An Experiment to Scrutinize the Impact of Lightweight Expanded Clay Aggregates (LECA) and Metakaolin on Structural Lightweight Concrete

Qazi Abu Haris Ateeq, Maneeth. P. D., Brijbhushan S.

Abstract: Lightweight concrete is to be treated as structural concrete (using LECA as CA), it must satisfy the density in range of 1120-1920 kg/m3 and strength not less than 20 N/mm². In order to accomplish required strength, LECA with metakaolin was used at different concentrations of (20% to 26%) by weight of cement at equal increments of 2%. Test results clearly indicates that, using LECA and metakaolin as selective substitution increases the compressive strength and durable properties. The prerequisite of using additional cementious material as metakaolin was to enhance the compressive strength, durability of LWC. Metakaolin content seems to lead high early age strength with relative increase in strength of 28 days. The effective content of metakaolin was 24% along with 60% LECA as partial substitution gave very much appreciable results. The percentage reduction in density recorded was 33%. The durable aspects such as resistance offered to acidic environment was also affirming when as compared to conventional concrete.

Keywords : Compressive Strength, LECA, LWC, Metakaolin.

I. INTRODUCTION

As the years pass by, fair significant paths have been discovered in concern of structural lightweight concrete[9]. The increasing issues related to environment, alongside sharp inclination of prices of normal aggregates have affected the construction industry all over the globe. LWC is most famous for importance in weight reduction of concrete which will in return reduce the heavy self-weight of tall structures[9]. The advantage of having less self-weight will probably help in ending up with structures of reduced sectional members, appropriately making construction even more convenient and economical one. Regarding construction cost, this can be minimized by usage of lightweight concrete for application of high-rise/ multi storeyed buildings. Even more, upon application of lightweight concrete, the cross-section of structural members can be reduced. These structural members can be columns, beams, plates, foundations and slabs[1].

LWC is a matrix made from lightweight coarse aggregate and other normal conventional concrete materials. Structural LWC has density in order of 1440-1840kg/m^3[5]. The various classes of lightweight concrete by the method of producing them are,

i. Lightweight concrete by using lightweight aggregates having specific gravity less than 2.0.

ii. By allowing voids in concrete in concrete or mortar, i.e by air entrainment, such types of concrete is called as cellular/ aerated/ foamed concrete [2].

Such type of concrete requires huge supervision and chemicals in order to produce foam with activator and catalyst.

The present study makes use of lightweight aggregate as LECA to restrict the concrete density. Lightweight concrete by LECA – LECA comprises of clay with less or no lime in it. At an extremely high temperature of about 1150°C, clay is dried, and then heated and burnt in a rotary kiln[8].While the process of heating continues, at an extreme high temperature of 1150°C, the gasses releases during the process gets captured upon condensation process. Due to which the particle is porous, lightweight and expands about 5-6 times about its original volume [8]. The potato shape of LECA is as the result due to the rotatory circular motion of the kiln [8]. LECA used in the study consisted $Si0_2$, Fe_20_3, Al_20_3, Ca0 and some alkalis K_2O and Na_20[20].

II. AIM AND OBJECTIVE

1) To find the optimum quantity of metakaolin that could be added in order to achieve structural LWC.

2) Compariation of density and strengths LWC with normal ordinary concrete.

3) To evaluate compressive strength by varying proportions of metakaolin by fractional replacement with cement.

4) To test the Tensile and Flexural-strength of LWC at varying percentage of replacements of metakaolin.

5) To examine the behaviour of LWC in acidic medium (corrosive environment) and to evaluation of durability aspects of LWC under the influence of metakaolin.

III. LITERATURE REVIEW

A. Mehdi Zohrabi et. al[11]

The project objective was to explore the impact of metakaolin by varying percentages of LWC by studying mechanical tests in concrete. The materials used in the program includes cement, metakaolin, fine aggregate (river sand) and LECA. Tests specimen was cast & cured for 7 & 28days. After carrying out the tests,

Revised Manuscript Received on January 05, 2020.

