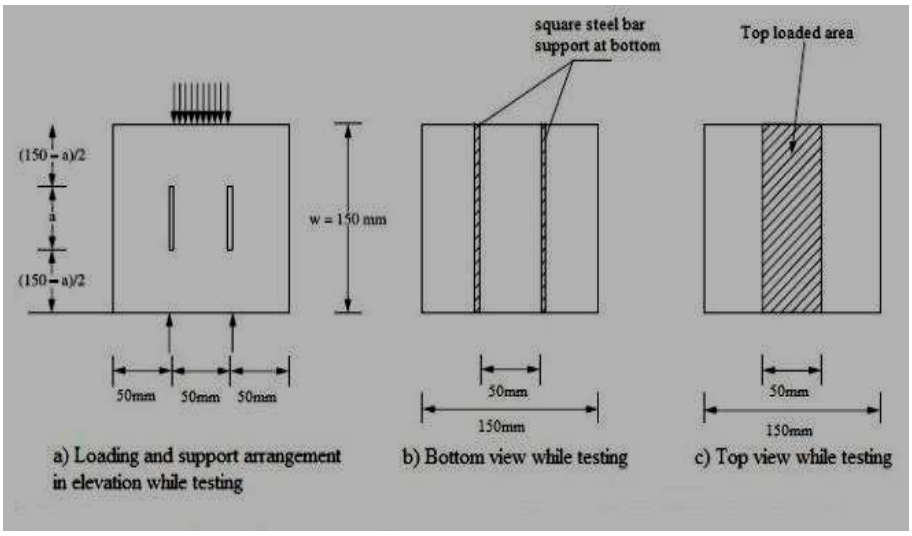

Figure.1. Details of DCN specimen geometry

Swamy R.N& Lambert G.H (1984) [5] studied about the light weight aggregates and proved that the thermal efficiency is very much more for the light weight concrete and the load carrying capacity of the light weight concrete is same as the normal concrete by using some mineral and chemical admixtures.

T. Sonia and R. Subhashini [6] investigated mechanical properties of light weight concrete M_{25} mix with partial and 100% replacement of natural aggregate with various percentage such as 20, 40, 60, 80 and 100 along with replacement of cement with fly ash at various percentage such as 15, 20 and 25% and found that optimum replacement of cement was 15% fly ash and 40% replacement of natural aggregates with LECA.

Ali-Nazari, et.al., (**2010**) **[7],** made an investigation on the series of blended concretes with 0.5%, 1.0%, 1.5% and 2.0% of Nano-TiO2 particles respectively and fixed w/c ratio of 0.4 was used. It was derived that the workability reduction, increased with the increasing NT (Nano Titanium Dioxide) content and compressive strength of concrete after 28 days was increased by 13.86%, 17.93%, 15.49% and 6.79% with the inclusion of 0.5%, 1%, 1.5%, and 2%NT respectively. The final result of 1% NT content is the optimum.

G. Campione, et.al., (2001) [8] studied about the mechanical properties of steel fibre reinforced light weight concrete with Pumice stone and expanded clay aggregates and found that there was no significant change in compressive strength for Pumice stone aggregate and increase was observed while using expanded clay aggregates. Tensile strength (using split tensile test) and fracture toughness were increased for both Pumice and expanded clay aggregates, with the main advantage of lower structural weight being maintained.

3. OBJECTIVE

1. Determining solution to avoid rapid depletion of natural resources used in construction industry by using alternate aggregates.
2. By replacing coarse aggregate in concrete with light weight aggregate to produce light weight concrete.

4. MATERIALS USED

The following materials were used for preparing the concrete mix.

