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Effect of Mineral Admixture, W/B Ratio and Elevated Temperature on Strength of Lightweight Expanded Clay Aggregate Concrete

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***Abstract*: The present paper focused on development of structural lightweight concrete by using light weight expanded clay aggregate (LECA) with unit weight of 1700 kg/m^3 to 1900 kg/m^3 and compressive strength of 40 MPa. In this study, investigation was done using LECA as coarse aggregate in concrete by replacing normal aggregate in three differing volume fractions i.e., 30%, 40% and 50% with different w/b ratios 0.40, 0.50 and 0.60 to produce lightweight expanded clay aggregate concrete (LECAC) with addition of chemical admixture. For that, concrete mix design was done using IS method and replacement of lightweight aggregate was calculated based on volume batching. The effect of mineral admixture (i.e., 10% microsilica) on the properties of lightweight expanded clay aggregate concrete and normal weight aggregate concrete such as workability of fresh concrete, compressive strength and flexural strength of concrete were compared. The studies also include the effect of elevated temperature on light weight expanded clay aggregate concrete and normal weight aggregate concrete.**

***Index Terms:* Normal weight aggregate concrete (NWAC), Light weight expanded clay aggregate (LECA). Light weight expanded clay aggregate concrete (LECAC), Elevated temperature.**

I. INTRODUCTION

Light weight expanded clay aggregate is a special type of aggregate which is formed by heating clay with no or very little content of lime. The clay is dried, heated and burned in rotary kiln at a temperature of 1100℃ - 1300℃. Since it is exposed to high temperature as a result, gas is released inside the pellets and entrapped in it during cooling whilst the organic compounds burnt off forcing the pellets to bloated producing ceramic pellets with porous and formed a honeycombed structure. Outer surface of each granule is sintered. Pore structure gives light weight and high crushing resistance, thermal as well as sound insulation to the material. It has a circular or a potato shape formed due to circular movements in the kiln.

LECA consist of rounded pellets with a vesicular texture. In generally, LECA is a dark brown or reddish or grey in colour. These differences in colours could be associated to the varieties in LECA chemical composition. LECA is available in different sizes varying 0.1 mm to 25 mm, which is suitable for fine aggregate, coarse aggregate, and both of them. Bulk density of LECA ranges from 250 to 750 kg/m^3. It is used in making lightweight concrete products and for other uses.

The aim of the present study is to determine the mechanical properties of LECAC. The LECA was used in place of normal weight coarse aggregate in three differing volume fractions i.e., LECAC30(30% LECA+70% GRAVEL), LECAC40(40% LECA +60% GRAVEL) and LECAC50 (50% LECA+ 50% GRAVEL), with different w/b ratios 0.40, 0.50 and 0.60 to produce a lightweight expanded clay aggregate concrete (LECAC). The effect of elevated temperature on the mechanical properties of the light weight expanded clay aggregate concrete is also studied.

II. LITERATURE REVIEW

Alaa M.Rashad studied use of light weight expanded clay aggregate as a building material. An overview of LECA as a building material is given. According to the study conclusions are LECA has a positive effect on workability, decreases the specific tensile creep. It improves sound isolation.

K. Akcaozoglu, S.Akcaozoglu made experimentally studied on the effect of elevated temperature on the lightweight concrete produced by expanded clay aggregate and calcium aluminate cement. The residual strength of mixtures produced by expanded clay aggregate were higher than the concrete produced by natural aggregates.

Abhijitsinh Parmar, Urvish Patel studied the fresh concrete properties using Lightweight Expanded clay aggregate (LECA) and Expanded Polystyrene Beads (EPS) by replacing coarse aggregates. LECA can be used as a replacement for coarse aggregate compared to EPS with low workability.

Anil Kumar R, P. Prakash studied the mechanical properties of structural concrete by blending cinder and LECA. The strength properties of lightweight concrete produced by replacing coarse aggregate for M30 grade of concrete were studied. Concrete with 60% Cinder and LECA 40% had an average compressive strength of 36.52N/mm^2 and split tensile strength of 2.5N/mm^2.

Omar A. Abdulkareem, A.M. Mustafa al Bakri examined that effect of elevated temperatures on the thermal behavior and mechanical performance of fly ash geopolymer paste, mortar and light weight concrete. They presented the characteristics of the FA geopolymer paste, mortar and LWAGC before and after exposed to elevated temperatures of 400℃, 600℃ and 800°C.

