International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June -2018 www.irjet.net p-ISSN: 2395-0072

AN EXPERIMENTAL STUDY ON EFFECT OF PARTIAL REPLACEMENT OF NORMAL WEIGHT AGGREGATES WITH LIGHTWEIGHT AGGREGATES IN FLYASH BASED GEOPOLYMER CONCRETE

D. Madhu Raj[1], J.V. Narasimha Raju[2], M. Suneel[3]

[1]M.Tech Student, Dept. of Civil Engineering, SRKR Engineering College, Andhra Pradesh, India
[2]College Engineer, Construction Department, SRKR Engineering College, Andhra Pradesh, India
[3]Assistant Professor, Dept. of Civil Engineering, SRKR Engineering College, Andhra Pradesh, India

---***---

Abstract - *Geopolymer concrete is being studied extensively and found as a greener alternative to Portland cement concrete. No cement is used in geopolymers concrete, instead fly ash and alkaline solution with a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) are used to make the binder necessary to manufacture the concrete. The high self weight of normal concrete can be reduced by using low density concrete, which obviously reduces the size of the sectional elements, foundation size, and thereby cost of construction. In the present study, it is aimed to produce lightweight geopolymer concrete by partial replacement of normal weight aggregates with 3 different types of lightweight aggregates like Pumice, LECA, and Sintagg. The percentage of replacement of normal weight aggregates varies from 0% to 20% in each case. Fresh properties of lightweight geopolymer concrete are studied by conducting slump cone test. Hardened properties of geopolymer concrete are assessed by conducting compressive strength test, split tensile strength test and flexural strength test on specimens subjected to 7 days, 14 days, and 28 days ambient curing.*

***Key Words*: Ambient curing, Lightweight aggregate, Geopolymer concrete, Alkaline solution, Sodium hydroxide, Sodium silicate, Pumice, LECA, Sintagg, etc.**

1. INTRODUCTION

In geopolymer concrete, Alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or industrial by-product materials to produce binders. Because, the chemical reaction that takes place in this case is a polymerization process. The source materials for geopolymers should be rich in silicon (Si) and aluminium (Al). By-product materials such as fly ash, GGBS , rice-husk ash, silica fume, red mud, etc., could be used as source materials. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate(Na_2SiO_3) or potassium hydroxide (KOH) and or potassium silicate(K_2SiO_3). In the fly ash based geopolymer concrete, the silica and alumina present in the source materials are the alkaline activators to form a gel known as aluminosilicate gel.

Light weight concrete can be produced by including large quantities of air in between the aggregate particles. The use of lower density concrete allows construction on ground with a low load bearing capacity. Pressure on formwork will be lesser than normal weight concrete, and also the total mass of materials can be reduced. When compared to normal weight concrete, lightweight concrete consumes more cement which results in more expensive. However, cost of materials cannot be limited but should be made on the basis of the design of the structure using lightweight concrete.

One of the most common methods used to produce lightweight concretes with the usage of lightweight aggregates (LWA's). It has many advantages such as low density, good thermal insulation, good fire resistance and reduced cost of transport. There are different types of LWA's, they are diatomite, pumice, scoria, volcanic cinders, tuff, expanded clay, sintagg, LECA, shale, slate, perlite, vermicelite. In the present experimental work pumice, LECA and sintagg aggregates are used as lightweight aggregates.

The objective of the present study is to develop the geopolymer concrete with higher (14M) concentration of NaOH solution by using lightweight aggregates in partial replacement of normal weight aggregates by volume in GPC. Another main objective is to study the effect of ambient curing.

2. REVIEW OF LITERATURE

D Hardjito and S E Wallah [1] presents the results of a study on geo-polymer concrete. The test parameters covered certain aspects of manufacture of geo-polymer concrete. The paper also reports the stress-strain behaviour of the concrete with compressive strength in the range of 40 to 65 MPa.