1. ACC cement of 53 grade
2. Fine aggregate i.e sand
3. Coarse aggregate
4. Light expandable clay aggregates (LECA)
5. Water

4.1 Cement: ACC 53 grade cement with specific gravity 3.26 was used as binder.

S.No	Name of the material		Properties Of Material	
1	cement		Specific gravity	3.26
			Initial setting time	50 minutes
			Final setting time	460 minutes
			Normal consistency	30%
			Fineness of cement	5%
2	Fine aggregate		Specific gravity	2.54
			Fine ness Modulus	2.75
3	Coarse aggregate	Natural aggregate	Specific gravity	2.6
		LECA	Specific gravity	1.18

4.2 Light Expandable clay aggregates: LECA is an acronym term for (Light Expandable Clay Aggregate) which is produced in rotary kiln at about 1200 degree centigrade. The base material is plastic clay which is extensively pre heated. Light Expandable Clay Aggregate is procured from Nexcus Buildcon Solution, India.

Specific gravity : 1.18
Aggregate Size mm : 10-12 mm
Bulk Density : 645 kg/m^3
Shape : Round pellets

4.3 Water: The local drinking water which is free from acids, impurities, and suspended solids etc has been used in this experimental investigation.

5. Casting of specimens:

The M20 concrete mix was designed using ISI method which gives a mix proportion of 1:1.58:2.88 with water cement ratio of 0.50. To proceed with the experimental program initially steel moulds of size 150x150x150 mm were cleaned and brushed with machine oil on all inner faces to facilitate easy removal of specimens afterwards. First fine aggregate, coarse aggregate and cement along with varying percentages of Light Expandable Clay aggregates were added to them. All of these were mixed thoroughly by hand mixing. For each mix three normal 150X150X150 mm cube specimens along with 12 No. of DCN specimens were cast with replacements of coarse aggregate by varying percentages (0%, 25%, 50%, 75%and 100%) of LECA and 6 No. Of Cylinders were cast with the same mixes in which 3 cylinders were used to find the split tensile strength and remaining 3 cylinders are used to determine the compressive strength. In addition, for each mix three numbers of 500mmX100mmX100mm beams were cast to know the flexural strength. The concrete was poured into the moulds in three layers with each layer being compacted thoroughly with tamping rod 25 times each time to avoid honey combing. Finally, all specimens were kept on the table vibrator after filling up the moulds up to the brim. The vibration was effected for 7 seconds and it was maintained constant for all specimens and all other castings. The steel plates forming notches were removed after 3 hours of casting carefully and neatly finished. After 28 days of curing the specimens were taken out of water and were allowed to dry under shade for few hours.

6. Testing of specimens

6.1. Compressive strength of cubes: Compressive strength of cubes was calculated by dividing load taken by the specimen by the cross sectional area. Values of compressive strength at different percentages replacement levels with LECA are given in table 1 and values are presented in figure 2 in graphical form.

6.2 Flexural Strength: Flexural strength is one measure of the tensile strength of the concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. The flexural strength test was done by standard test method of two-point loading. In this study, three beams of size 100x100x500 mm were used to find the flexural strength. The flexural strength results are tabulated in table 2 and the values are presented in figure 3 in graphical form.

6.3 Cylinder Compression Test: In this test the cylindrical specimens were kept vertically so that its axis was vertical between the compressive plates of the 3000KN digital compression testing machine. Narrow strips of the packing material i.e., plywood was placed between the plates and the cylinder to receive compressive load. The load was applied uniformly until the cylinder fails. Compressive strength results of cylinders are tabulated in table 3.

6.4 Cylinder Split tensile Test: In this test the cylindrical specimens were kept horizontally so that its axis was parallel to the compressive plates of the 3000KN digital compression testing machine. Narrow strips of the packing material i.e., plywood was placed between the plates and the cylinder to receive compressive load. The load was applied uniformly until the cylinder fails. Split tensile strength results of cylinder are tabulated in table 4 and values are graphically presented in figure 4.

6.5 Modulus of elasticity: The theoretical modulus of elasticity was calculated using IS code formula.

$E=5000*\sqrt{f_{ck}}$ [9] Where,
f_{ck} = Characteristic Compressive strength of concrete in N/mm^2 The modulus of elasticity values were also calculated from the other empirical formula suggested by Takafumi[10] for light weight concrete.