Qazi Abu Haris Ateeq, PG Student, Department of Construction Technology, VTU Regional centre for PG studies, Kalaburagi, India.

Maneeth P. D, Assistant professor, Department of Construction Technology, VTU Regional centre for PG studies, Kalaburagi, India

Brijbhushan S, Course co-ordinator, Department of Construction Technology, VTU Regional centre for PG studies, Kalaburagi, India

it was established that metakaolin at 20% replacement with cement with LECA give a respective 28 days of compressive strength as 28.97 N/mm².

B. Kishan R Patel et. al

There has been an attempt to research and compariation of concrete, partially replaced coarse aggregate with light weight material such as light weight expanded aggregate (LECA) on mechanical properties of concrete. The study involves the replacement of normal aggregate from 0-100% with an increment of 25% with respect to coarse aggregate. After carrying out the tests, conclusion was made as the compressive strength value declined as increase in the LECA content. As LECA content increases, the compressive resistance decreases. After 28 days of cure, weight reductions of around 28% with 100% LECA substitute of coarse aggregates were noted, representing a decrease of 16.87% in Compressive strength, 17.20% in Split Tensile strength and 13.29 percent in Flexural strength. However, the negligible loss of strength is noted with 25% LECA substitution. Materials such as Silica-Fume, metakaolin, Fly- ash, slag, steel and poly-propylene fibers could be applied to improve its power to alter the mechanical characteristics of LECA-containing concrete.

C. Sunny A. Jagtap et. al[10]

The primary purpose of the program was to explore the effect of metakaolin on the mechanical characteristics and durable resistance of concrete. Metakaolin was partially replaced by weights of cements at different stages of 0, 5, 10, 15, 20, 25% respectively. The compressive strength was assessed at early day 7days and 28days duration of curing.

After the tests were conducted, the optimum percentage of metakaolin worked out to be 25% with compressive strength of 50.29 N/mm², beyond which addition of metakaolin did not contributed strength instead increased water demand. The flexural strength of concrete at optimum percentage of metakaolin obtained were 2.83 N/mm² and 4.84 N/mm² respectively.

D. M. Mahdy[5]

A study was carried out on structural lightweight concrete produced from cured LECA, silica fume and high range water reducer confirming ASTM C494 type f. The study involved varying percentages of silica fume from 0-15% with an increment of 5%. The tests specimen were casted and were tested after 28days curing period. Based on results the conclusions were drawn, With silica fume content the compressive strength improves. The compressive power of silica fumes is relatively marginal and no advantage from content above 10% is certain. In general, this also applies to bending strength. The impact on concrete strength can be negligible if the concentration of Silica Fume solution was increased by 10 to 20%.

E. R. N. Raj Prakash et. al [4]

The study represents LECA experimental research on impact on partial substitution of normal CA. The aim of this project is primarily to compare concrete weight and strength. Compression strength, tensile strength, partly replacing natural-ordinary aggregates with LECA substituting from 20%-100%, with increments in 20%.

The conclusions that were made after carrying the tests, Compressive strength attained at 20% replacement of 28 days curing was 29.85 N/mm² and 25.40 N/mm² compressive strength was attained at 40% substitution. From this it is confirmed increase in LECA content reduced the compressive strength. Increment in LECA quantity decreased the workability due to its water absorption.

IV. MATERIALS ANALYSIS

A. Cement

Cement for all of the research parameters was OPC 53 grade of Ultra-tech brand confirming to IS: 12269[16]. The characteristics of cement is indicated below.

Table I: Represents Characteristics of Cement

Attributes of cement	Experimental values
Normal consistency	34%
Sp. Gravity	3.10
Time of initial set	34 mins
Time of final set	240 mins
% of Fineness	5%

B. Fine Aggregate

Riverbed sand validating zone II as said by IS 383:1970 was used. The fine aggregate was procured from shahpur, Yadgir district, Karnataka.