N A Lloyd and B V Rangan [2] presents Geopolymer Concrete results from the reaction of a source material that is rich in silica and alumina with alkaline liquid. Test data are used to identify the effects of salient factors that influence the properties of the Geopolymer Concrete and to propose a simple method for the design of Geopolymer Concrete mixtures.

B. Devi Pravallika, K.Venkateswara Rao [3] proposed that the strength and durability properties of M40 concrete by partial replacement of coarse aggregate with natural light weight aggregate pumice stone. The properties of conventional M40 concrete are compared with properties of concrete with light weight aggregate, produced by replacing coarse aggregate with pumice stone by 0%, 10%, 20%, 30%, 40% and 50%.

K. Guru Kesav Kumar, C. Krishnaveni [4] Studied on partial replacement of aggregate by pumice stone in cement concrete. Their study aims at finding out the sustainability of pumice stone as a construction material, its cost effectiveness and the reduction in density can be obtained by using replacement of coarse aggregate partially in concrete.

R.N. Raj Prakash, A.Krishnamoorthi [5] Presents paper on experimental study on effect of partial replacement of coarse aggregate by lightweight expanded clay aggregate (LECA). They compare the weight of concrete and mechanical properties of light weight concrete against conventional concrete by partially replacing natural aggregates by LECA by 20%, 40%, 60%, 80% and 100%.

R. Vijayalakshmi and S. Ramanagopal [6] Presents a paper on structural concrete using expanded clay aggregate and it is possible to produce concrete having compressive strength between 23 to 60 MPa and density 1290 to 2044 kg/m^3.

Zaid Topiwala, Prof. D.R Tarachandani [7] presents a paper on experimental study on utilizing sintered fly ash aggregates as replacement of coarse aggregates in concrete. In this study, the physical properties of sintered fly ash aggregates have been investigated. The unit weight of both the type of concrete has been compared by considering weight of the cube specimens.

A. Arokiaprakash, V. Thenarasan [8] examined the strength properties of concrete, partially replaced with sintagg aggregate to coarse aggregate. The test specimens are prepared with sintagg aggregate mixed partially at 10%, 20%, 30%, 40% and 50% to the coarse aggregate in concrete.

3. MATERIALS

The materials used for making flyash based geopolymer concrete by partial replacement of normal weight aggregates with light weight aggregates are Fly ash, Sodium hydroxide, Sodium silicate, Fine aggregate (Sand), Coarse aggregates (20 mm, 12 mm, and 6 mm), Lightweight aggregates (Pumice, LECA, and Sintagg), and Water.

3.1 Fly-Ash

Fly-Ash is a finely divided residue that results from the combustion of ground (or) pulverized coal and is transported from boilers by flue gases is known as “fly ash”. The pulverized coal is introduced into the furnace in a stream of air 75 to 85% of ash resulting from the combustion of pulverized coal is carried out of the furnace with fuel gases and extracted by “cyclone separator”, electro static precipitators in the form of a “fine gray powder” called fly ash or pulverized fuel ash (P.F.A).

3.2 Sodium Hydroxide (NaOH)

Generally the sodium hydroxide is available in solid state in the form of pellets and flakes. The cost of the sodium hydroxide is mainly varied according to the purity of the substance. In this investigation the sodium hydroxide pellets are used. Sodium hydroxide solutions were prepared with concentration of 14M.

3.3 Sodium Silicate (Na_2SiO_3)

Sodium silicate is also known as water glass or liquid glass is available in liquid (gel) form. As per the manufacture, silicates are supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of Geopolymer Concrete. Sodium silicate gel is added to sodium hydroxide solution of desired concentration, This alkaline solution (NaOH solution and Na_2SiO_3) prepared 24 hours prior to preparation of concrete.

3.4 Pumice

Pumice called pumicite. The cellular structure of Pumice and its low density is created by the formation of bubbles or voids when gases contained in molten lava flowing from volcanoes become trapped on cooling. The cells are elongated and parallel to one another and are sometimes interconnected. They are light enough and yet strong enough to be used in natural state, but the variable quantities dependent upon its source.

