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Mechanical Properties of Structural Light Weight Concrete (SLWC) and Economical Perspective of using SLWC in Construction

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Abstract

Concrete is one of the most researched topics in the field of civil engineering. In this study, light expanded clay aggregates (LECA) is used for producing structural lightweight concrete (SLWC) and silica fume is added for improving the strength. Expanded clay aggregates highly helps in reducing the self-weight and cost of production of structural lightweight aggregate concrete. In this research, investigation is done by using expanded clay aggregate in concrete by replacing conventional natural aggregate up to 20% by volume along with the micro silica to produce a structural lightweight concrete. This study examines the structural behavior of the concrete using LECA and also use of LECA highly helps in reducing the density of concrete in the order of 1398 kg/m3 to 1550 kg/m3. The experimental results shows that concrete produced with 80% LECA and 20% natural aggregate with silica fume as mineral admixture increases the strength and make the concrete more workable and durable. An analysis is also has been made for the study of Deflection and Rebar Percentage of SLWC (from the results the best proportion of replacement was taken) and normal weight concrete (NWC) using ETABS software.

Keywords – *Light weight expanded clay aggregate, silica fume, compressive strength, flexural strength.*

I. INTRODUCTION

The main objective of this research is to study the influence of light expanded clay aggregates in the structural behaviour of light weight concrete and to establish the best blend of admixtures which produces optimum results in engineering properties.

The detailed scope of the study is summarized as below:

• Identifying the mineralogical composition present in the light expanded clay aggregates and silica fume.

• To conduct experimental studies to measure the physical properties of expanded clay, cement, sand and coarse aggregate.

• Studying the effect of adding varying percentages of expanded clay aggregate and silica fume in concrete on fresh and hardened characteristics.

• Conducting experimental studies in order to evaluate hardened characteristics of structural light weight.

• To study the economical perspective of structural light weight concrete in construction.

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II. LITERATURE REVIEW

Many researchers have investigated the hardened characteristics of structural light weight concrete and its durability behaviour and also the various materials used to control the density of concrete.

SmitaBadur et al described how admixtures help in improve the properties of LWC. Adding fly ash about 15-35% in the concrete increases the strength, reduces the water content and improves the workability.

SerkanSubasi studied the effect of using expanded clay aggregate and fly ash of about 0-30% in the high strength light weight aggregate concrete. The results of compressive and split tensile strength increased by 8% and 9%.

FathollahSajedi, PayamShafigh (2012), investigated air cured lightweight structural concrete by applying curing admixture on the surface. It was found that the density of the concrete is achieved about 1,610–1,965 kg/m3 and compressive strength above 60 MPa was achieved.

Thomas Tamu et al, studied the behavior of expanded polystyrene (EPS) beads in the lightweight concrete. The result shows higher the percentage of EPS beads results in reduces the strength of the concrete.

Nagashree B, S. Vijaya, investigated light weight concrete using leca and cinder. The resultant concrete produced with 40% leca and 60% cinder shows high strength, less weight and low density.

M. Mahdy had investigated concrete with various proportions of silica fume and two different proportions of coarse aggregate. The resultant concrete shows high early strength with relatively smaller increase in later age strength. The optimum proportion of silica fume is found as 10% with coarse aggregate percentage as 0.48 increases compressive strength and flexural strength.

III. MATERIALS

3.1 Cement

Cement is a substance it can bind with all the materials in the concrete together. The cement used in our study is 53grade ordinary portland cement (OPC) and the properties of cement are shown in the table.

Table 3.1 Properties of Cement

Property	LECA
Specific gravity	3.14
Fineness	7%
Consistency	29%
Initial Setting Time	28 minutes
Final setting Time	6 hours 20 minutes.

3.2 Sand

River sand of particle size 2.36 mm is used for our study. The test results of sieve analysis and fineness modulus concluded sand is confirming to zone II. The value of fineness modulus of sand is 3.312 and specific gravity is 2.65.

3.3 Coarse Aggregate

Angular crushed granite broken stone is used for investigation and its specific gravity is found as 2.70.