Table II: Represents Characteristics of FA

FA characteristics	Experimental results
Sp. Gravity.	2.540
% of Water absorption	1.21%
Bulk density at loose condition	1.45 g/cc.
Bulk density at compacted condition	1.610 g/cc.
Fineness modulus	2.94
Silt content	2.10

A. Coarse Aggregate

Crushed and angular basalt aggregate of down size 20mm and 12mm was used for the study[13],[14].

Table III: Represents Characteristics of CA

Property of CA	Experimental value.
Sp. Gravity	2.72
Water absorption	1.05%
Bulk density at loose condition	1.14 g/cc.
Bulk density at compacted condition	1.51g/cc.

B. Lightweight Expanded Clay Aggregate (LECA)

For the present study, LECA was procured from PERL TECH, Ahmedabad[19].

Figure I: Represents Sample of LECA used in study.

Table IV: Represents the attributes of LECA[19].

Attributes	Experimental results
Sp. Gravity	0.95
Water Absorption	15%
Shape	Spherical
Impact Value	15.62%
Crushing Value	20.59%
Bulk density	400 kg/m^3

E. Metakaolin

For the present study, metakaolin was procured from Raviraj Mineral Industries, Udaipur, Rajasthan. The metakaolin used had 2.71 specific gravity[20].

Table V: Represents Chemical Composition of MetakaoliN[20].

Ingredient	Percentage
$Si0_2$.	50% - 55%.
Al_20_3.	40% - 45%.
Fe_20_3.	0.21%.
$Ti0_2$.	0%.
Ca0.	0.012%.
Mg0.	0.041%.
K_20.	1% - 3%.
Na_20.	0.10%.

F. Viscosity Modifying Admixture (VMA)

Viscosity modifying agent, “MasterMatrix SDC150” was used to enhance the workability [21][22]. The specific gravity was 1.01. The dosage was 1.5% by weight of cement.

G. Potable Water

For the blending and curing of concrete, potable water, which is free of organic matter conforming to IS: 456 was used.

V. MIX DESIGN

Design combinations for the casting of various mix of concrete was done as per IS:10262-2009 for conventional concrete[13] and ACI 211.2-98[12] for concrete containing LECA (lightweight concrete). The mix design was done to create a M40 grade concrete.

Table VI: Represents the Mix Variations involved in the study.

Mix ID	Cement (%)	Metakaolin (%)	CA	LECA
CC	100	0	100	0%
S1	100	0	40	60
S2	80	20	40	60
S3	78	22	40	60
S4	76	24	40	60
S5	74	26	40	60

VI. EXPERIMENTAL PROGRAM

The current experiment program involves studying of properties like fresh state properties, mechanical properties to assess strength[17],[18] and durability of LWC. Flexure strength test, Slump tests, Split Tensile strength tests & compression test, sorptivity test & acids tests was conducted.

VII. RESULTS

A. Slump cone test

The consequences of the slump cone testings which indicate the ease of mixing of freshly mixture concrete mix are shown in figure 4.1 below. It was clear that with the intrusion of LECA, metakaolin the workability of the mix decreases. This is due to the fact of more water absorption by LECA and the water demand by metakaolin.

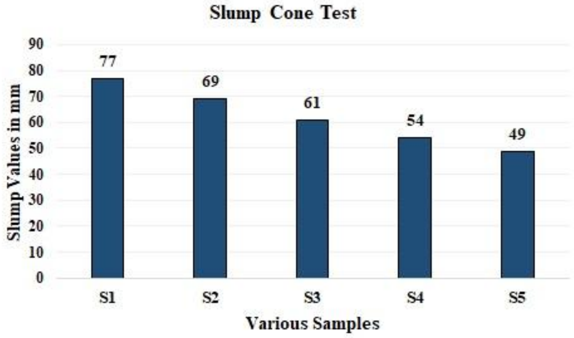

Figure II: Represents Slump cone test results.

B. Compression strength test

To evaluate this strength, cubes were tested after three different ages[17]. The outcomes displayed that there was a significant increment in strength resistance owing to the incorporation of metakaolin.