3.5 LECA

LECA means Light Expanded Clay Aggregate. LECA consists of small, lightweight, bloated particles of burnt clay. The thousands of small, air-filled cavities give LECA its strength and thermal insulation properties. The base material is plastic clay which is extensively pre-treated and then heated and expanded in a rotary kiln.

3.6 Sintagg

Sintered Fly Ash is one of the most important type of structural Lightweight aggregate used in modern times. Fly Ash is finely divided residue, comprising of spherical glassy particles, resulting from the combustion of powdered coal. By heat treatment these small particles can be made to combine, thus forming porous pellets or nodules which have considerable strength.

4. EXPERIMENTAL INVESTIGATION

Conventional geopolymer concrete is made with combined aggregate content as 70%, alkaline liquid to flyash ratio as 0.5, concentration of NaOH as 14M and NaOH to Na_2SiO_3 ratio as 2.5. Keeping all the contents same as in conventional geopolymer concrete, the effect of partial replacement of normal weight aggregates with light weight aggregates is investigated.

Light weight aggregate geopolymer concrete is produced by partial replacement of natural crushed aggregates with the 3 different types of Lightweight aggregates like Pumice, LECA, and Sintagg. For each type of light weight aggregate 4 mixes are prepared. The percentage of replacement of natural crushed aggregates varies from 0% to 20% in each case and the properties of fresh and hardened geopolymer concrete are studied.

4.1 Preparation of Alkaline Solution

Alkaline solution is a combination of NaOH solution and Na_2SiO_3. In alkaline solution the concentration of sodium hydroxide solution and the ratio of sodium silicate solution to sodium hydroxide solution influence the strength of the concrete. It is strongly recommended that the alkaline solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it turns to semi-solid state. So the prepared solution should be used within this time.

4.2 Preparation of NaOH Solution

The molecular weight of NaOH is 40. To prepare 14M NaOH solution take 14 x 40 = 560 grams of NaOH pellets and dissolve them in distilled water to make one liter solution. The solution thus prepared is known as 14M NaOH solution. The mass of NaOH solids is measured as 420 grams per kg of NaOH solution.

Table -1: Quantities of GPC
Materials required for 1m^3 of GPC

Mass of F.A (kg)	Mass of A.L (kg)	mass of NaOH (kg)	Mass of Na_2SiO_3 (kg)	Mass of combined aggregate (kg)
480	240	68.57	171.43	1680

Mass of fine aggregate (kg)	mass of coarse aggregate (kg)		
	20 mm	12 mm	6 mm
504	823.20	235.20	117.60

Table -2: Quantities of LWA
Lightweight aggregates required for 1 m^3 of LWA GPC(Weights of LWA's Taken by Volume)

% LWA	Weight of Pumice (kg)	Weight of LECA (kg)	Weight of Sintagg (kg)
5	12.87	9.38	23.13
10	23.76	18.74	46.30
15	38.62	28.08	69.46
20	51.52	37.46	92.68

4.3 Curing

The specimens of LWA GPC are kept for ambient curing for period of 7 days, 14 days and 28 days. Since there is a delay in setting time of GPC, all the specimens are given three days rest period before they are demoulded and kept for ambient curing. During the rest period the specimens along with the mould were kept in sunlight to facilitate demoulding easily. The specimens are demoulded after three days of rest period.

4.4 Details of Specimens

- Cubical specimens of size 100 mm × 100 mm × 100 mm are casted for the determination of compressive strength.
- Cylindrical specimens of size 100 mm × 200 mm are casted for the determination of split tensile strength.
- Beams of size 500 mm × 100 mm × 100 mm are casted for the determination of flexural strength.

4.5 Testing

For studying the fresh properties of LWA GPC, Slump cone test and hardened properties of LWA GPC, compressive strength test, split tensile strength and flexural strength test have been conducted and determined.

5. RESULTS AND DISCUSSION

5.1 Slump Cone Test

Table -3: Workability for LWA GPC

S.No	% of Lightweight Aggregate	Slump (mm)		
		Pumice	LECA	Sintagg
1	0	62	62	62
2	5	70	65	67
3	10	79	71	72
4	15	91	78	88
5	20	98	86	92

It can be observed that the slump values are increased with increase in percentage of lightweight aggregate i.e., Workability is increasing.