3.4 Light expanded clay aggregate (LECA)

LECA is a high quality, light weight durable aggregate produced in rotary kiln at about 1200°C.The less weight of the material highly helps in reduces the density of concrete as well as makes the concrete strength and durable. The density of LECA is varied from 380 to 710 kg/m3

LECA wide applicability	Gradation	Density (Max)
Light weight concrete, light weight blocks, Prefabricated panels & slabs. Light filler, LECA Mortar and Water Purification system.	0-4 mm	<710 kg/m^3
Light Weight Concrete, light	4-10 mm	< 480

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weight block, Prefabricated Panels & Aquaculture, Ornamentation.		kg/m^3
Lightweight Filler Concrete, Sewage system. Landscaping, Agriculture and Aquaculture, Drainage.	10-25 mm	< 380 kg/m^3
Flooring and Roofing, Road Construction.	0-25 mm	< 430 kg/m^3

Table 3.2 Properties of LECA

Property	LECA
Specific gravity	0.70
Fineness Modulus	5.99
Water absorption	10%
Bulk Density	357 kg/m^3
Impact Value	16.5%

3.5 Silica fume

Silica fume is a high reactive pozzolan obtained from the by-product of silicon or alloys containing silicon in an electric arc furnaces. Due to its high reactive pozzolanic content it increases the strength tremendously and makes the concrete more durable,

Table 3.3 Chemical composition of LECA

Chemical composition	Percentage by Mass
SiO2	90-98%
CaO	0.2 – 0.7%
Al2O3	0.4-0.9%
Fe2O3	1-2%
Other	2-3%
S.G	2200kg/m^3
Bulk Density	550-650 kg/m^3
Surface Area	20000m^2/kg

3.5 Experimental investigation and testing methodology

The following tests were conducted on concrete with three different proportions of expanded clay aggregates 90%, 85% and 80%.

i. Compressive strength of concrete cubes.

ii. Split tensile strength of concrete cylinder.

iii. Flexural strength of concrete prism.

iv. ETABS analysis

By incorporating properties of expanded clay aggregate, concrete was designed for M20 grade as per IS10262-2009, and the mix proportion obtained as follows.

Table 3.4 Mix Proportion of NWC & LWC

Grade of Concrete	Cement	Water	FA	CA	LECA	Admix ture	Micro silica
Normal concrete	1	0.4	1.5	3	-	-	-
Light weight concrete	1	0.4	2.29	-	0.766	0.017	0.023

IV. RESULTS AND DISCUSSION

The laboratory tests were performed by adding expanded clay aggregates in concrete as 90%, 85%, and 80% respectively. The summary of test results is presented in Tables5.1, 5.2 and 5.3 respectively. The measured characteristics are also presented in Fig. 5.1, 5.2 and 5.3 respectively.

4.1. Effect of LECA on strength parameters

The structural behaviour of LECA concrete is studied using the following strength parameters such as compressive strength, split tensile strength and flexural strength. The results of the above strength parameters at different ages are presented in the below tables 4.1.1, 4.1.2 and 4.1.3 and also variation in the strength parameters are graphically plotted Fig 4.1.1, 4.1.2 and 4.1.3.

Table 4.1.1 Compressive strength of NWC & LWC

Mix Specification	7 Days Strength in N/mm^2	14 Days Strength in N/mm^2	28 Days Strength in N/mm^2
Control Mix (NWC)	13.26	16.82	18

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90% LECA	15.33	18	18.88
85% LECA	18.88	19.33	22
80%LECA	21.55	22.44	23.77

Table 4.1.2 Split tensile strength of NWC & LWC

Mix Specification	7 Days Strength in N/mm^2	14 Days Strength in N/mm^2	28 Days Strength in N/mm^2
Control Mix (NWC)	1.514	1.79	1.81
90% LECA	1.868	1.995	2.024
85% LECA	2.066	2.094	2.157
80%LECA	2.066	1.995	2.363