Table VII: Represents Compressive Strength Results

Mix proportions	Average compression strength (N/mm^2)		
	3 days	7 days	28 days
S1	11.41	24.69	36.48
S2	13.15	25.73	37.39
S3	13.42	28.26	39.28
S4	15.48	32.51	44.11
S5	14.38	29.05	42.25

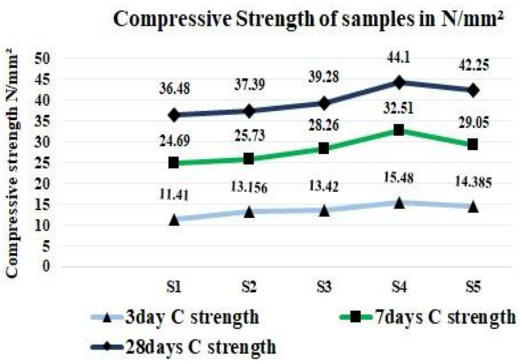

Figure III: Represents Compressive Strength Results at Various Age.

From the above data, it can be drawn that there is actual increase in cube strength resistance of altered concrete than that of conventional concrete. The sample 4 i.e., LECA 60% and metakaolin 24% showed higher strength than any other mix.

C. Split tensile strength test

The test is performed for the cylinders at 2 different ages[18]. The outcome shows that there has been an increment in strength with the presence of metakaolin. The optimum content of metakaolin was 24%, which remarkably increased the strength.

Table VIII: Represents Split tensile test results of 7,28 Days Curing Period.

Mix proportions	Average split tensile strengths (N/mm^2)	
	7 days	28 days
S1	0.91	1.16
S2	1.11	1.31
S3	1.50	1.72
S4	1.88	2.24
S5	1.71	1.97

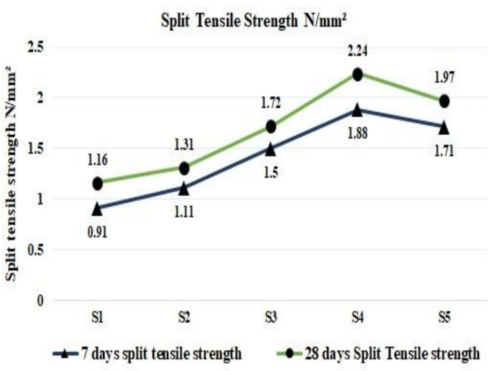

Figure IV: Represents Split Tensile Strength Results at Various Ag

D. Flexural strength test

Beam specimens having depth and width 100mm and total length 500mm was tested to achieve the flexural-strength. The specimens were tested at three different ages using two point loading method.

Table IX: Represents Flexural Strength at Various Age.

Mix proportions	flexure strength (N/mm^2)	
	7 days	28 days
S1	1.12	1.36
S2	1.36	1.67
S3	1.63	2.21
S4	1.81	2.64
S5	1.60	2.12

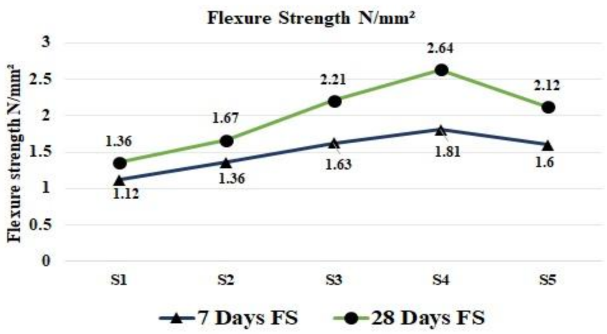

Figure V: Represents Flexural Strength results at Various Age.

E. Sorptivity test

After the samples (CC and optimum mix i.e S4) casting and treatment, samples was taken out & finals weight was taken. The sorptivity was then found out. The results of sorptivity is shown in below table.