5.2 Compressive Strength Results of LWA GPC

Table -4: Compressive Strength Results of Pumice

% of LWA Pumice	Density (kg/m³)	Compressive Strength (N/mm²)		
		7 days	14 days	28 days
0	2382	14.66	20.86	30.33
5	2343	10.73	17.33	26.26
10	2261	9.53	16.13	22.50
15	2257	9.80	14.20	21.83
20	2217	9.67	14.13	20.63

Referring to table 4, GPC with 5% pumice content, shown better results at 28 days than the other percentages of Pumice content. The compressive strength of GPC with all percentages of pumice content increases up to 28 days of ambient curing. It is also observed that the density of LWA GPC decreases with increase in % of pumice content.

Table -5: Compressive Strength Results of LECA

% of LWA LECA	Density (kg/m³)	Compressive Strength (N/mm²)		
		7 days	14 days	28 days
0	2382	14.66	20.86	30.33
5	2354	10.20	17.07	23.53
10	2299	7.53	15.20	21.53
15	2281	6.80	13.87	20.80
20	2227	6.93	13.60	21.06

Referring to table 5, GPC with 5% LECA Content shown better results at 28 days than the other percentages of LECA content. The compressive strength of GPC with all percentages of LECA content increased up to 28 days ambient curing. It is also observed that the density of LWA GPC decreases with increase in % of LECA content.

Table -6: Compressive Strength Results of Sintagg

% of LWA Sintagg	Density (kg/m³)	Compressive Strength (N/mm²)		
		7 days	14 days	28 days
0	2382	14.66	20.86	30.33
5	2332	12.66	21.27	27.66
10	2328	9.33	19.73	28.60
15	2321	8.40	17.20	26.20
20	2268	9.20	16.67	24.53

Referring to table 6, GPC with 10% sintagg content better results at 28 days than the other percentages of sintagg content. The compressive strength of GPC with all percentages of sintagg content increased up to 28 days ambient curing. It is also observed that the density of LWA GPC decreases with increase in % sintagg content.

5.3 Split Tensile Strength Results of LWAGPC

Table -7: Split Tensile Strength Results of Pumice

% of LWA Pumice	Density (kg/m³)	Split Tensile Strength (N/mm²)		
		7 days	14 days	28 Days
0	2330	1.10	1.82	2.20
5	2257	1.14	1.82	2.12
10	2200	0.25	0.55	1.27
15	2194	0.55	0.70	1.40
20	2159	0.40	0.72	1.27

Referring from table 7, GPC with 5% pumice content shown better results than the other percentages of pumice content. The split tensile strength of GPC with all percentages of pumice content increases up to 28 days ambient curing. It is also observed that the density of LWA GPC decreases with increase in % of pumice content.

Table -8: Split Tensile Strength Results of LECA

% of LWA LECA	Density (kg/m³)	Split Tensile Strength (N/mm²)		
		7 days	14 Days	28 Days
0	2330	1.10	1.82	2.20
5	2265	0.65	1.08	1.27
10	2227	0.43	0.83	1.23
15	2216	0.29	0.63	0.91
20	2208	0.55	0.86	1.04

Referring from table 8, GPC with 5% LECA Content shown good results than the other percentage of LECA content.

The split tensile Strength of GPC with all percentages of LECA content increases up to 28 days ambient curing. It is also observed that the density of LWA GPC decreases with increase in % of LECA content.

Table -9: Split Tensile Strength Results of Sintagg

% of LWA Sintagg	Density (kg/m³)	Split Tensile Strength (N/mm²)		
		7 days	14 days	28 Days
0	2330	1.10	1.82	2.20
5	2268	1.10	1.23	1.76
10	2280	0.87	1.44	1.67
15	2255	0.53	1.27	1.61
20	2207	0.53	1.21	1.40

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June -2018 www.irjet.net p-ISSN: 2395-0072

Referring from table 9, GPC with 5% sintagg content shown good results than the other percentage of sintagg content.

