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A Comparative Study of Normal Concrete Modified With Light Weight Expandable Clay Aggregate and Copper Slag

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ABSTRACT
Major disadvantages of the ordinary concrete are the high self weight of the concrete and the scarcity of natural resources. An attempt is made for the reduction of the self weight of concrete and the scarcity of natural resources along with increase in the strength and efficiency of the concrete. This experimental research is to analyze the strength parameters of M25 grade concrete made with substitution of ordinary coarse aggregates with various proportions of Light weight expandable clay aggregates (LECA) ranging from 0%, 25%, 50%, 75% and 100% and again for each proportion, natural fine aggregate is replaced with various percentages of copper slag ranging from 0%, 25%, 50%, 75% and 100%. Thus totally 600 concrete specimens are made with 25 mixes. Later 28 days of curing, various strength tests are conducted on the all specimens of modified M25 grade concrete i.e., compression, split tensile, flexural In-plane shear strength through mode-II fracture and impact test. The main intention of this project is to understand better and compare the various strength parameters with those of conventional M25 grade concrete. The obtained end test values are examined to be satisfactory.

Keywords: Light weight expandable clay aggregate (Leca), Copper slag, compression, Split tensile, Flexural, In- plane shear, Impact strength.

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I. INTRODUCTION

In design of concrete structures, the natural resources like coarse aggregates and fine aggregates are being used widely. Utility of these natural resources is increasing day by day due to urbanization and industrialization, and this is become a major concern due to its hazardous effect to environment and making serious imbalance to ecosystem. This leads to look for alternative materials to substitute natural resources. Disposal of solid waste and by-products produced from various factories and industries is major concern in developing countries like India, as it makes environment being more polluted. Many researches have proved that concrete made with industrial waste and by-products has shown excellent properties. Hence, in this project coarse aggregate is substituted with Light expandable clay aggregate (Leca) and normal sand is substituted with copper slag.

LECA is produced by heating clay up to a 1200 C in a revolving kiln. Density of these aggregates ranges from 360-700 kg/m^3 depending upon the size. It has very good thermal insulation, sound insulation and fire resistance, so that Leca can be used instead of coarse aggregate in the concrete. Similarly, Copper slag is a squander material which is obtained during smelting of copper in the extraction process which is used instead of natural fine aggregate in the concrete.

II. LITERATURE REVIEW

M.V. Patel [1] examined the effect of replacement of fine aggregate with copper slag in 10%, 20%, 30%, 40%, 50%, 60%, 80% and 100% and concluded that as the percentage of copper slag increases compressive strength and flexural strength also increases. And at the 60% replacement of copper slag, the strength of concrete in compression will be higher than the ordinary concrete.

Naveed A shaik [2] Stated that copper slag can be used as filler material in building industry and concluded that 40% replacement of copper slag gives maximum strength in concrete.

Sumathy raju [3] presented his research work on substitution of normal sand with copper slag for 0%, 10%, 20%, 30%, 40%, 50% and 60% and concluded that up to 50 % of replacement strength will be increases.

Hanamanth Shebannavar [4] made a report on the utilization of light weight aggregate for getting low density concrete. After curing for 28 days, in the modified M20 grade concrete, by replacing 100% natural coarse aggregate with light weight expandable clay aggregate (Leca), the concrete density was reduced by 35%

Lokesh Kumar [5] stated that concrete made of 100% lightweight expandable aggregates is by no means inferior to natural aggregates.

III. OBJECTIVE

1. To evade the scarcity of natural resources used in the building industry by replacing with industrial waste and by-products.
2. To determine the strength parameters of modified concrete made with Leca instead of coarse aggregate and copper slag instead of normal sand and compare with those of conventional concrete.

IV. MATERIALS USED

Cement: In this project, OPC 53 grade is used.

Normal Fine aggregate (sand): River sand brought from locally available chitravathi river which passes through 4.75 mm sieve and confirms to grading zone – II of IS: 383-1970 is used.

Conventional coarse aggregate: Regionally available crushed stone aggregate of maximum size of 20 mm confirming to IS: 383-1970 is used.

Light Expandable Clay Aggregate: These aggregates brought from LITAGG industries Pvt Ltd, Ahmedabad, Gujarat and used in the present work.

Copper slag: Copper slag is brought from Sri Srinivasa Metallizers, Hyderabad, Telangana.

Water: Regionally obtainable potable tap water is used for mixing and curing.

Table 1: Characteristics of Elementary Materials

<table>
<tr><th colspan="2">Characteristics of Cement</th><th>Specific gravity</th><th colspan="2">Normal consistency</th><th>Initial setting time</th><th colspan="2">Final setting time</th><th>Fineness</th></tr>
<tr><td colspan="2">Test values</td><td>3.15</td><td colspan="2">31%</td><td>50 minutes</td><td colspan="2">580 minutes</td><td>5.4%</td></tr>
<tr><th colspan="2">Characteristics of Fine aggregate</th><th colspan="2">Specific gravity</th><th colspan="3">Fineness modulus</th><th colspan="2">Water absorption</th></tr>
<tr><td rowspan="2">Test values</td><td>Natural Fine aggregate</td><td colspan="2">2.61</td><td colspan="3">2.7</td><td colspan="2">0.5%</td></tr>
<tr><td>Copper slag</td><td colspan="2">3.54</td><td colspan="3">2.53</td><td colspan="2">0.55%</td></tr>
<tr><th colspan="2">Characteristics of Coarse aggregate</th><th colspan="2">Specific gravity</th><th colspan="3">Bulk density compacted</th><th colspan="2">Water absorption</th></tr>
<tr><td rowspan="2">Test values</td><td>Natural Coarse aggregate</td><td colspan="2">2.67</td><td colspan="3">1620 kg/m^3</td><td colspan="2">0.25%</td></tr>
<tr><td>Light weight expandable aggregates</td><td colspan="2">1.18</td><td colspan="3">645 kg/m^3</td><td colspan="2">18%</td></tr>
</table>

V. EXPERIMENTAL WORK

Concrete mix is prepared with obtained mix proportion with various replacements such as coarse aggregate is replaced by Light expandable clay aggregate in amounts of 0%, 25%, 50%, 75%, 100% and fine aggregate is replaced by Copper slag in amounts of 0%, 25%, 50%, 75%, 100% with each percentage replacement of coarse aggregate. Mix is made with various percentage replacements and poured into the moulds in the form of three layers each layer being well compacted and vibrated. In this way, all specimens are cast and tested for various strengths after 28 days of curing.

Thus totally 25 mixes are prepared and all these 25 mixes are again divided into 5 sets and each set consists of 5 different mix proportions.

1. Compression test for 3 cubes having size of 150mmx150mmx150mm.
2. Split tensile strength for 3 cylinders having size of 300(height)mmx150(dia)mm.

3. Flexural test for beams having size of 100mmx100mmx500mm.
4. In-plane shear test for 3 cubes having size150mmx150mmx150mm with notches a/w = 0.3, 0.4, 0.5 and 0.6 through mode-II fracture shear test.
5. Impact strength test for circular discs having size of 150(dia)mmx75(hight)mm.

5.1 Mix design

Mix design is made in accordance with the guidelines of Indian Standard 10262:2009 code book for M_{25} grade concrete. The mix ratio obtained is 1: 1.52: 2.62 (C: FA: CA) with constant w/c ratio of 0.45. Thus totally 25 mixes are prepared. All these 25 mixes are again divided into 5 sets and each set consists of 5 different mix proportions as shown in table 2.