III. MATERIALS

Cement

Ordinary Portland cement of 53 grade cement is used. The Physical properties are tested according to IS 4031-1998 and results are tabulated in Table I.

TABLE I.
PHYSICAL PROPERTIES OF OPC 53

S. No.	Property	Test method	Test Results	IS Specification
1	Fineness	Sieve test	2.4%	10%
2	Specific Gravity	Specific gravity bottle	3.14	3.10-3.25
3	Normal Consistency	Vicat apparatus	31%	26-33%
4	Initial Setting time	Vicat apparatus	45 min	Not less than 30 min

COARSE AGGREGATE

Gravel

Aggregates passing from 12mm and retained on 20 mm aggregates are used. Properties of coarse aggregates are tabulated in Table II.

LECA

Light weight expanded clay aggregate of size from 8mm to 12mm is used as coarse aggregate. properties of LECA are tested and results are tabulated in Table II.

TABLE II.
PHYSICAL PROPERTIES OF F.A, C.A(GRAVEL AND LECA)

S.No.	Property	Fine Aggregate	Coarse Aggregate	
			Gravel	LECA
1	Fineness modulus	3.08	6.41	5.84
2	Specific gravity	2.6	2.88	0.66
3	Bulk density	1440 Kg/m^3	1450 kg/m^3	413 kg/m^3
4	Water absorption	1%	0.6%	15%

Water

Portable water is used in the preparation of concrete mixes.

Super Plasticizer

CONPLAST SP 430 is used as the chemical admixture.

Micro Silica

Micro silica is used as a mineral admixture in the concrete.

TABLE III.
QUANTITIES REQUIRED FOR 1 M^3

w/c ratio	Cement Kg/m^3	Micro silica Kg/m^3	Water Kg/m^3	SP dosage %	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3		
						LECAC30 (30%LECA +70%Gravel) Kg/m^3	LECAC40 (40%LECA +60%Gravel) Kg/m^3	LECAC50 (50%LECA +50%Gravel) Kg/m^3
0.4	331	0	132	1.5%	711	96.228+952.56	128.30+816.48	160.38+680.4
0.4	331	33.1	145	1.5%	702	95.04+940.8	126.72+806.04	158.4+672
0.5	331	0	165	1%	718	89.1+882	118.8+756	148.5+630
0.5	331	33.1	182	1%	704	84.38+860	108.504+740.88	135.64+575.4
0.6	331	0	199	0%	723	82.368+815.36	109.824+698.88	137.2+582.4
0.6	331	33.1	218	0%	697	80.388+795.76	107.18+682.08	133.98+568.4

FINE AGGREGATE

River sand is used as fine aggregate. The requirements of sand is confirming to IS: 383-1970 and the properties of fine aggregate tested are tabulated in Table II.

IV. Experimental Study

Workability

The workability is measured by conducting the Slump cone test using standard Procedure prescribed in IS: 1199 - 1959. Results are tabulated in Table IV.

TABLE IV.
WORKABILITY AND UNIT WEIGHT

w/c ratio.	LECA vol. fraction %	SP dosage	Without Micro silica		With micro silica	
			Slump (mm)	Unit weight (kg/m^3)	Slump (mm)	Unit weight (kg/m^3)
0.40	0	1.5%	50	2288	47	2388
	30	1.5%	52	1829.8	50	1890.2
	40	1.5%	52	1754.2	54	1825.1
	50	1.5%	55	1731.2	58	1746.2
0.50	0	1%	52	2314	49	2341
	30	1%	56	1821.4	52	1882.3
	40	1%	60	1749.5	58	1820.4
	50	1%	67	1728.6	66	1745.5
0.60	0	0%	64	2256	62	2286
	30	0%	70	1809	66	1874.4
	40	0%	73	1747.8	68	1813.5
	50	0%	88	1722.5	75	1742.9

Compressive strength

Cube size of 150mm x150mm x 150mm cube specimens are caste and cured for 28 days and tested under Automatic compression testing machine of 3000KN capacity and the results are tabulated in Table V.