Table 4.1.3 Flexural strength of NWC & LWC

Mix Specification	7 Days Strength in N/mm^2	14 Days Strength in N/mm^2	28 Days Strength in N/mm^2
Control Mix (NWC)	2.038	2.761	3.29
90% LECA	2.948	4.021	4.69
85% LECA	3.052	4.165	4.85
80%LECA	3.145	4.57	5.3

4.2. Design comparison of NWC & LWC using ETABS

A Design comparison of light weight concrete (LWC) with normal weight concrete (NWC) is performed using ETABS. The selected structure (Beam element) was studied in ETABS (Extended3D Analysis of building System) 2015 program were analyzed in order to investigate some economic advantages of using LWC in these structures.

In the analysis, the dimensions of the structural elements were not changed and only the amounts of reinforcement steel by using normal weight concrete (having 2400 kg/m3 density) and LWC (having 1659 kg/m3 density, from 80% of LECA) were calculated. Concrete grade was selected as M20. Material Properties of Lightweight Concrete are as shown below and represented in Fig 4.2.1.

- Shear strength Reduction Factor is taken as 0.75
- Mass per Unit Volume = 1659.8 kg/m^3
- Modulus of Elasticity was worked out based on formula recommended by

ACI $=310{,}000K_1w^{2.5}(f_c)^{0.33}$

- Fck of LWC was taken as 20N/mm^2 for our experimental results

As the other aspects such as load on the structure and dimensions of the structure elements are the same. The Comparative study of Deflection, Shear force and Moment on one critical element (B17, beam element) is represented in Fig 4.2.2for NWC & Fig 4.2.3for LWC. It clearly shows that the deflection has been considerably reduced from 2mm to 1.1mm in the Light weight concrete using LECA aggregate due to reduced its Dead Load. This in turn increases the stiffness of the structure calculated using the formula K=P/Deflection. Another important aspect to be noted is the Equivalent Load on the element. It has been reduced to 1.37 kN/m by using Light Weight Concrete. The rebar percentage in another important aspect which clearly places a role in the cost of any structure constructed using RCC elements.

Use of Light weight concrete in place of NWC has reduced to reinforcement percent by significant margin which are shown in the Fig. 4.2.4for NWC and Fig. 4.2.5 for LWC. In a typical Beam Element (B 17) the reduction in rebar percentage is from 0.52% to 0.35%. In considering one element this might seem like a small reduction in rebar percentage but on a larger magnitude of construction that is multi-storey buildings this might play a considerate role in reduction in steel rebar which in turn would lead to reduction in cost by on a large scale.

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V. SUMMARYAND CONCLUSIONS

The following points are concluded based on the test results and ETABS analysis.

• Increasing the percentage of light weight aggregate decreases the cubes weight from 8.9kg to 5.2kg. But simultaneously there was decreasing strength. Blending of light expanded aggregates with normal aggregates showed better performance in this case.

• Compressive strength of structural light weight concrete (SLWC) increases with higher proportion of normal conventional aggregate with LECA, but increase in percentage of normal aggregate results in increase in density. Beyond 20% replacement of LECA with normal aggregate increased density which leads to removal of lightweight concrete tag. So 20% of normal aggregate was found to be an optimum value.

• Compressive strength at 7, 14 and 28 day with optimum proportion of 20% LECA and 80% natural aggregate are 21.55, 22.44 and 23.77 N/mm2 respectively.

• Split tensile and flexural strength of lightweight concrete also follows the same pattern as similar to that of compressive strength. So at the optimum proportion of 20-80%, the 28 day split tensile strength and flexural strength is found as 2.363 N/mm2 and 5.3 N/mm2 respectively.

• Increase in percentage of conventional natural aggregates beyond 20% is not advisable due to higher density constraints.

• It clearly shows that the deflection has been considerably reduced (from 2mm to 1.1mm) in the Light weight concrete using LECA aggregate due to reduced its Dead Load.

• In a typical Beam Element (B 17) the reduction in rebar percentage is from 0.52% to 0.35%. In considering one element this might seem like a small reduction in rebar percentage but on a larger magnitude of construction that is multi-storeybuildings this might play a considerate role in reduction in steel rebar which in turn would lead to reduction in cost by on a large scale.