Table: 2 Design Details of specimens

Set 1										
S.No	Name of the Mix	Coarse Aggregate		Fine Aggregate		No of Specimens cast and tested				
		NCA (%)	LECA (%)	NFA (%)	CS (%)	Cubes	Cylinders	Beams	DCN Cubes	Impact Discs
1	V1	100	0	100	0	3	3	3	12	3
2	V2	100	0	75	25	3	3	3	12	3
3	V3	100	0	50	50	3	3	3	12	3
4	V4	100	0	25	75	3	3	3	12	3
5	V5	100	0	0	100	3	3	3	12	3

Set 2										
S.No	Name of the Mix	Coarse Aggregate		Fine Aggregate		No of Specimens cast and tested				
		NCA (%)	LECA (%)	NFA (%)	CS (%)	Cubes	Cylinders	Beams	DCN Cubes	Impact Discs
6	V6	75	25	100	0	3	3	3	12	3
7	V7	75	25	75	25	3	3	3	12	3
8	V8	75	25	50	50	3	3	3	12	3
9	V9	75	25	25	75	3	3	3	12	3
10	V10	75	25	O	100	3	3	3	12	3

Set 3										
S.No	Name of the Mix	Coarse Aggregate		Fine Aggregate		No of Specimens cast and tested				
		NCA (%)	LECA (%)	NFA (%)	CS (%)	Cubes	Cylinders	Beams	DCN Cubes	Impact Discs
11	V11	50	50	100	0	3	3	3	12	3
12	V12	50	50	75	25	3	3	3	12	3
13	V13	50	50	50	50	3	3	3	12	3

14	V14	50	50	25	75	3	3	3	12	3
15	V15	50	50	0	100	3	3	3	12	3

Set 4										
S.No	**Name of the Mix**	**Coarse Aggregate**		**Fine Aggregate**		**No of Specimens cast and tested**				
		NCA (%)	**LECA (%)**	**NFA (%)**	**CS (%)**	**Cubes**	**Cylinders**	**Beams**	**DCN Cubes**	**Impact Discs**
16	V16	25	75	100	0	3	3	3	12	3
17	V17	25	75	75	25	3	3	3	12	3
18	V18	25	75	50	50	3	3	3	12	3
19	V19	25	75	25	75	3	3	3	12	3
20	V20	25	75	0	100	3	3	3	12	3

Set 5										
S.No	**Name of the Mix**	**Coarse Aggregate**		**Fine Aggregate**		**No of Specimens cast and tested**				
		NCA (%)	**LECA (%)**	**NFA (%)**	**CS (%)**	**Cubes**	**Cylinders**	**Beams**	**DCN Cubes**	**Impact Discs**
21	V21	0	100	100	0	3	3	3	12	3
22	V22	0	100	75	25	3	3	3	12	3
23	V23	0	100	50	50	3	3	3	12	3
24	V24	0	100	25	75	3	3	3	12	3
25	V25	0	100	0	100	3	3	3	12	3

NCA = Natural coarse aggregate, **LECA** = Light Expandable Clay aggregate
NFA = Natural fine aggregate, **CS** = Copper slag

Here V1 mix represents the conventional concrete.
Therefore the total concrete specimens cast and tested are 600.

VI. TESTING

6.1 Compressive strength for cubes

This test is done by compression testing machine (CTM) having a capacity 2 MN (Mega Newton). Cube specimens are placed in such away between the plates that the load is applied concentrically on the cube. Load is applied at the rate of 14 N/mm^2/sec till the concrete specimen fails and the load at failure is taken as ultimate load. Ultimate load divided by the cross sectional area of the specimen gives compressive strength value. The obtained results of all 25 mixes are shown as 5 sets in table 3 and values are shown graphically in figures 1(a)&1(b).

Table 3: Compressive Strength results

Set 1			Set 2		
Name of the mix	**Cube compressive strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Cube compressive strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V1	34.44	0.00	V6	30.85	-10.42
V2	37.88	9.99	V7	34.12	-0.93
V3	40.61	17.92	V8	37.38	8.54
V4	38.03	10.42	V9	35.69	3.63
V5	35.89	4.21	V10	32.54	-5.52
Set 3			**Set 4**		
Name of the mix	**Cube compressive strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Cube compressive strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V11	28.23	-18.03	V16	26.40	-23.34
V12	33.38	-3.08	V17	29.65	-13.91
V13	35.74	3.77	V18	32.85	-4.62
V14	33.92	-1.51	V19	30.72	-10.80
V15	30.80	-10.57	V20	27.18	-21.08
Set 5					
Name of the mix	**Cube compressive strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**			
V21	23.87	-30.69			
V22	28.54	-17.13			
V23	31.12	-9.64			
V24	28.67	-16.75			
V25	26.13	-24.13			

6.2 Split Tensile strength for cylinders

In this test, the cylinder specimen is held on a level plane such that its axis is in the direction of compressive plates of the machine having a capacity of 2 MN. Load is applied uniformly on the specimen until the specimen fails by compression. The obtained test results of all 25 mixes are shown as 5 sets in below table 4 and test values are shown in graphical format in figures 2(a)&2(b).

Table 4: Split tensile strength test results

Set 1			Set 2		
Name of the mix	**Split tensile strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Split tensile strength(N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V1	3.73	0.00	V6	3.27	-12.33
V2	3.92	5.09	V7	3.48	-6.70
V3	4.22	13.14	V8	3.90	4.56
V4	4.05	8.58	V9	3.77	1.07

V5	3.98	6.70	V10	3.42	-8.31
Set 3			**Set 4**		
Name of the mix	**Split tensile strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Split tensile strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V11	2.87	-23.06	V16	2.58	-30.83
V12	3.05	-18.23	V17	2.72	-27.08
V13	3.48	-6.70	V18	3.14	-15.82
V14	3.31	-11.26	V19	2.93	-21.45
V15	3.08	-17.43	V20	2.77	-25.74
Set 5					
Name of the mix	**Split tensile strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**			
V21	2.35	-37.00			
V22	2.58	-30.83			
V23	2.84	-23.86			
V24	2.66	-28.69			
V25	2.53	-32.17			

6.3 Flexural strength for beams
Flexural strength is a tensile strength of concrete specimen which is to withstand against a failure in bending. This test is performed by two point load method and the deflections are recorded through dial gauges. Test results of all 25 mixes of 5 sets are shown in below table 5 and test values are shown in graphical format figures 3(a)&3(b).

Table 5: Flexural strength test results of beams

Set 1			**Set 2**		
Name of the mix	**Flexural strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Flexural strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V1	3.75	0.00	V6	3.31	-11.73
V2	3.93	4.80	V7	3.56	-5.07
V3	4.31	14.93	V8	4.01	6.93
V4	4.125	10.00	V9	3.85	2.67
V5	3.92	4.53	V10	3.42	-8.80
Set 3			**Set 4**		
Name of the mix	**Flexural strength (N/mm2) (28 Days)**	**Percentage variation of strength (%)**	**Name of the mix**	**Flexural strength (N/mm2) (28 Days**	**Percentage variation of strength (%)**
V11	2.92	-22.13	V16	2.63	-29.87
V12	3.05	-18.67	V17	2.68	-28.53
V13	3.60	-4.00	V18	3.08	-17.87
V14	3.42	-8.80	V19	2.98	-20.53
V15	3.17	-15.47	V20	2.80	-25.33

Set 5		
Name of the mix	**Flexural strength(N/mm2) (28 Days)**	**Percentage variation of strength (%)**
V21	2.32	-38.13
V22	2.53	-32.53
V23	2.90	-22.67
V24	2.71	-27.73
V25	2.58	-31.20

6.4 Mode-II Fracture test:

To find in-plane shear strength of the concrete, DCN cube specimens of size 150x150x150mm are cast with two notches that are placed at one third portion centrally. These doubled central notched specimens are tested on compression machine having a capacity of 3000 KN. The central 1/3 portion between two notches is loaded with a uniformly distributed load, so that the middle 1/3 portion could get sheared along the notches at the time of ultimate load. The test set up and its loading arrangement is presented in below plate 1.