TABLE V.
PERCENTAGE INCREASE IN COMPRESSIVE STRENGTH ATAGE OF 28 DAYS WITH AND WITHOUT ADDITION OF MINERAL ADMIXTURE (MICROSILICA).

w/ c ratio	leca vol. fraction %	compressive strength mpa		% of increase in compressive strength
		without micro silica	with micro silica	
0.4	0	55	59	7.2
	30	27.04	29.2	7.9
	40	24.93	27.04	8.5
	50	20.56	24.9	21.1
0.5	0	52	56.36	8.4
	30	24.7	27.04	9.5
	40	23.3	25.73	10.4
	50	18.8	22.66	20.53
0.6	0	46.6	50.7	9.2
	30	22.1	24.24	9.7
	40	20.66	22.88	10.7
	50	18.2	21.53	18.34

Flexural strength

Prisms of size 100mm x100mm x500mm were caste and cured for 28 days and tested in flexural testing machine and results are tabulated in Table VI and Table VII.

TABLE VI.
FLEXURAL STRENGTH OF NWAC MIXES WITH AND WITHOUT MICROSILICA

W/C ratio	Flexural strength (MPa)	
	Without Micro silica	With Micro silica
0.4	5.19	5.3
0.5	4.9	5.2
0.6	4.7	4.9

TABLE VII.
FLEXURAL STRENGTH OF LECAC30 MIXES WITH AND WITHOUT MICRO SILICA

W/C ratio	Flexural strength (MPa)	
	Without Micro silica	With Micro silica
0.4	3.64	3.8
0.5	3.4	3.6
0.6	3.2	3.4

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Effect of elevated temperature

High temperature furnace of 1000^0C capacity is used to evaluate the fire resistance. The casted cubes are placed in the high temperature furnace for 02 hrs at different temperatures 200°C, 400°C, 600°C & 800^0C. After two hours cubes were taken out and tested residual compressive strength, weight loss and the results are tabulated in Table VIII - Table XIII.

TABLE VIII.
RESIDUAL COMPRESSIVE STRENGTH OF NWAC CUBES

W/ C	Te mp erat ure (°C)	Compressive strength (MPa)		% of variation	
		NWAC Without micro silica	NWAC with micro silica	NWAC without micro silica	NWAC with micro silica
0.4	0	55	59	0	0
	200	50.63	52.4	7.9	11.1
	400	49.2	49.4	10.5	16.2
	600	44.9	45	18.3	23.7
	800	18	21	67.2	64.4
0.5	0	52	57	0	0
	200	44.8	47.2	13.8	17.1
	400	42.3	35.4	18.6	37.8
	600	38.4	28.3	26.1	50.3
	800	11.65	18.4	77	67.7
0.6	0	46.6	50.9	0	0
	200	36.9	38.9	20.8	23.5
	400	32.16	32.63	30.9	35.8
	600	27.14	22.6	41.7	55
	800	9.4	12.8	79.8	74.8