$E=k_1k_2*1.486*10^{-3}*f_{ck}^{1/3}*\gamma^2$

Where f_{ck} = Compressive strength in N/mm^2, γ = Density in Kg/m^3, K_1 =0.95 (correction factor corresponding to coarse aggregate), K_2 =1.026, (correction factor corresponding to mineral admixtures).
The values of the modulus of Elasticity are tabulated in table 5 and values are graphically presented in figure 5.

6.6 Mode II fracture test: For testing DCN specimens of size 150x150x150mm, notches were introduced at one third portion centrally during casting. The Mode II fracture test on the DCN cubes was conducted on 3000KN digital compression testing machine. The rate of loading applied is 0.5 KN/sec. Test results are shown in table 8 and presented graphically vide in figure 6. Uniformly distributed load was applied over the central one third part between the notches and steel supports of square cross section were provided at bottom along the outer edges of the notches, so that the central portion could get punched/ sheared through along the notches on the application of loading.

6.6.1 In-Plane shear strength: The in plane strength of modified concrete was calculated using the formula
In plane shear strength = $P/2*d(d-a)$ N/mm^2
Where P= Ultimate load in mode-II shear
d= size of the cube = 150mm
a= depth of notch in mm
The values of plane shear strength of modified concrete for various a/w ratios in mode-II shear are presented in Table 9 and values are presented graphically in figure 7.

Table1: Compressive strength of cubes

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Cube compressive strength in N/mm^2	Percentage increase or decrease of compressive strength
MIX 1	100	100	0	41.08	0.0
MIX 2	100	75	25	34.06	-17.10
MIX 3	100	50	50	29.41	-28.40
MIX 4	100	25	75	26.64	-35.20
MIX 5	100	0	100	24.06	-41.40

Table 2: Flexural strength of beams

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Flexural strength in N/mm^2	Percentage increase or decrease of flexural strength
MIX 1	100	100	0	3.21	0.0
MIX 2	100	75	25	3.04	-5.25
MIX 3	100	50	50	2.66	-17.05
MIX 4	100	25	75	2.28	-28.86
MIX 5	100	0	100	1.69	-47.22

Table 3: Compressive strength of Cylinders

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Cylinder compressive strength in N/mm^2	Percentage increase or decrease of compressive strength
MIX 1	100	100	0	28.01	0.00
MIX 2	100	75	25	25.16	-10.17
MIX 3	100	50	50	21.30	-23.97
MIX 4	100	25	75	19.82	-29.24
MIX 5	100	0	75	17.43	-37.77

Table 4: Split tensile strength of Cylinders

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Split tensile strength in N/mm^2	Percentage increase or decrease of compressive strength
MIX 1	100	100	0	3.58	0.00
MIX 2	100	75	25	2.88	-19.61
MIX 3	100	50	50	2.67	-25.54
MIX 4	100	25	75	2.48	-30.81
MIX 5	100	0	75	2.04	-42.93

Table 5: Modulus of elasticity

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Modulus of elasticity in N/mm^2		Percentage increase or decrease of modulus of elasticity based on Empirical formula
				IS code formula	Empirical formula	
MIX 1	100	100	0	3.21	2.87	0
MIX 2	100	75	25	2.92	2.46	-14.23
MIX 3	100	50	50	2.71	2.03	-29.34
MIX 4	100	25	75	2.58	1.68	-41.52
MIX 5	100	0	100	2.45	1.45	-49.42

Table 6: Density

Mix	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Density in Kg/m^3	Percentage increase or decrease in density
MIX 1	100	100	0	2397.04	0
MIX 2	100	75	25	2290.37	-4.45
MIX 3	100	50	50	2130.37	-11.12
MIX 4	100	25	75	1970.37	-17.80
MIX 5	100	0	100	1863.70	-22.25

Table 7:Ratio of cylinder strength to cube strength

mix	% Volume replacement of Cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	Cylinder strength	Cube strength	Ratio of cylinder strength to cube strength
MIX 1	100	100	0	28.01	41.08	0.68
MIX 2	100	75	25	25.16	34.06	0.74
MIX 3	100	50	50	21.30	29.41	0.72
MIX 4	100	25	75	19.82	26.64	0.74
MIX 5	100	0	100	17.43	24.06	0.72