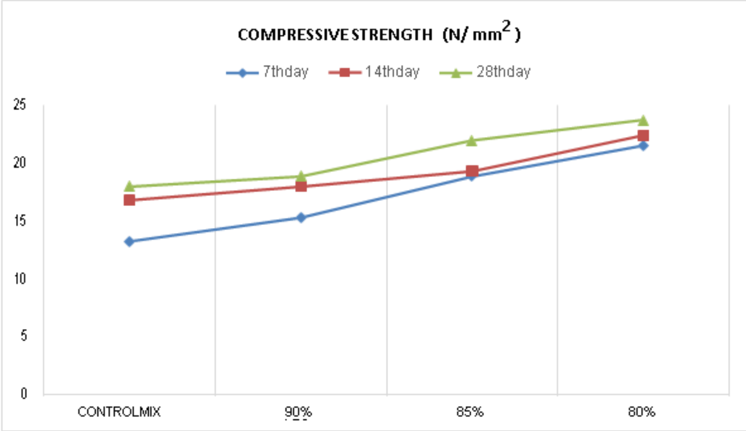

Fig 4.1.1 Line diagram showing compression strength of various mix

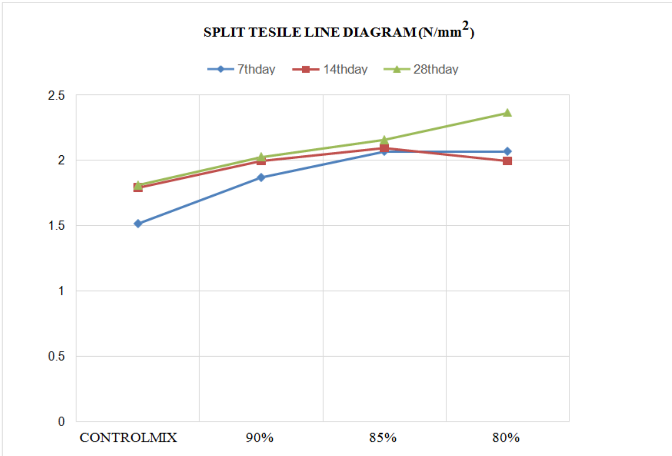

Fig 4.1.2 Line diagram showing split tensile strength of various mix

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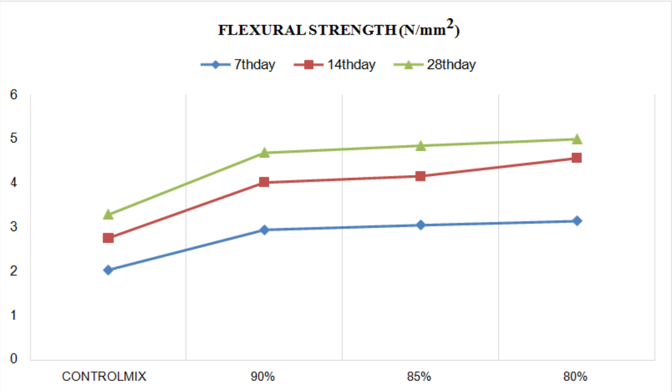

Fig 4.1.3 Line diagram showing flexural strength of various mix

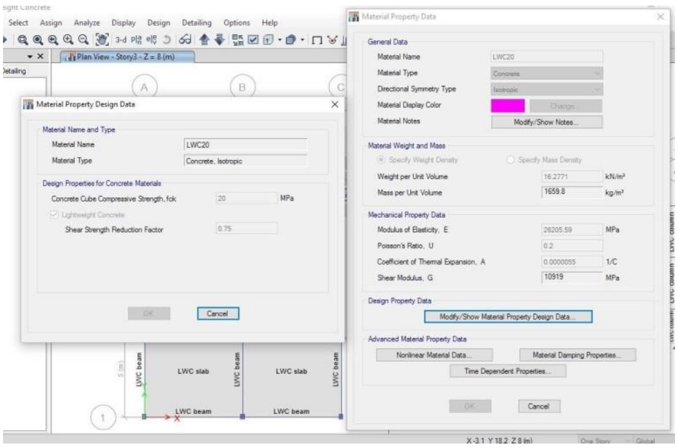

Fig 4.2.1 Material properties of light weight concrete

Fig 4.2.2 Deflection, SFD & BMD of NWC.