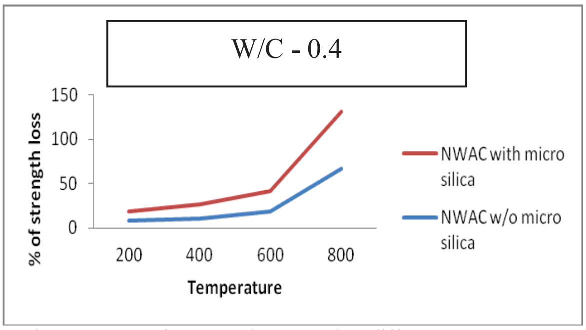

Figure 1. Loss of compressive strength at different temperatures - NWAC

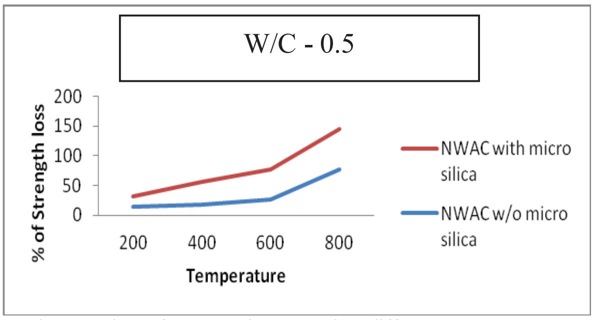

Figure 2. loss of compressive strength at different temperatures - NWAC

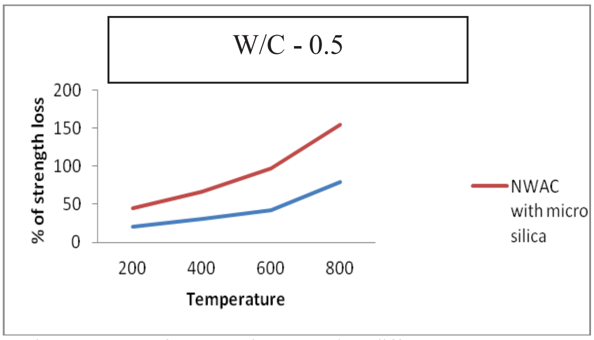

Figure 3. Loss of compressive strength at different temperatures - NWAC

TABLE IX.
RESIDUAL COMPRESSIVE STRENGTH OF LECAC30 CUBES

W / C	Te mp erat ure (°C)	Compressive strength (MPa)		% of variation	
		LECAC 30 withou t micro silica	LECAC 30 with micro silica	LECAC 30 without micro silica	LEC AC 30 with micro silica
0.4	0	27.04	29.20	0	0
	200	26.6	28.2	1.6	3.4
	400	24.7	27.96	8.6	4.2
	600	22.5	26.4	16.8	9.5
	800	18.53	21.3	31.4	27
0.5	0	24.7	27.2	0	0
	200	23.73	27	3.9	7.3
	400	21.76	24.56	11.9	9.7
	600	18.92	21.1	23.4	22.4
	800	10.93	15.1	55.7	44.4
0.6	0	22.1	23.9	0	0
	200	18.25	21.6	17.4	19.6
	400	17.86	21.5	19.1	10.0
	600	16.5	18.1	25.3	24.2
	800	7.54	12	66	49.7

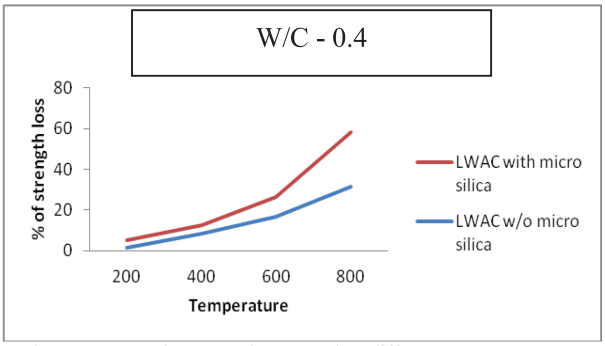

Figure 4. Loss of compressive strength at different temperatures – LECAC30

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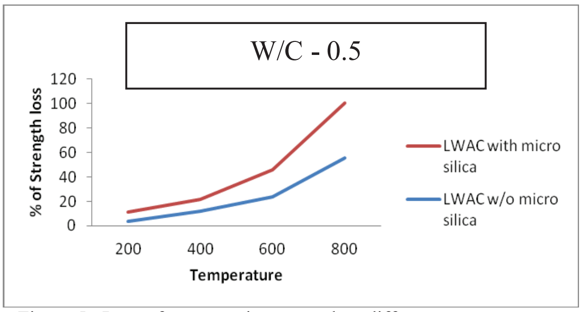

Figure 5. Loss of compressive strength at different temperatures – LECAC30

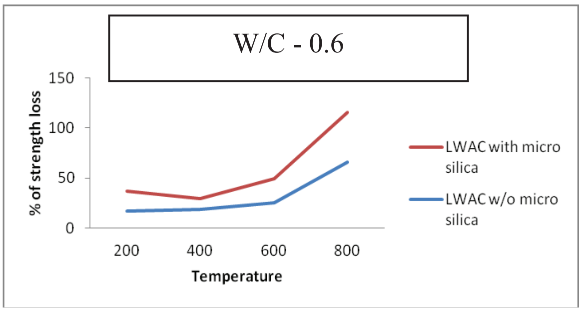

Figure 6 . Loss of compressive strength at different temperatures – LECAC30

TABLE X.
AVERAGE PERCENTAGE OF WEIGHT LOSS OF NWAC WITHOUT MICROSILICA AT DIFFERENT TEMPERATURES

W/C	Temperature (℃)	Weight before placing in furnace (kg)	Weight after placing in furnace (kg)	% of variation
0.4	200	8.57	8.52	1.0
	400	8.55	8.25	3.5
	600	8.37	8.02	4.1
	800	8.48	8.03	5.3
0.5	200	8.39	8.29	1.1
	400	8.58	8.28	3.4
	600	8.45	7.99	5.4
	800	8.43	7.92	6.0
0.6	200	8.54	8.4	1.6
	400	8.29	7.91	4.5
	600	8.36	7.88	5.7
	800	8.29	7.58	8.5