The split tensile strength of GPC with all percentages of sintagg content increases up to 28 days ambient curing. It is also observed that the density of LWA GPC decreases with increase in % of sintagg content.

5.4 Flexural Strength Results of LWA GPC

Table -10: Flexural Strength Results of Pumice

% of LWA Pumice	Density (kg/m³)	Flexural Strength (N/mm²)		
		7 days	14 days	28 days
0	2381	4.95	5.08	6.63
5	2338	4.25	4.72	6.58
10	2269	2.34	2.97	3.67
15	2253	2.68	3.77	3.95
20	2221	2.06	3.30	3.50

Referring from table 10, GPC with 5% pumice content shows good results than the other percentage of pumice content.

The flexural strength of GPC with all percentages of Pumice content increases up to 28 days ambient curing. It is also observed that, the density of LWA GPC decreases with increase in % of pumice content.

Table -11: Flexural Strength Results of LECA

% of LWA LECA	Density (kg/m³)	Flexural Strength (N/mm²)		
		7 days	14 Days	28 Days
0	2381	4.95	5.08	6.64
5	2340	1.86	2.95	3.10
10	2284	2.23	3.18	3.42
15	2261	2.06	3.03	3.58
20	2245	2.14	3.15	3.76

Referring from table 11, GPC with 20% LECA content shows good results than the other percentage of LECA content.

The flexural strength of GPC with all percentages of LECA content increases up to 28 days ambient curing. It is also observed that, the density of LWA GPC decreases with increase in % of LECA content.

Table -12: Flexural Strength Results of Sintagg

% of LWA LECA	Density (kg/m³)	Flexural Strength (N/mm²)		
		7 days	14 days	28 Days
0	2381	4.95	5.08	6.64
5	2355	3.51	4.47	5.15
10	2338	2.88	4.60	6.35
15	2318	2.38	4.45	5.13
20	2300	2.14	4.21	5.01

Referring from table 12, GPC with 10% sintagg content shows good results than the other percentages of sintagg content. The flexural strength of GPC with all percentages of sintagg content increases up to 28 days ambient curing. It is also observed that, the density of LWA GPC decreases with increase in % of sintagg content.