Table 8: Ultimate loads in Mode -II fracture test

MIX	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
				Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load	Ultimate Load in KN	%increase or decrease of ultimate load
MIX 1	100	100	0	144	0	105	0	95	0	90	0
MIX 2	100	75	25	142	-1.38	93	-11.43	90	-5.26	88	-2.57
MIX 3	100	50	50	127	-11.80	88	-16.19	76	-20	69	-23.98
MIX 4	100	25	75	123	-14.35	78	-25.71	65	-31.58	67	-25.45
MIX 5	100	0	100	90	-37.26	60	-42.54	52	-45.26	35	-60.88

Table 9: In plane shear stress and percentage increase or decrease of in plane shear

MIX	% Volume replacement of cement	% Volume replacement of coarse aggregate	% Volume replacement of LECA	a/w=0.3		a/w=0.4		a/w=0.5		a/w=0.6	
				In plane shear strength N/mm^2	%increase or decrease of in plane shear strength	In plane shear strength N/mm^2	%increase or decrease of in plane shear strength	In plane shear strength N/mm^2	%increase or decrease of in plane shear strength	In plane shear strength N/mm^2	%increase or decrease of in plane shear strength
MIX 1	100	100	0	4.57	0	3.88	0	4.22	0	5.01	0
MIX 2	100	75	25	4.50	-1.38	3.44	-11.42	4.00	-5.26	4.88	-2.57

MIX 3	100	50	50	4.03	-11.8	3.25	-16.19	3.37	-20	3.81	-23.98
MIX 4	100	25	75	3.90	-14.58	2.88	-25.71	2.88	-31.57	3.74	-25.45
MIX 5	100	0	100	2.85	-37.5	2.23	-42.54	2.31	-45.26	1.96	-60.88