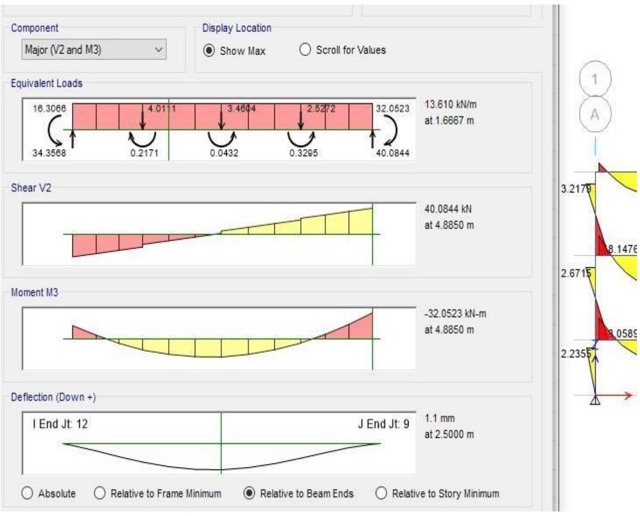

Fig 4.2.3 Deflection, SFD & BMD of SLWC.

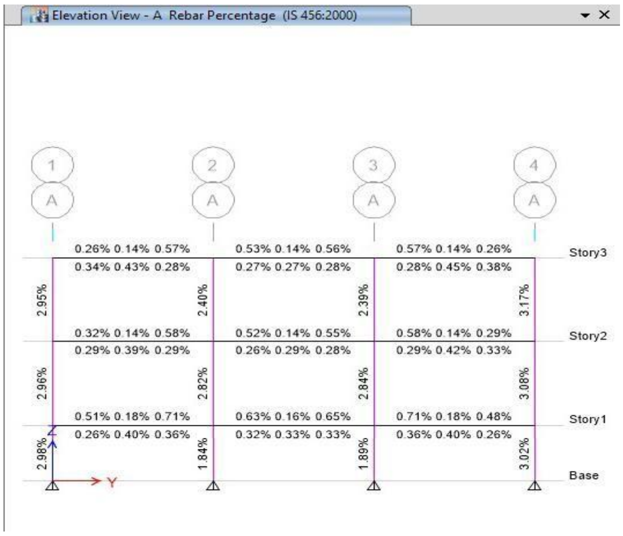

Fig4.2.4 Reinforcement % of beam in NWC.

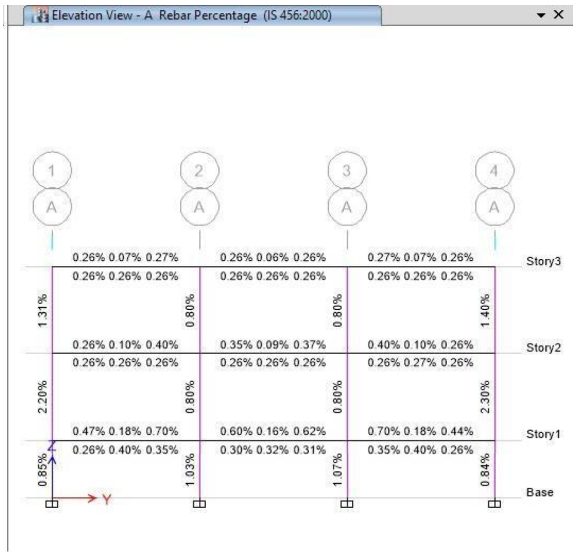

Fig 4.2.5 Reinforcement % of beam in SLWC.

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