GRAPHS

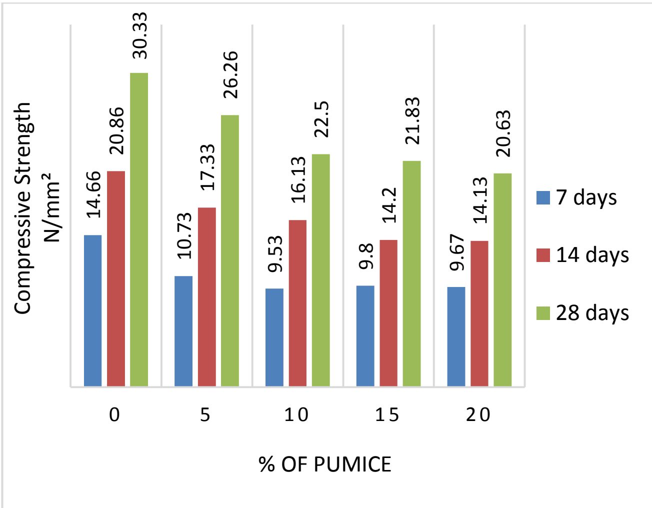

Chart -1: Compressive strength values of pumice

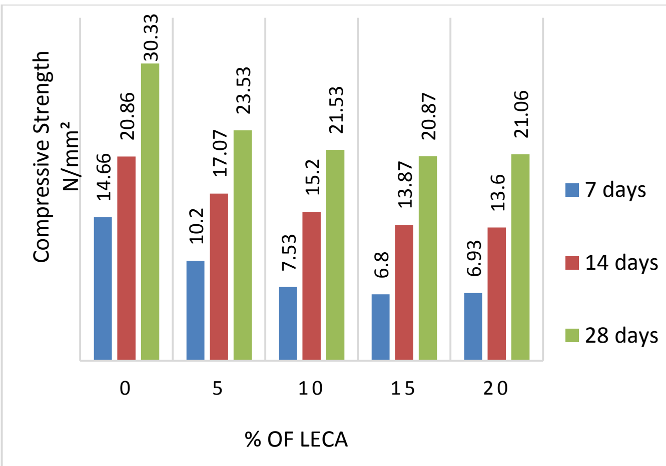

Chart -2: Compressive strength values of LECA

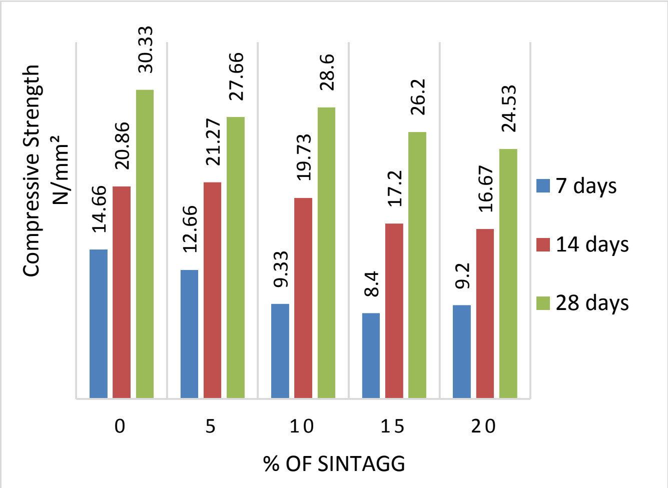

Chart -3: Compressive strength values of sintagg

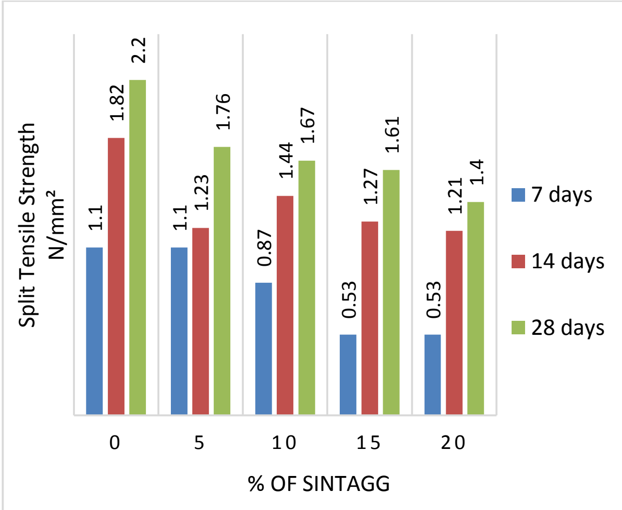

Chart -6: Split tensile strength values of sintagg

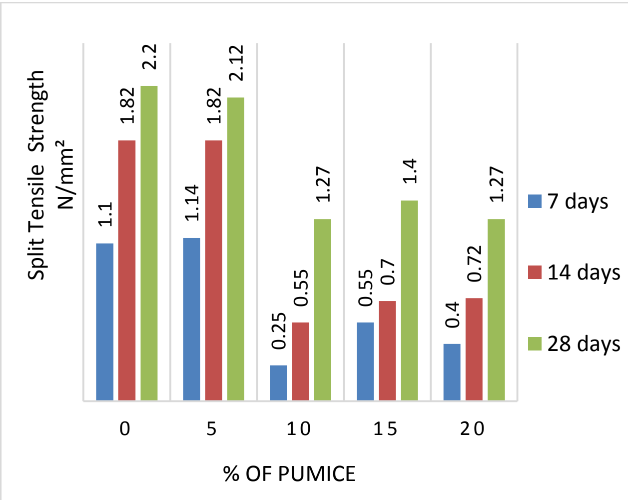

Chart -4: Split tensile strength values of pumice

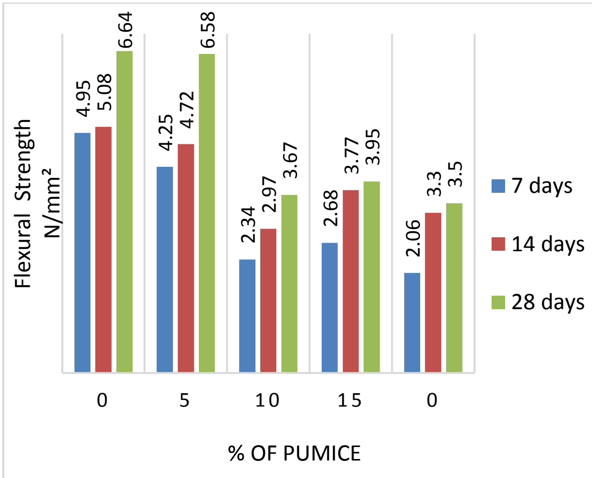

Chart -7: Flexural strength values of pumice

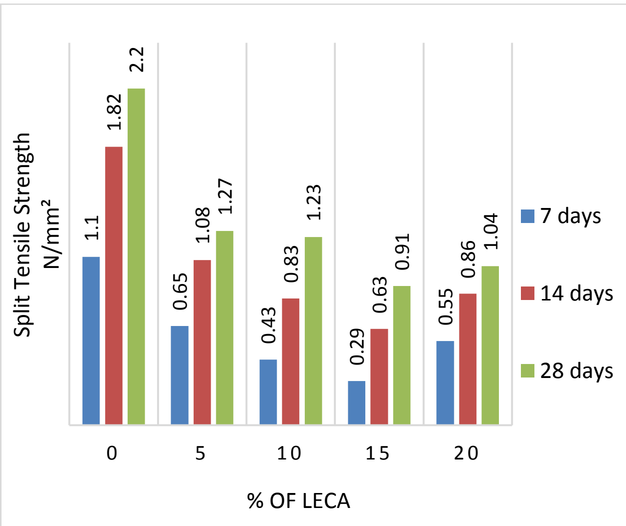

Chart -5: Split tensile strength values of LECA

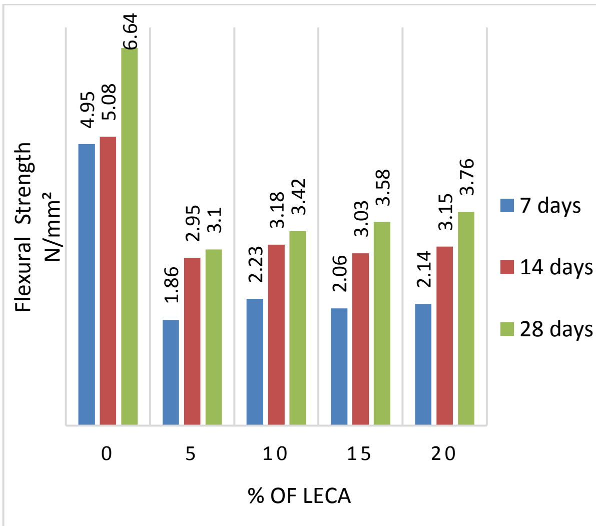

Chart -8: Flexural strength values of LECA

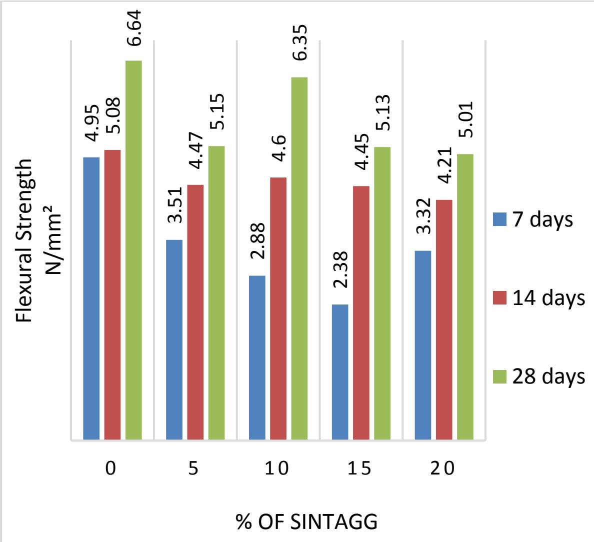

Chart -9: Flexural strength values of Sintagg

6. CONCLUSIONS

1. The weight of LWA GPC with Pumice, LECA, and Sintagg is low compared to that of NWA GPC. However, there is no considerable reduction in weights.

2. It is observed that, the workability of LWA GPC is decreased, when LWA's are used without soaking. However, from the test results obtained, it is noticed that the workability is improved when the LWAs are soaked in water.

3. Generally Pumice, LECA, and Sintagg have more water absorption compared to the natural coarse aggregates which in turn effects the workability. To overcome this problem soaking of aggregates is done before mixing.