Table X: Represents Sorptivity Test Results

Mix: ID	Dry weight (grams)	Wet weight (grams)	Sorptivity in mm/min$^{0.5}$	Average value
CC	821.42 819.12 823.89	826.34 825.41 828.74	0.114 0.146 0.112	0.124
Optimum mix (S4)	627.12 614.87 609.45	631.14 618.71 614.12	0.093 0.089 0.108	0.097

F. Acid attack test

The cubes were submerged in sulphuric acid and hydrochloric acid mediums (5%) for about 7 days. The percentage weight loss gives the resistive power of the LWC.

Table XII: Represents Acid Attack Test Results

Mix: ID	Initial weight of cube	Weight of cube after 7 days (Kg)	Percentage loss in weight (%)	Average percentage loss (%)
CC	8.427 8.325 8.471	8.102 7.994 8.134	3.85 3.97 3.97	3.93
Optimum Mix (S4)	5.912 5.841 5.621	5.741 5.698 5.474	2.89 2.44 2.61	2.65

VIII. DISCUSSION

A. Density of various mix

The density of the concrete varied as the proportion of LECA was altered. As the content of LECA was increased, the density reduced drastically which also reduced its compressive strength. Strength is solely a parameter which is directly proportional to density. Hence concrete with 60% LECA and 40% CA was chosen as concentration of coarser aggregate material.

Table XII: Represents Density, Compression Strength of Concrete with Varying Percentages of LECA.

Concrete type (mix ID)	Compressionstrength (N/mm^2)	Density (kg/m^3)	% change in density (%)
Conventional Concrete (100% CA)	41.36	2397.3	--
A1 (20% LECA + 80% CA)	39.25	2175.1	9.26
A2 (40% LECA 60% CA)	37.48	1990.8	16.95
A3 (60% LECA + 40% CA)	34.48	1605.3	33.03
A4 (80% LECA + 20% CA)	24.05	1397.0	41.72
A5 (100% LECA)	19.24	1279.1	46.64

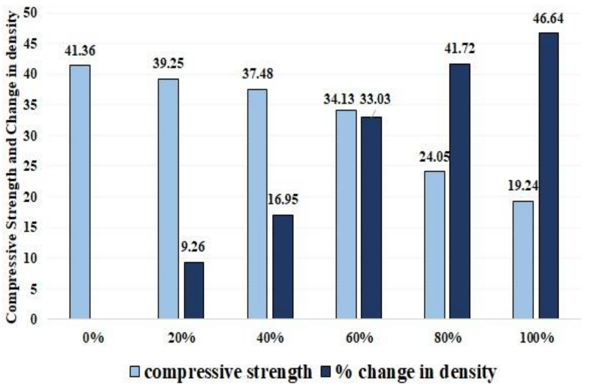

Figure VI: Represents Density & Compression Strength of Concrete with Varying Percentages of LECA.

B. Effect of metakaolin on compressive strengths

The compressive strength increases as the concentration of metakaolin was incremented. There is rise in compression strength due to addition of pozzolonic material up to 24% metakaolin (optimum mix S4) upon which the compressive strength declined. Hence, mix variation sample S4 was the optimum mix in order to attain high strength LWC.

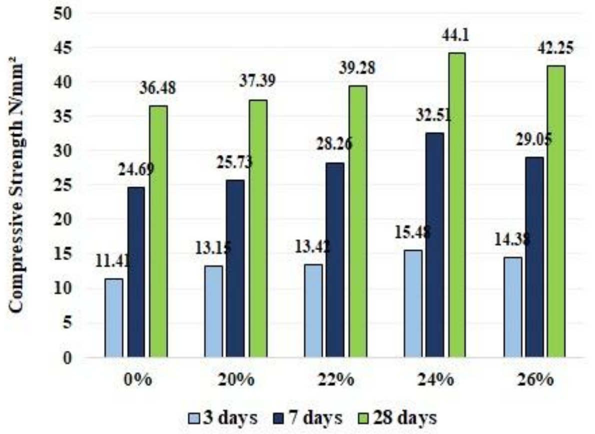

Figure VII: Represents Effect of Concentration of Metakaolin on Compressive Strength