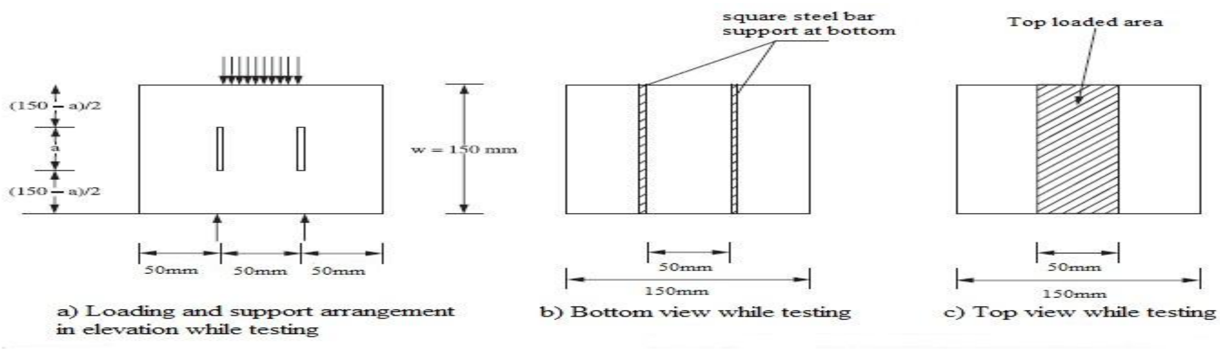

Plate1: Loading pattern of Ultimate shear DCN Specimen

In-plane shear stress: The in-plane shear stress is calculated by the following given expression.
In-plane shear strength (N/mm2) = Shear force(N) / Shear area(mm^2)
Where,

Shear force = P/2, P = Ultimate load (N)
Shear area = d*(w-a)
d= depth of specimen (mm), w= width of specimen
a= notch depth with various sizes 45mm,60mm, 75mm, 90mm

The test results of 25 mixes of 5 sets are tabulated in below table 6 and represented in graphical format in figures 4(a) to 4(e).

Table 6: Ultimate load and In plane shear stresses in mode II shear test results

Set 1								
Name of the mix	**a/w= 0.3**		**a/w= 0.4**		**a/w= 0.5**		**a/w= 0.6**	
	Extreme load (KN) (28 Days)	**In-plane shear strength (N/mm^2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm^2)**
V1	144	4.57	126	4.66	108	4.8	98	5.44

V2	164	5.2	142	5.25	112	4.97	102	5.66
V3	175	5.55	161	5.96	132	5.86	111	6.16
V4	162	5.14	140	5.18	119	5.28	105	5.83
V5	154	4.88	133	4.92	115	5.11	97	5.38

Set 2								
Name of the mix	**a/w= 0.3**		**a/w= 0.4**		**a/w= 0.5**		**a/w= 0.6**	
	Extreme load (KN) (28 Days)	**In-plane shear strength (N/mm^2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm^2)**
V6	132	4.19	116	4.30	102	4.53	93	5.17
V7	143	4.54	128	4.74	105	4.67	97	5.39
V8	155	4.92	148	5.48	122	5.42	104	5.78
V9	142	4.51	126	4.67	109	4.84	99	5.50
V10	138	4.38	123	4.56	106	4.71	94	5.22

Set 3								
Name of the mix	**a/w= 0.3**		**a/w= 0.4**		**a/w= 0.5**		**a/w= 0.6**	
	Extreme load(KN) (28Days)	**In-plane shear strength (N/mm^2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm^2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm^2)**
V11	117	3.71	104	3.85	90	4.00	77	4.28
V12	137	4.35	119	4.41	102	4.53	85	4.72
V13	148	4.70	137	5.07	111	4.93	93	5.17
V14	139	4.41	121	4.48	103	4.58	87	4.83
V15	124	3.94	113	4.19	92	4.09	79	4.39

Set 4								
Name of the mix	**a/w= 0.3**		**a/w= 0.4**		**a/w= 0.5**		**a/w= 0.6**	
	Extreme load(KN) (28Days)	**In-plane shear strength (N/mm2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm2)**	**Extreme load(KN) (28Days)**	**In-plane shear strength (N/mm2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm2)**
V16	101	3.21	93	3.44	81	3.60	71	3.94
V17	117	3.71	107	3.96	88	3.91	75	4.17
V18	136	4.32	127	4.70	107	4.76	89	4.94
V19	115	3.65	100	3.70	90	4.00	78	4.33
V20	109	3.46	96	3.56	85	3.78	74	4.11

Set 5								
Name of the mix	**a/w= 0.3**		**a/w= 0.4**		**a/w= 0.5**		**a/w= 0.6**	
	Extreme load(KN) (28 Days)	**In-plane shear strength (N/mm2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm2)**	**Extreme load (KN) (28 Days)**	**In-plane shear strength (N/mm2)**	**Extreme load(KN) (28 Days)**	**In-plane shear strength (N/mm2)**
V21	96	3.05	86	3.19	76	3.38	66	3.67
V22	109	3.46	98	3.63	89	3.96	75	4.17
V23	127	4.03	116	4.30	99	4.40	84	4.67
V24	112	3.56	103	3.81	88	3.91	77	4.28
V25	104	3.30	96	3.56	82	3.64	71	3.94

6.5 Impact test: To find the impact strength, circular specimens of concrete are made with dimensions of 150mm (diameter) x 75mm (height). After 28 days of curing, the concrete specimens are permitted to dry completely for some time and prepared for testing. Testing equipment which is indigenously made resembles the proctor's testing equipment in the soils lab that consists of steel casing, steel round ball and hammer having weigh of 2.3 kg. Later the concrete specimens are housed in the testing equipment and blows are given to the concrete specimens by the hammer until the specimen gets failed. The number of blows are counted and recorded in this test. These number of blows directly indicate the impact strength of concrete. The results of impact strength of 25 mixes of 5 sets are tabulated in below table 7 and test results are represented in graphical format in figures 5(a)&5(b)

Table 7: Impact strength test results

Set 1			Set 2		
Name of the mix	**Number of Impact blows (28 Days)**	**Percentage variation of blows (%)**	**Name of the mix**	**Number of Impact blows (28 Days)**	**Percentage variation of blows (%)**
V1	655	0.00	V6	602	-8.09
V2	683	4.27	V7	652	-0.46
V3	725	10.69	V8	701	7.02
V4	712	8.70	V9	667	1.83
V5	694	5.95	V10	648	-1.07
Set 3			**Set 4**		
Name of the mix	**Number of Impact blows (28 Days)**	**Percentage variation of blows (%)**	**Name of the mix**	**Number of Impact blows (28 Days)**	**Percentage variation of blows (%)**
V11	533	-18.63	V16	442	-32.52
V12	567	-13.44	V17	468	-28.55
V13	620	-5.34	V18	512	-21.83
V14	586	-10.53	V19	489	-25.34
V15	578	-11.76	V20	472	-27.94