4. Pumice, LECA and Sintagg being light in weight tends to move up during compaction of GPC, which results in non uniform surface.

5. The maximum compressive strength of LWA GPC with Pumice, LECA, and Sintagg is observed as 26.26 Mpa for 5%, 23.53 Mpa for 5% and 28.6 Mpa for 10% respectively at 28 days. Further increase in LWA content decreases the compressive strength values.

6. The maximum Split Tensile strength of LWA GPC with Pumice, LECA, and Sintagg is observed as 2.12 Mpa, 1.27 Mpa, and 1.76 Mpa respectively for 5% at 28 days. Further increase in LWA content decreases the Split Tensile strength values.

7. The maximum Flexural strength of LWA GPC with Pumice, LECA, and Sintagg is observed as 6.58 MPa for 5%, 3.76 Mpa for 20% and 6.35Mpa for 10% respectively at 28 days. Further increase in LWA content decreases the flexural strength values.

8. From the test results it is observed that LWA GPC with Sintagg shown better results than that of Pumice and LECA.

Finally, it may be concluded that the lightweight geopolymer concrete is more eco friendly and it is suitable for many practical applications. Also, Usage of LWA GPC will minimize the consumption of naturally available normal weight aggregates.

REFERENCES

[1] D.Hardjito et al., "Introducing fly ash based Geopolymer Concrete: Manufacture and Engineering Properties", Curtin University of Technology, Australia, 2005.