C. Sorptivity

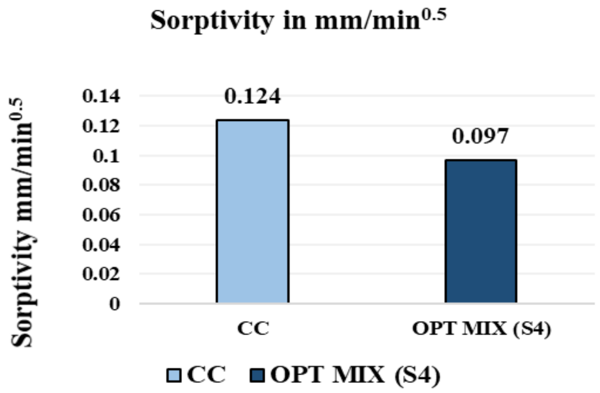

Figure VIII: Represents Sorptivity Values of Conventional Concrete and Optimum Mix

The absorptive/sorptive effect of conventional concrete is more when as compared to lightweight optimum concrete mix. This is because the pozzolonic effect of metakaolin helps in filling those minute voids and enhancing this type of durable properties.

D. Acid attack test

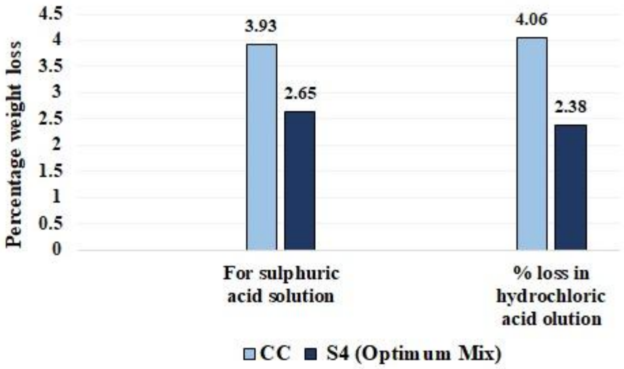

Figure IX: Represents Percentage weight loss data of Conventional Concrete Mix and Optimum Mix

The resistance to acid medium was greatest incorporated by cubes containing LECA and metakaolin, as compared to conventional concrete. The percentage loss for cubes under sulphate attack was 2.65% for optimum mix and percentage loss for conventional concrete was 3.93%. Similarly, The percentage loss for cubes under chloride attack for optimum mix was 2.38% and 4.06% for conventional concrete. Optimum mix with LECA & metakaolin gave good resistance as compared to CC. this might because LECA is an inert material accompanied by mineral admixture metakaolin.

IX. CONCLUSION

1) The workability of the LWC lowered as the content of LECA and metakaolin is increased, this is due to absorption of LECA and water demand by metakaolin.
2) Replacement of CA by LECA was at 60%, which worked out to be wiser with respect to density criteria.
3) The density of the optimum mix was 1605.33kg/m^3. The percentage in density of the optimum mix when compared to conventional concrete was 33.03%
4) The optimum content of metakaolin was 24% in concrete containing 60% LECA (Sample S4).
5) The compressive strength incremented as the content of metakaolin was raised until 24% later declined. Maximum increase of 17.27% when compared to S1.
6) The spit tensile strength for the optimum mix was 2.24 N/mm^2. The magnitude increase in the strength was 48.21%.
7) The resistance offered by Lightweight concrete with 24% metakaolin gave good resistance under acidic medium (2.38% <4.06%).
8) The sorptivity value of the optimum mix was 0.097 mm/min$^{0.5}$ whereas on other hand the sorptivity value for CC was 0.124 mm/min$^{0.5}$.