Set 5		
Name of the mix	**Number of Impact blows (28 Days)**	**Percentage variation of blows (%)**
V21	310	-52.67

V22	347	-47.02
V23	402	-38.63
V24	372	-43.21
V25	328	-49.92

VII. GRAPHICAL VARIATION OF TEST RESULTS

7.1 Compression test results:

7.1.1 Compressive strength variation with % Light expandable clay aggregate

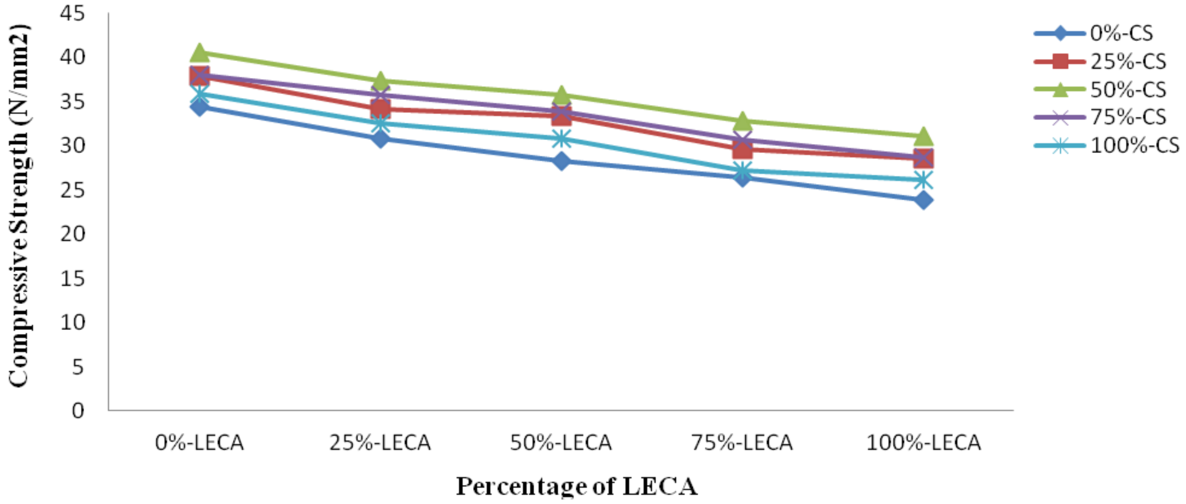

Figure 1(a): Compressive strength of cubes with various percentages of Leca
Where LECA= Light expandable clay aggregate, CS= Copper slag

7.1.2 Compressive strength variation with % Copper slag

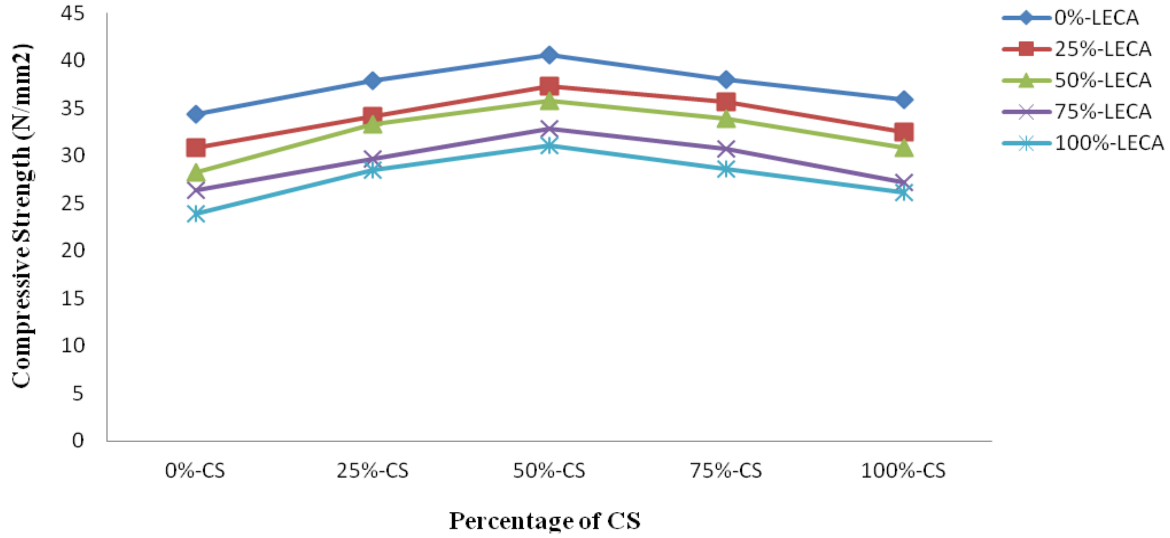

Figure 1(b): Compressive strength of cubes with various percentages of Copper slag
Where LECA= Light expandable clay aggregate, CS= Copper slag

7.2 Split tensile strength test results:

7.2.1 Split Tensile strength variation with % Light expandable clay aggregate

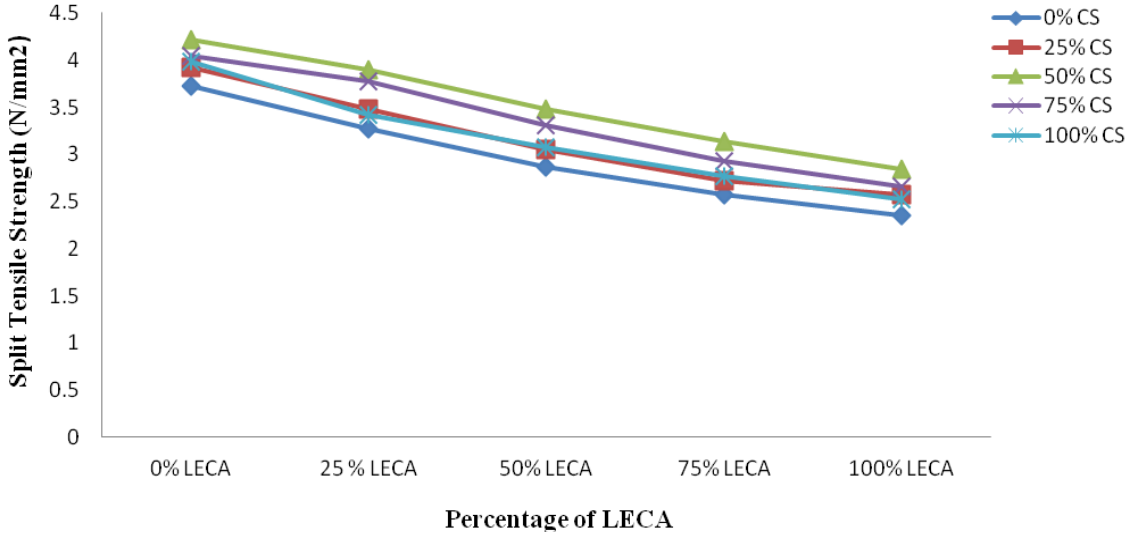

Figure 2(a) : Split Tensile strength results for various percentages of Leca
Where LECA= Light expandable clay aggregate, CS= Copper slag