TABLE XI.
AVERAGE PERCENTAGE OF WEIGHT LOSS OF NWAC WITH MICROSILICA AT DIFFERENT TEMPERATURES

W/C	Temperature (℃)	Weight before placing in furnace (kg)	Weight after placing in furnace (kg)	% of variation
0.4	200	8.32	8.23	1.6
	400	8.4	8.03	4.4
	600	8.29	7.66	7.5
	800	8.37	7.65	8.6
0.5	200	8.55	8.44	1.2
	400	8.04	7.66	4.7
	600	8.16	7.59	6.9
	800	8.42	7.8	7.3
0.6	200	8.25	8.12	1.6
	400	8.36	7.9	5.5
	600	8.35	7.52	9.9
	800	8.37	7.48	10.6

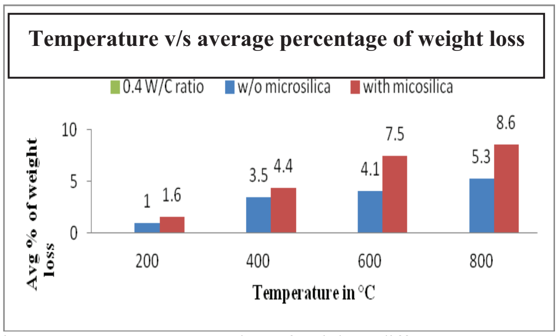

Figure 7. Average percentage loss of weight at different temperatures- NWAC

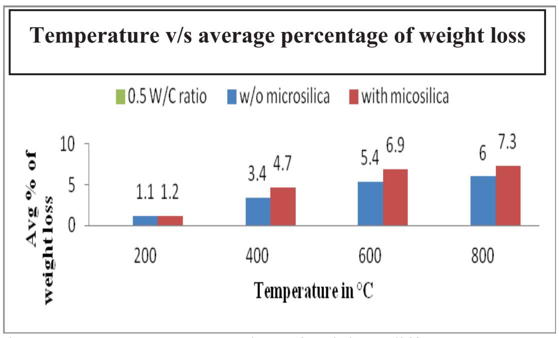

Figure 8 . Average percentage loss of weight at different temperatures- NWAC

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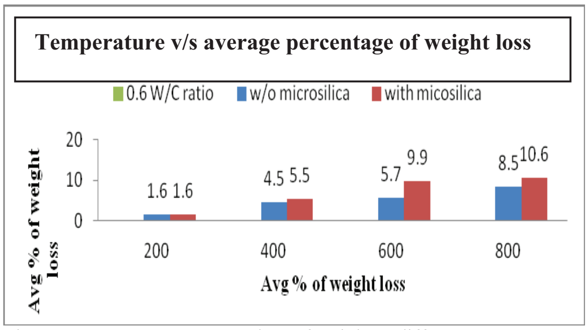

Figure 9. Average percentage loss of weight at different temperatures-NWAC

TABLE XII.
AVERAGE PERCENTAGE OF WEIGHT LOSS OF LECAC30 WITHOUT MICROSILICA AT DIFFERENT TEMPERATURES

W/C	Temperature (°C)	Weight before placing in furnace (kg)	Weight before placing in furnace (kg)	% of variation
0.4	200	7.58	7.37	2.7
	400	7.48	7.09	5.2
	600	7.53	7.13	5.3
0.5	800	7.58	7.1	6.3
	200	7.26	7.16	1.3
	400	7.43	7.02	5.5
	600	7.5	7.03	6.2
0.6	800	7.5	6.88	7.2
	200	7.29	7.19	1.3
	400	7.4	7.06	4.5
	600	7.3	6.72	7.9

TABLE XIII.
AVERAGE PERCENTAGE OF WEIGHT LOSS OF LECAC30 WITH MICROSILICA AT DIFFERENT TEMPERATURES

W/C	Temperature (°C)	Weight before placing in furnace (kg)	Weight after placing in furnace (kg)	% of variation
0.4	200	7.505	7.3	2.7
	400	7.57	7.22	5.6
	600	7.54	6.99	6.8
	800	7.57	6.92	8.5
0.5	200	7.58	7.45	1.7
	400	7.4	7.13	3.6
	600	7.64	7.11	6.9
	800	7.44	6.83	8.5
0.6	200	7.48	7.34	1.8
	400	7.25	6.79	6.3
	600	7.46	6.78	9.1
	800	7.42	6.71	9.5