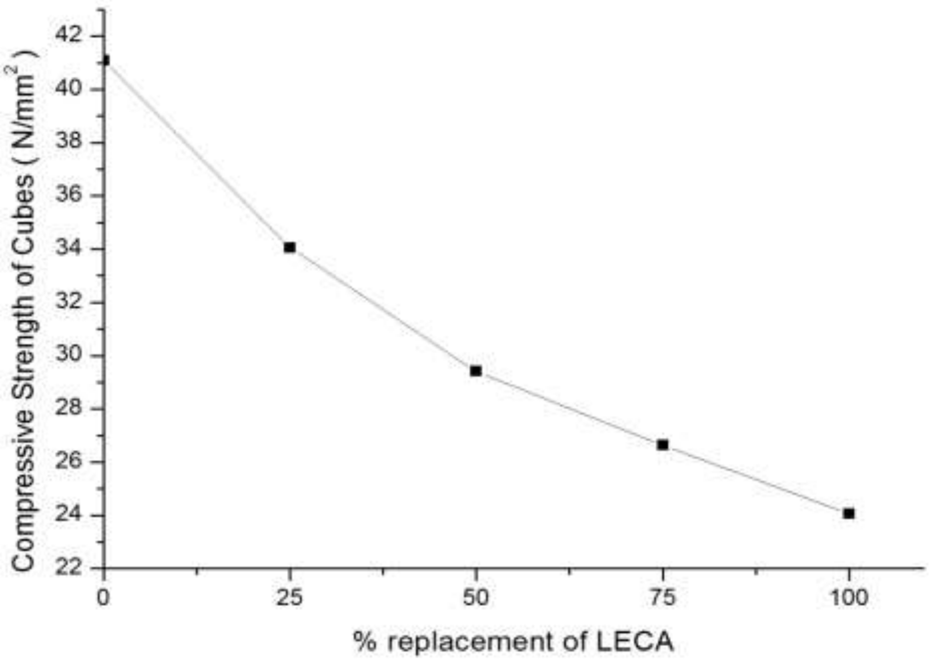

Figure 2: compressive strength of cubes

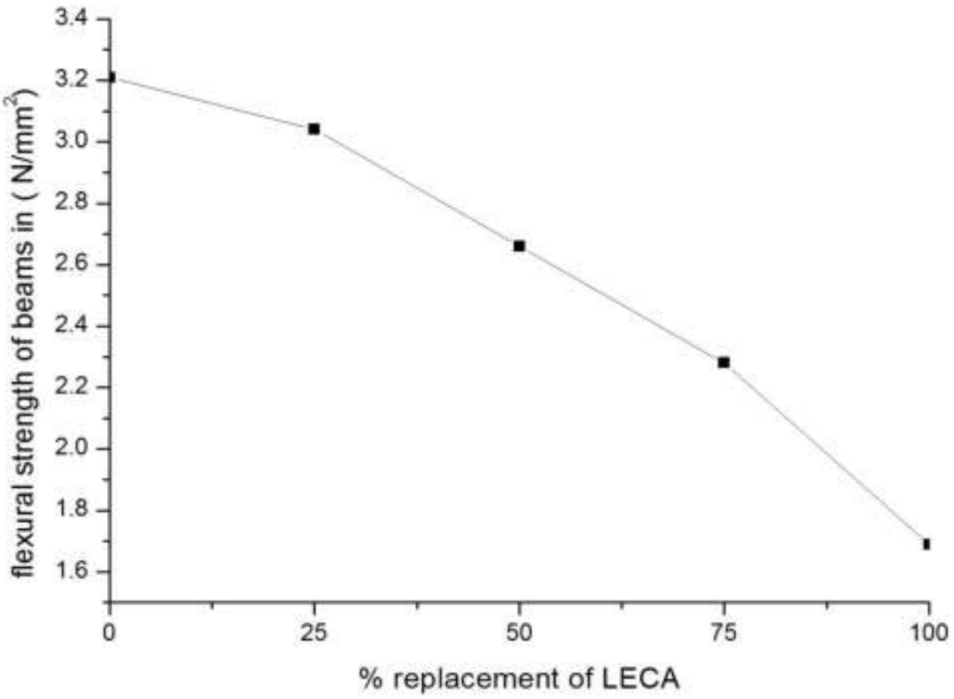

Figure 3: flexural strength of beams

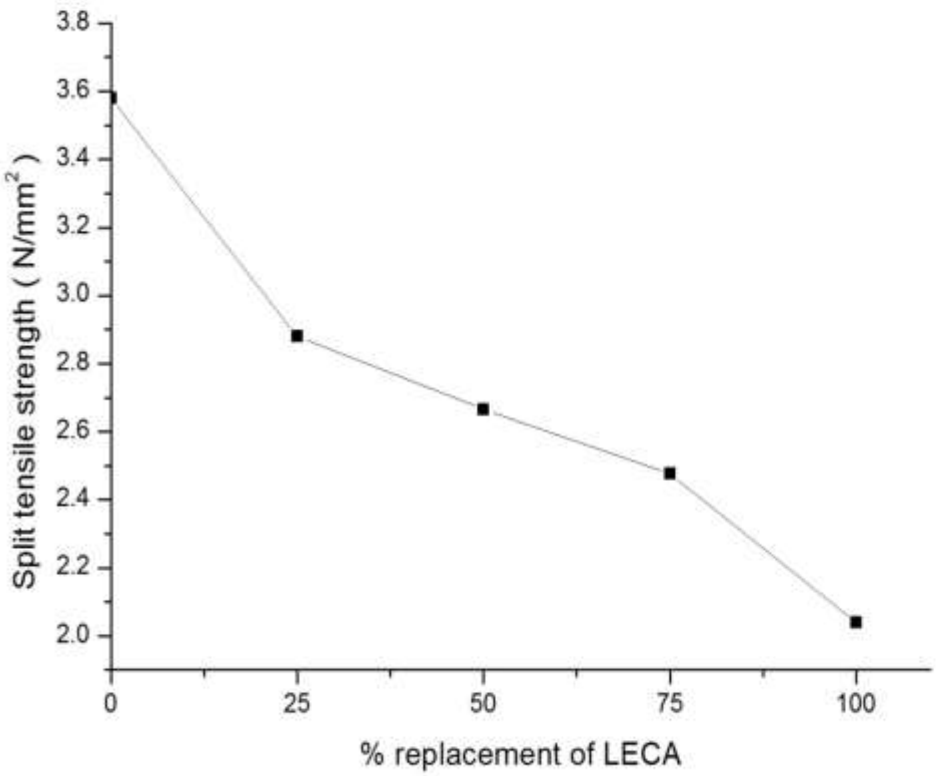

Figure 4: split tensile strength of cylinder

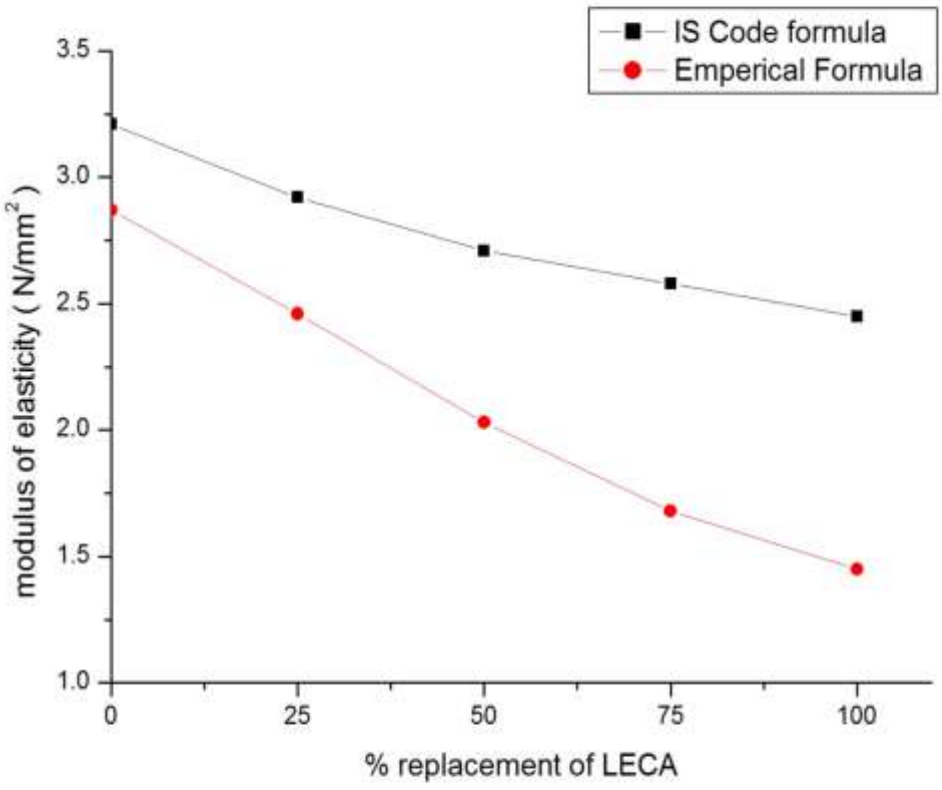

Figure 5: modulus of elasticity

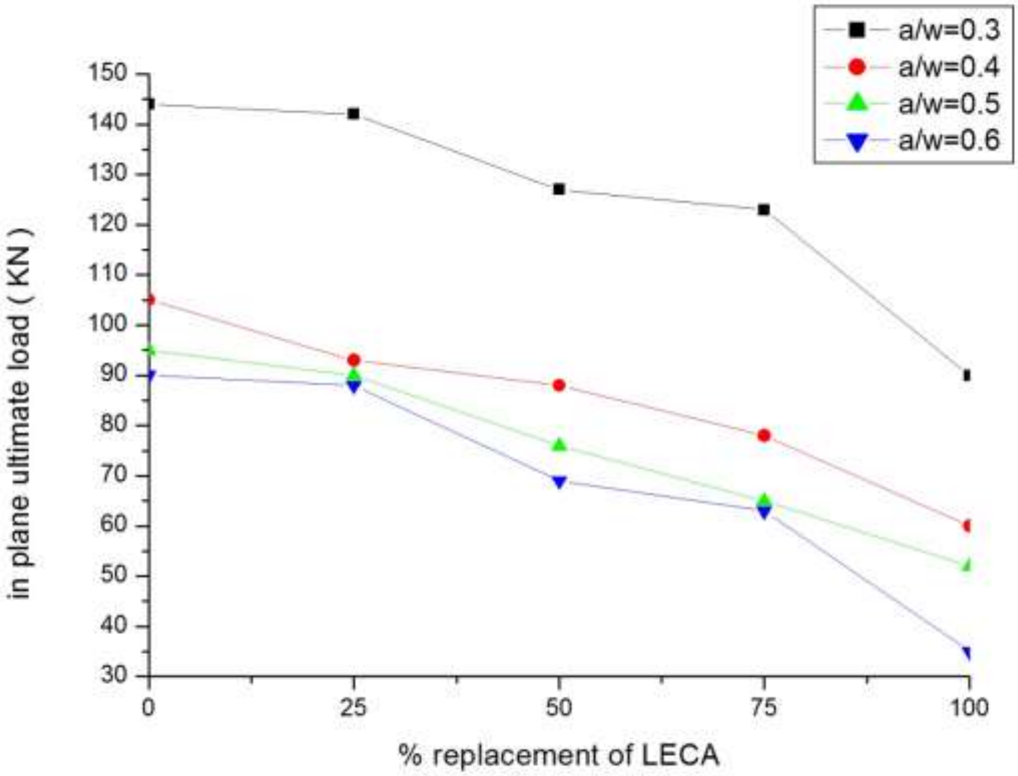

Figure 6: super imposed loads for different a/w ratios

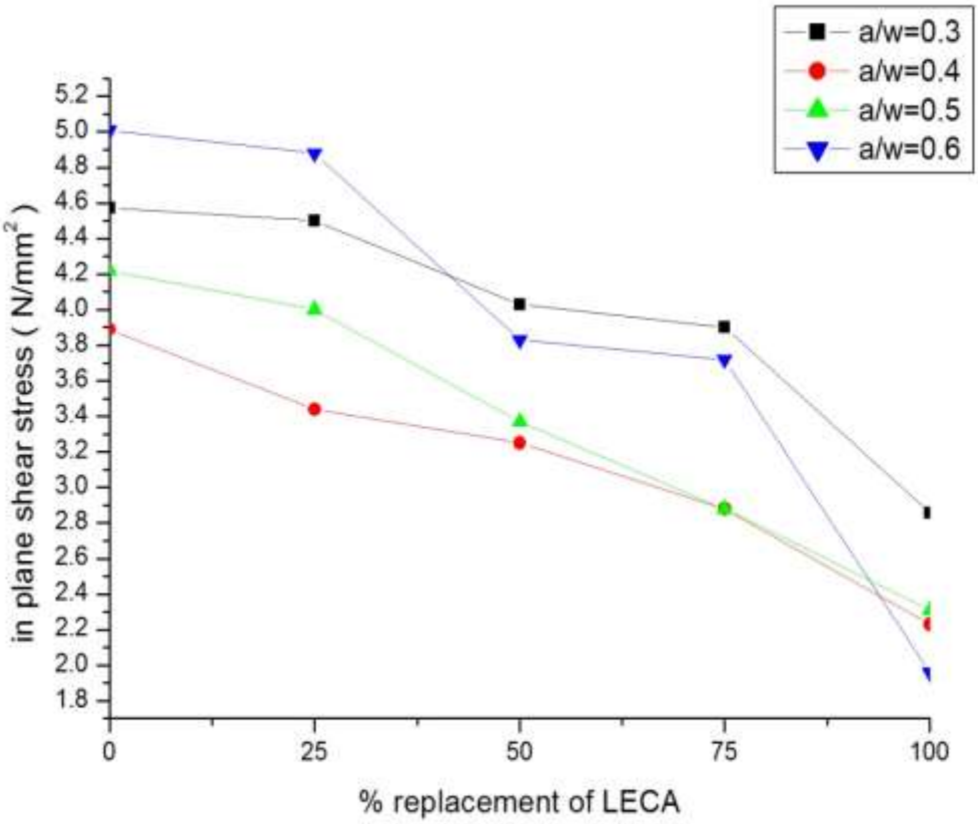

Figure 7: In plane shear stress for different a/w ratios

7. DISCUSSION OF TEST RESULTS

Influence of replacement with LECA over compressive strength:

In the present study natural aggregate has been replaced with light expandable clay aggregates (LECA) with varying percentages of 0, 25, 50, 75 and 100% of natural coarse aggregate. The cube compressive strength is presented vide table 1 and graphically represented vide figure 2. From them it is found that the cube compressive strength is decreased continuously with increase in percentage replacement of LECA. Also it can be observed that even with 75% replacement target mean strength is achieved which is our prime motto. However even with 75% replacement the strength decrease is only around 35%.