7.2.2 Split tensile strength variation with % Copper slag

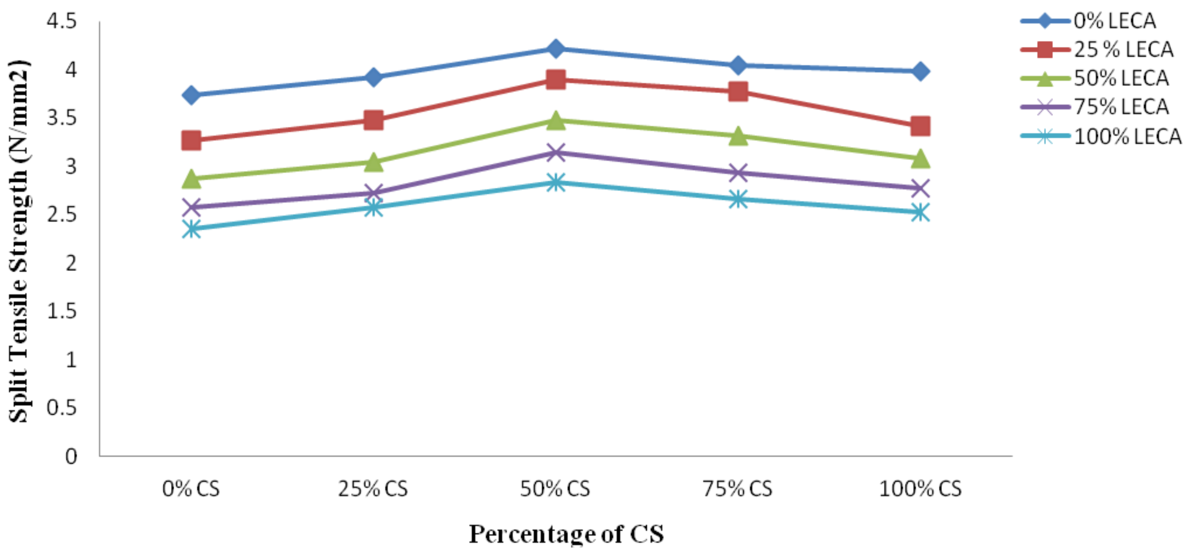

Figure 2(b): Split Tensile strength results for various percentages of copper slag
Where LECA= Light expandable clay aggregate, CS= Copper slag

7.3 Flexural strength test results:

7.3.1 Flexural strength variation with % Light expandable clay aggregate

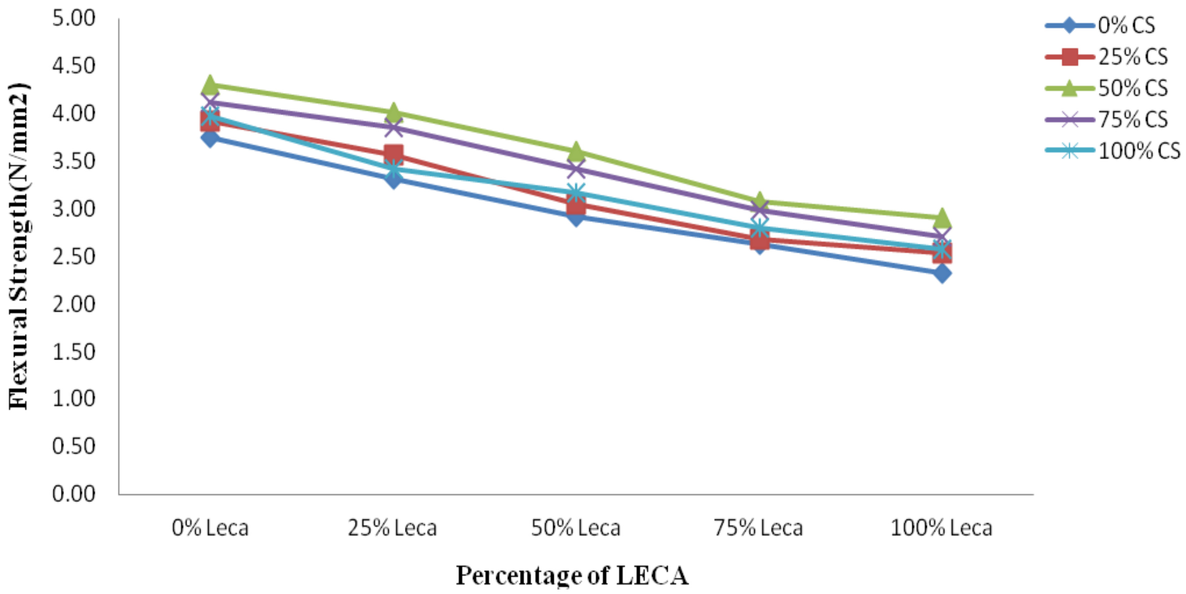

Figure 3(a): Flexural strength results for various percentages of Leca
Where LECA= Light expandable clay aggregate, CS= Copper slag

7.3.2 Flexural strength variation with % Copper slag

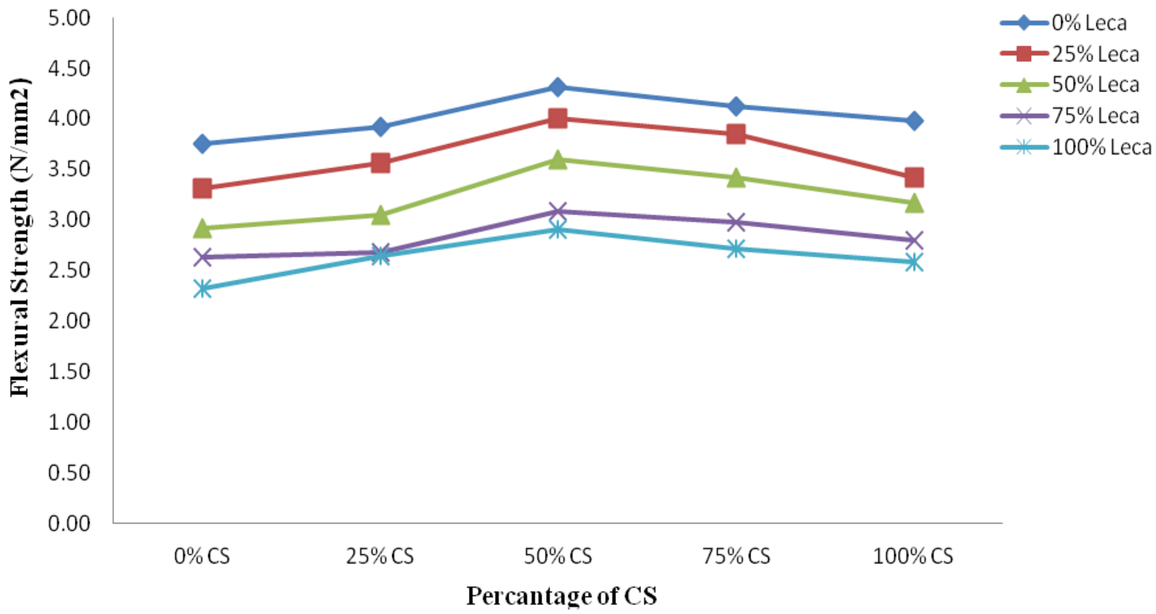

Figure 3(b): Flexural strength results for various percentages of copper slag
Where LECA= Light Expandable clay aggregate, CS= Copper slag