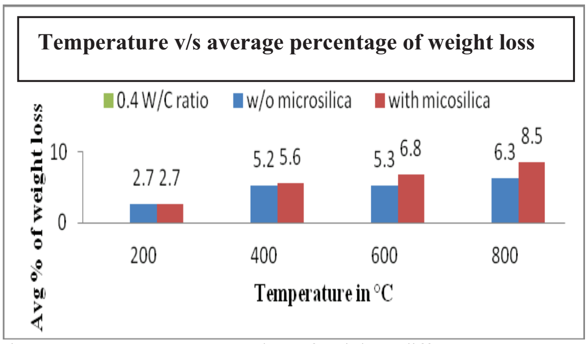

Figure 10. Average percentage loss of weight at different temperatures-LECAC30

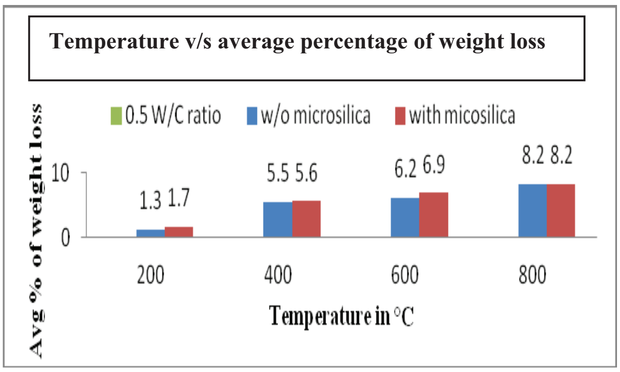

Figure 11. Average percentage loss of weight at different temperatures-LECAC30

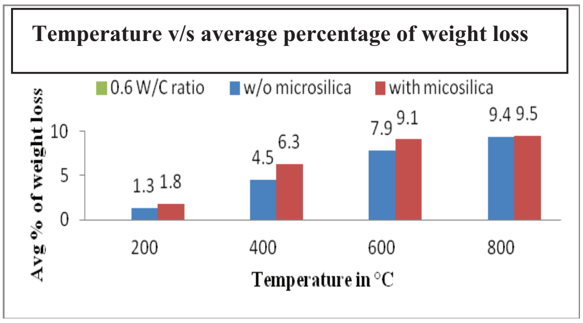

Figure 12. Average percentage loss of weight at different temperatures- LECAC30

V. Conclusions

The unit weight of LECAC30, LECAC40& LECAC50 mixes was found to be in the range of 1700 kg/m^3 to 1890 kg/m^3, which is less than the unit weight of Normal Weight Aggregate concrete.

The addition of chemical admixture (Conplast SP430) improved the workability of LECAC and the optimum dosage for water- cement ratios 0.40, 0.50, and 0.60 is 1.5 %, 1 %, and 0 % were respectively to achieve medium workability.

The optimum replacement of LECA to NWA for all w/b ratios 0.40, 0.50 and 0.60 is 30% i.e. 30 % LECA & 70 % Gravel.

Compressive strength and flexural strength are observed to be maximum for LECAC30 at 0.4 w/b ratio with 10 % Micro silica. The values obtained were 29.2 MPa and 3.8 MPa respectively.

The addition of 10 % mineral admixture (Micro silica) to NWAC, LECAC30, LECAC40 and LECAC50 results an improvement in compressive strength of 8.26 %, 9.03 %, 9.86 % and 19.99 % respectively.

The addition of Micro silica improved the compressive strength more in LECAC50 when compared to NWAC, LECAC30 and LECAC40 as Micro silica reacts with the water available in the pores of the partially saturated surface dry LECA.

The compressive strength loss was minimum for LECAC30 with 0.4 w/b ratio at all temperatures 200°C, 400°C, 600°C and 800°C. And the average loss of compressive strength at 800°C temperature for NWAC and LECAC30 obtained are 74.66 % and 51 % respectively.

The weight loss is also minimum for LECAC30 with 0.4 w/b ratio at all temperatures 200°C, 400°C, 600°C and 800°C. And the average loss of weight at 800°C temperature for NWAC and LECAC30 obtained were 8.9 % and 8.4 % respectively.

LECAC30 has high resistance to the elevated temperatures with respect to compressive strength and weight loss.

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