Influence of LECA on flexural strength of beam specimens

In the present study natural aggregate has been replaced with light expandable clay aggregates (LECA) with varying percentages of 0, 25, 50, 75 and 100% of natural coarse aggregate. The flexural strength results are tabulated in table 2 and graphically shown in figure 3. The flexural strength of beams is decreased continuously with increase in percentage replacement of LECA. However even with 75% replacement the strength decrease is only around 29%.

Influence of LECA on split tensile strength of specimens:

From figure 3 it can be noticed that the split tensile strength of cylinder decreases from 0% to 100% replacement of LECA. However even with 75% replacement the strength decrease is only 31%.

Influence of LECA on modulus of elasticity:

The modulus of elasticity results with various percentages of LECA are presented in table 5 for 28 days based on IS code empirical formula and the other empirical formula as suggested in the literature. From the results it is observed that modulus of elasticity has been decreased continuously up to 100% replacement of LECA. It is also observed that the modulus of elasticity values calculated from IS codes are slightly higher when compared with those calculated by the other empirical formula. The graphical variation is presented in figure 5.

Discussion on the effect of LECA on in plane shear strength

All the DCN specimens with different a/w ratios i.e 0.3, 0.4, 0.5 and 0.6 and with different percentages of LECA were tested with load in Mode-II (in plane shear). The variations of ultimate loads and percentage increase or decrease in ultimate loads verses percentage replacement of cement with LECA are presented in table 6 which are presented for different a/w ratios after 28 days of curing. The values are decreased from 0% to 100% replacement of LECA as shown in figure 6. However even with 75% replacement the strength decrease is only around 25%.

Influence of LECA on Density:

From table 6 it can be construed that the density of the specimens decreases with increase in replacement levels of LECA.

8. CONCLUSIONS

- The target mean strength of M_{20} concrete is 26.60 N/ mm^2. From the experimental study it is observed that the 28 days cube compressive strength of modified concrete with 100% Light Expandable Clay aggregate is 24.06 N/ mm^2 which is slightly nearer to the target mean strength of M_{20} concrete. Also it can be observed that compressive strength of 26.64 N/mm^2 is achieved even with 75% replacement of natural aggregate with LECA which is nearer to the target mean strength of M_{20} concrete.
- From the test results it can be observed that flexural strength, split tensile strength and density decreases with increase in replacement level of LECA. However the percentage decrease even with 75% replacement is only around 30%.
- From the analysis of test results it is observed that in plane shear stress decreases with increase in replacement level of LECA. However even with 75% replacement level the percentage decrease is around 31%.
- The light weight concrete prepared by 100% Light expandable Clay aggregate as coarse aggregate is in no way inferior to the natural aggregate.

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