7.4 Mode II Shear strength test results:

7.4.1 In-plane shear stress test results for SET 1 with various notches

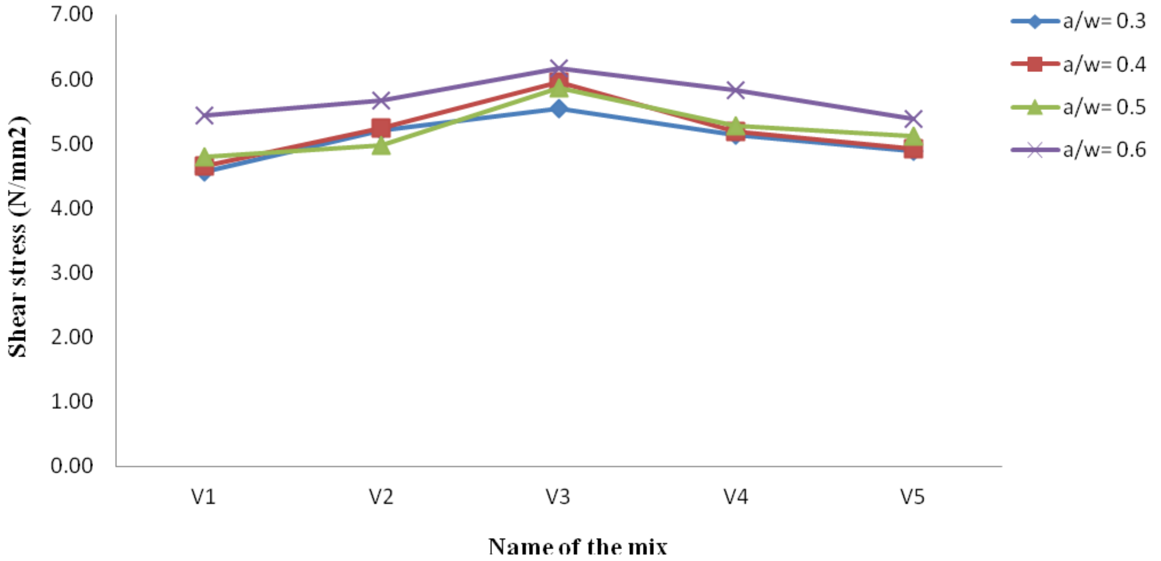

Figure 4(a): In plane shear stress test values of set 1 for various notch sizes

7.4.2 In-plane shear stress test results for SET 2 with various notches

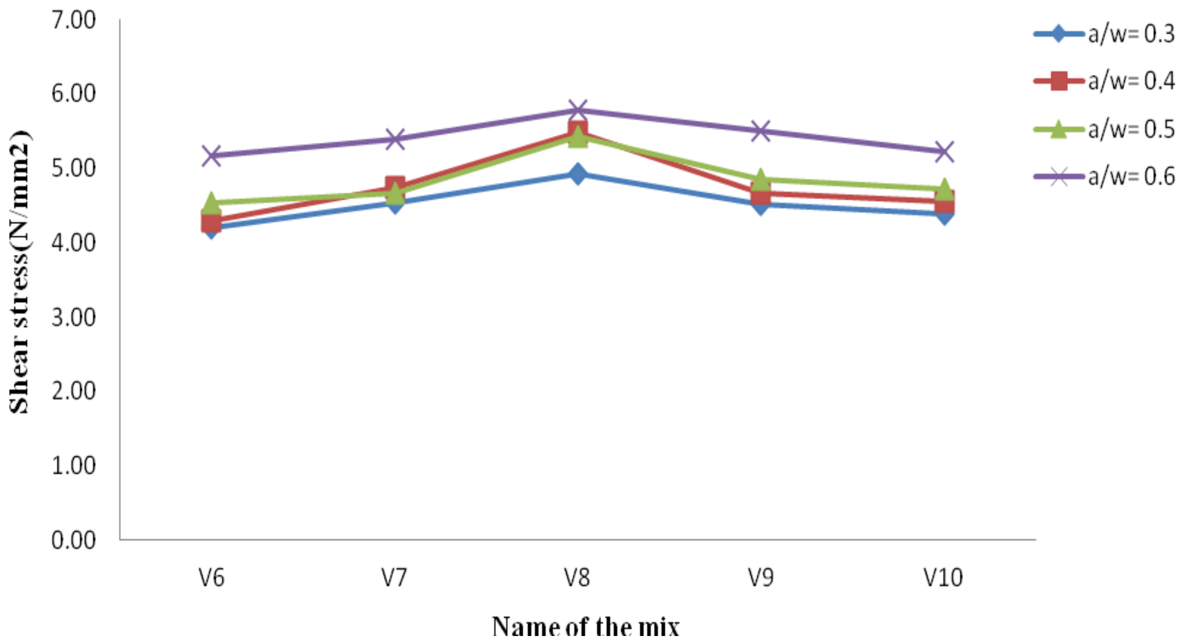

Figure 4(b): In plane shear stress test values of set 2 for various notch sizes

7.431 In-plane shear stress test results for SET 3 with various notches

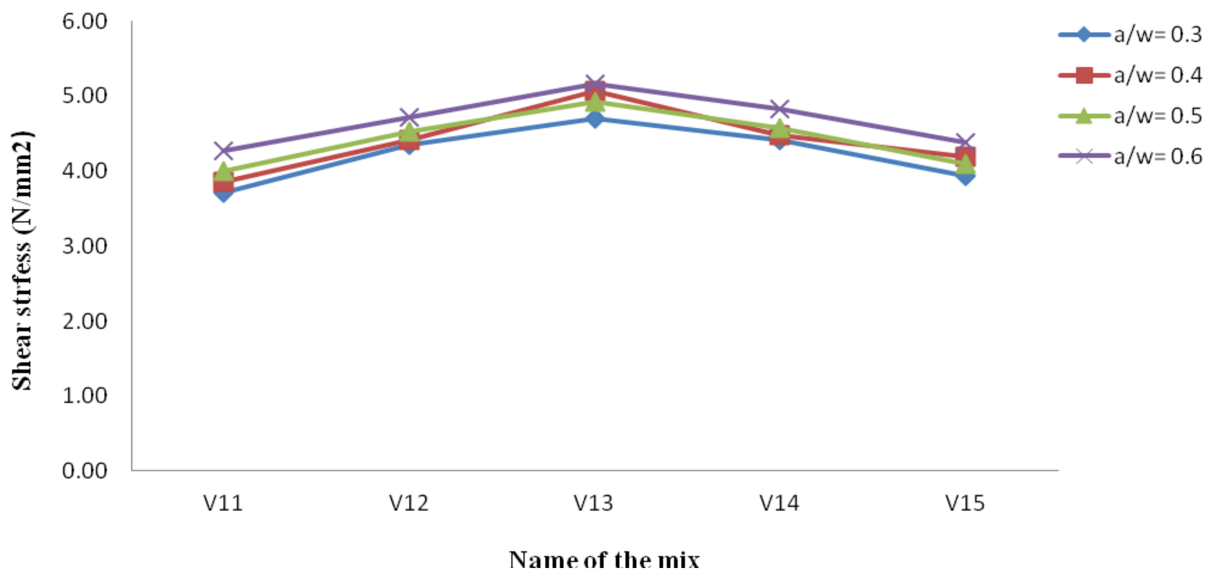

Figure 4(c): In plane shear stress test values of set 3 for various notch sizes

7.4.4 In-plane shear stress test results for SET 4 with various notches

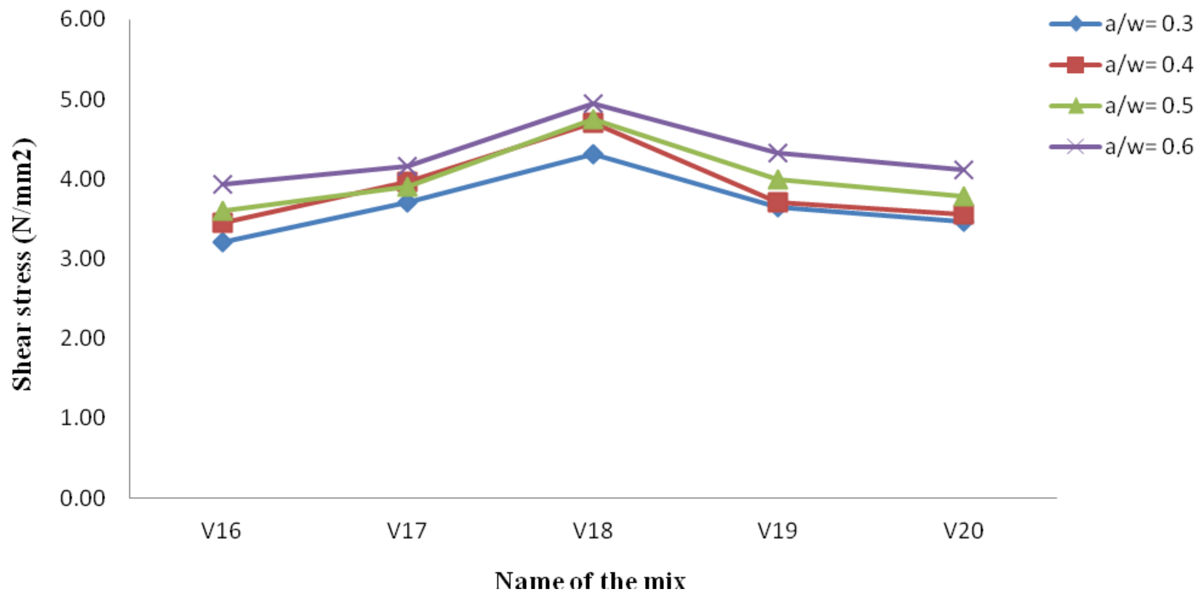

Figure 4(d): In plane shear stress test values of set 4 for various notch sizes

7.4.5 In-plane shear stress test results for SET 5 with various notches

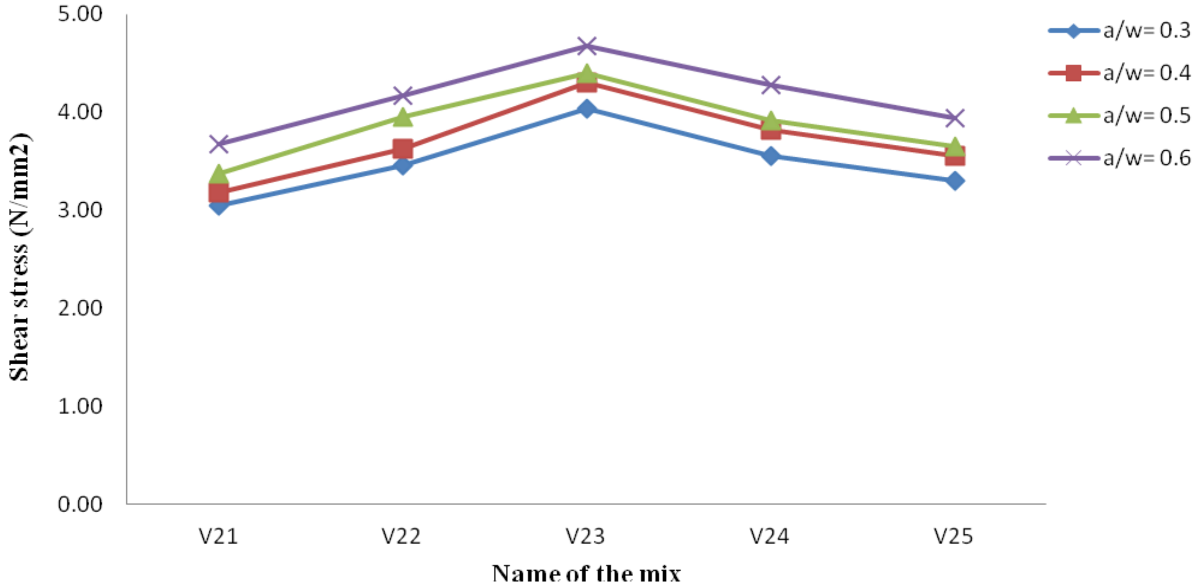

Figure 4(e): In plane shear stress test values of set 5 for various notch sizes

7.5 Impact strength test results:

7.5.1 Impact strength variation with % Light expandable clay aggregate

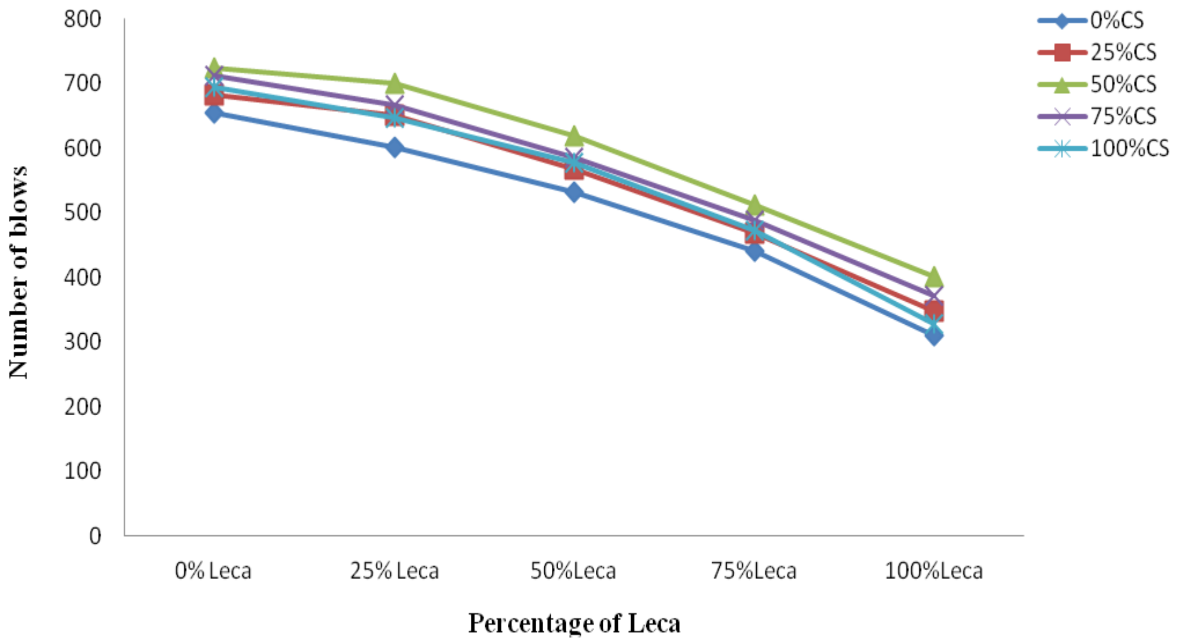

Figure 5(a): Impact strength test results for various percentage of Leca

Where LECA= Light expandable clay aggregate, CS= Copper slag

7.5.2 Impact strength variation with % Copper slag

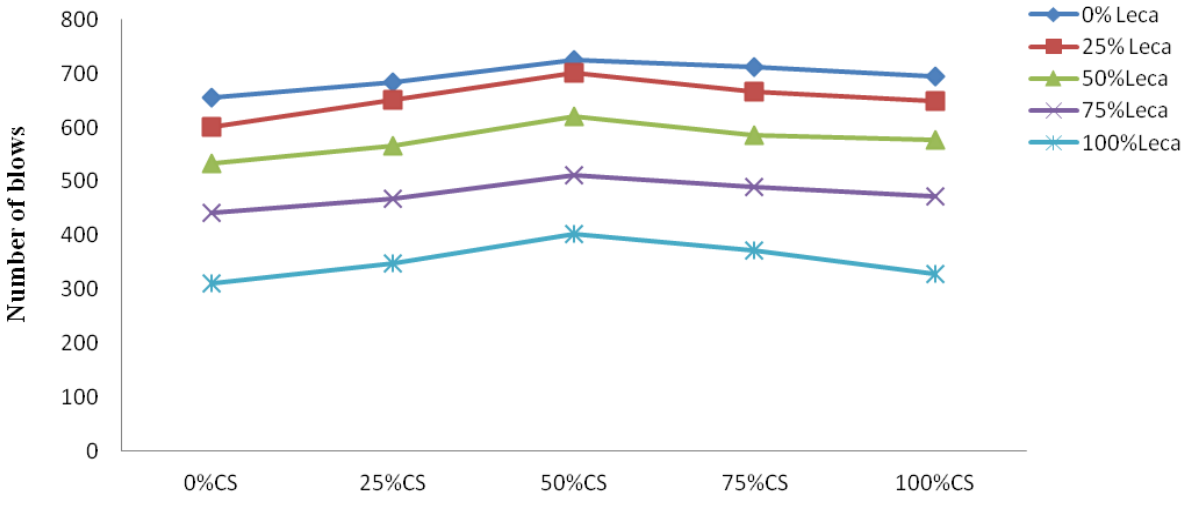

Figure 5(b): Impact strength test results for various percentages of copper slag
Where LECA= Light Expandable clay aggregate, CS= Copper slag

VIII. DISCUSSION ON TEST RESULTS

8.1 Influence of Light expandable clay aggregate and copper slag on compressive strength

From the compressive strength test values tabulated in table 3 and figures 1(a) &1(b), it is observed that with increase in the percentage substitution of Leca, the compression strength has decreased for a given percentage substitution of normal sand by copper slag and increased with increase in the percentage replacement of copper slag up to 50% and thereafter strength has decreased. Hence the maximum strength is obtained at the 0% Leca and 50% replacement of copper slag. Hence V3 mix gives the optimum compressive strength.

The obtained characteristic compression strength of conventional concrete is 34.44 N/mm^2 after 28 days of curing and the strength of optimum mix at 0% Leca and 50% replacement of copper slag is 40.61 N/mm^2. From them it is found that the optimum mix (V3) has got 17.92% more strength. However V2, V4, V5, V7, V8, V9, V13 mixes are also good at compressive strength which have got more compression strength than the nominal mix.