[2] N.A. Lloyd and B.V. Rangan, "Geopolymer Concrete with flyash", Curtain University of Technology, Australia, 2010.

[3] B. Devi Pravallika and K. VenkateswaraRao, "The Study on Strength Properties of Light Weight Concrete using Light Weight Aggregate", International Journal of Science and Research, Volume 5, Issue 6, 2016.

[4] K. Guru Kesav Kumar and C. Krishnaveni, "Study On Partial Replacement of Aggregate by Pumice Stone in Cement Concrete", The International Journal of Science & Technoledge, Volume 4, Issue 3, 2016.

[5] R.N. Rajprakash and A. Krishnamoorthi," Experimental Study on Light Weight Concrete Using Leca", International Journal of Chemtech Research, Volume 10, Issue 8, 2017.

[6] R. Vijayalakshmi* and S. Ramanagopal, "Structural Concrete Using Expanded Clay Aggregate: A Review", Indian Journal of Science and Technology, Volume 11, Issue 16, 2018.

[7] Zaid Topiwala et al., "Compressive Strength analysis of Lightweight Aggregate Concrete with Sintered FlyAsh Aggregates", International Journal of Modern Trends in Engineering and Science, Volume 4, Issue 4, 2017.

[8] A. Arokiaprakash and V. Thenarasan, "Experimental Study of Properties of Light Weight Concrete as a Partial Replacement of Sintagg Aggregate To Coarse Aggregate", International Journal Of Civil Engineering And Technology (IJCIET) Volume 9, Issue 3, 2018.