REFERENCES

1. Fathollah Sajedi, Payam Shafigh, "High-Strength Lightweight Concrete Using Leca, Silica Fume, and Limestone," Arab Journal Science Engineering
2. T. Divya Bhavana, Rapolu Kishore Kumar, S. Nikhil, P. Sairamchander, "Study Of Light Weight Concrete," International Journal of Civil Engineering And Technology, 8(4), 2017, pp. 1223-1230
3. Michala Hubertova, Rudolf Hela, "Durability of Lightweight Expanded Clay Aggregate Concrete," Elsevier Ltd 10.1016/2013.09.002
4. R. N. Raj Prakash, A. Krishnamoorthi, "Experimental Study On Light Weight Concrete Using Leca," International Journal of ChemTech Research, vol.10 No.8, pp 98-109, 2017
5. M. Mahdy, "Structural Lightweight Concrete Using Cured LECA," International Journal of Engineering and Innovative Technology (IJEIT), vol.5, Issue 9, March 2016
6. Hanamanth Shebannavar, Maneeth P. D, Brijbhushan S, "Comparative Study Of Leca As A Complete Replacement Of Coarse Aggregate By ACI Method With Equivalent Likeness Of Strength Of Is Method," International Research Journal of Engineering and Technology, Vol.2, Issue 08, Nov.2015
7. M. Narmatha, T. Felixkala, "Meta kaolin- The Best Material for Replacement of Cement in Concrete," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Vol.13, Issue, Ver.1 (Jul-Aug, 2016) PP 66-71
8. Kishan R. Patel, Siddharth G. Shah, Kedar Desai, "To Study the Effect of Addition of Lightweight Expanded Clay Aggregate on fresh and hardened properties of concrete," International Journal of Technical innovation in Modern Engineering and Science (IJTIMES), Vol.5, Issue 04, April-2019
9. Ali Sadr Momtazi, Reza Kohani Khoshkbijari, Seyed Mani Sharemi Jam, Saied Lessani Abdi, Seyed Sahand Mosavi, "Pozzolan's Effect on Durability of Light Concretes Made of LECA (Light Exapnded Clay Aggregate) and Scoria in Corrosive Environments Containing Sulfuric Acid," European Online Journal of Natural and Social Science 2015, Vol.3
10. Sunny A. Jagtap, Mohan N. Shirsath, Sambhaji L. Karpe, "Effect of Metakaolin on the Properties of Concrete," International Journal of Engineering and Technology (IRJET), Vol 04, Issue.07, July 2017
11. Mehdi Zohrabi, Amir Zohrabi, Amir Ghadimi Chermahini, "Investigation of the Mechanical Properties of Lightweight Concrete Containing LECA with Metakaoline Pozzolan Using Polypropylene and Steel Fibers," Journal of Applied Environmental and Biological Sciences, 5(12S)11-15,2015
12. Standard Practice for Selecting Proportions for Structural Lightweight Concrete (ACI 211.2-98)
13. IS-10262:2009, "Provision for Concrete Mix Design"
14. IS-456:2000, "Reference for Concrete Mix Design"
15. IS-383:1970, "Standards for Coarse and Fine Aggregates"
16. IS-12269:1987, " Specification of OPC 53 grade"
17. IS-516:1959,"Method of test for Compressive Strength and Flexural Strength of Concrete"
18. IS-5816:1970, "Method of test for Split-Tensile Strength of Concrete"
19. Information of LECA , provided from Perl Tech Ahmedabad
20. Information of Metakaolin provided from Raviraj Mineral Industries, Rajasthan
21. Guidelines for Viscosity Modifying Agents, EFNARC 2006
22. MasterMatrix SDC 150: High performance viscosity modifying agent (VMA) for fluid concrete - EN 934-2: T13.

AUTHORS PROFILE

Qazi Abu Haris Ateeq, PG student, Department of construction Technology, VTU Regional Centre for PG studies, Kalaburagi, India,
Email: abuharisateeq1@gmail.com

Maneeth P. D, Assistant professor, Department of Construction Technology, VTU Regional centre for PG studies, Kalaburagi, India
Email: maneeth.pd@gmail.com

Brijbhushan S., Course co-ordinator, Department of Construction Technology, VTU Regional centre for PG studies, Kalaburagi, India