8.2 Influence of Light expandable clay aggregate and copper slag on split tensile strength

From the split tensile strength test values shown in figures 2(a) &2(b), it can be observed that with increase in the percentage replacement of Leca, the split tensile strength has decreased for a given percentage replacement of normal sand by copper slag and increased with increase in the percentage replacement of copper slag up to 50% and thereafter strength has decreased. Hence the maximum strength is obtained at the 0% Leca and 50% replacement of copper slag.

The obtained 28 days split tensile strength of conventional concrete is 3.72 N/mm^2 and the strength of optimum mix at 0% Leca and 50% replacement of copper slag is 4.22 N/mm^2. By observing both the values it is found that the optimum mix (V3) has got 13.14% more strength. However from the split tensile strength test results it can be observed that V2, V4, V5, V8 and V9 mixes are also good at split tensile strength which have got more strength than the nominal mix.

8.3 Influence of Light expandable clay aggregate and copper slag on flexural strength

From the results of table 5 and figures 3(a) &3(b), it can be observed that with increase in the percentage substitution of Leca, flexural strength has decreased for a given percentage replacement of normal sand by copper slag and increased with increase in the percentage replacement of copper slag up to 50% and thereafter decreases. Hence V3 mix gives the optimum flexural strength which has 0% Leca and 50% copper slag.

The obtained flexural strength of conventional concrete is 3.75 N/mm2 after 28 days of curing and the strength of optimum mix at 0% Leca and 50% copper slag is 4.31 N/mm^2 which is found to be 14.93% more than the conventional concrete. By observing the flexural strength result values the mix proportions of V2, V4, V5, V8 and

V9 are also good at flexural strength which have got more flexural strength compared to the nominal mix.

8.4 Influence of Light expandable clay aggregate and copper slag on in-plane shear stress

Double central notched (DCN) cube specimens having various a/w ratios i.e., 0.3, 0.4 ,0.5 and 0.6 with different percentage of Light expandable clay aggregate instead of coarse aggregate and copper slag instead of normal sand are tested in mode II fracture. By observing the values of table 6 and figures 4(a) to 4(e), as a/w ratio increases then the in-plane shear strength also more or less increases and optimum strength values are developed at 0% Leca and 50% copper slag. Hence V3 mix gives optimum strength.

8.5 Influence of Light expandable clay aggregate and copper slag on impact strength

From the values of table 6 and figures of 5(a) &5(b), the impact strength is maximum for V3 mix which consists of 0% Leca and 50% copper slag substituted as natural fine aggregate. When compared to the nominal mix, V3 mix has got 10.69% more impact blows. V2, V4, V5, V8 and V9 mixes are also good at impact blows compared to nominal mix.

IX. CONCLUSIONS

1. From the current exploratory examination, it is observed that the modified concrete can be generated by substituting light expandable clay aggregate instead of coarse aggregate and copper slag instead of normal sand to an optimum extent.
2. As light expandable clay aggregates are being small in size and rounded in shape the workability of concrete is considerably increased and density is reduced due to its light weight. This light weight modified concrete can be used for tall structures, precast building blocks and partition walls.
3. As Copper slag granules are being small and irregular in shape with sharp edge has better interlocking property and gives more strength compared to conventional concrete. As the copper slag percentage increases workability also increases.
4. From the laboratory experimental investigation, it is observed that the modified concrete has attained the maximum compressive, flexural, split tensile, in-plane shear stress and impact strength when coarse aggregate replaced with 0% Leca and fine aggregate replaced with 50% copper slag. Hence V3 mix gives the optimum strength.
5. From examining the all results, it can be seen that V2, V3, V4, V5, V7, V8 and V9 mixes satisfy all the desired strength parameters when compared to nominal mix (V1).
6. By replacing 50% Leca instead of coarse aggregate and 50% copper slag instead of fine aggregate it is possible to get the more compressive strength when compared to design strength of M25 grade concrete. V13 mix also satisfies the desired strength criteria.

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