An Experimental Study on Light Weight Concrete by Partial Replacement of Coarse Aggregate by Pumice Stone and Cement by GGBS

M Praveen Kumar[1] Dr.K.Rajasekhar[2]
[1]P.G. Student [2]Professor
[1,2]Department of Civil Engineering
[1,2]Siddartha Educational Academy Group of Institutions Integrated Campus, Tirupati(R),JNTUA, A.P

Abstract— Today's construction industry, use of concrete is going on increasing rapidly. Cement is major constituent material of the concrete which produced by natural raw material like lime and silica. Once situation may occurs there will be no lime on earth for production of .This situation leads to think all people working in construction industry to do research work on cement replacing material and use of it. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. Use of GGBS as cement replacement will simultaneously reduces cost of concrete and help to reduce rate of cement consumption. And also In this study, an attempt has been made to study the Mechanical Properties of a structural grade light weight concrete using the light weight aggregate pumice stone as a partial replacement to coarse aggregate. The conventional mix has been designed for M30 grade concrete. Coarse aggregate replaced with Pumice aggregate in volume Percentages of 25% and 35% further Cement replaced with the Ggbs in weight percentages of 5%,10%,15%, 20%, 25%, 30% for study in the present investigation. The properties like Compressive strength, Split tensile strength, Flexural strength of above combinations were studied and compared with conventional design mix concrete. It is observed that there is retardation in Compressive strength, Split tensile strength, Flexural strength for the light weight aggregate replaced concrete when compared to the concrete made with normal aggregate. For these light weight aggregate concrete mixes when 'cement' was replaced by 'GGBS' it is noticed that there is a marginal improvement in the properties studied. For 25% and 35% replaced light weight aggregate when cement was replaced by 5%,10%,15%, 20%, 25%, 30%.

Key words: Light weight concrete, Pumice Stone, Ground granulated Blast Furnace Slag, Compressive strength, Tensile strength, Flexural Strength, Density

I. INTRODUCTION

Light weight concrete has become most popular in recent years outstanding to the very great advantages it offers over the predictable concrete but at the same time strong enough to be used for the structural purpose. The most important characteristic of light weight concrete is its low thermal conductivity. This properties improves with decreasing density. Concrete with a density between 1350 and 1900 kg/m^3 and a minimum compressive strength of 17MPa is defined as structural lightweight concrete (ACI 213R-87, 1998).

Lightweight aggregate, because of their cellular structure, can absorb more water than normal weight aggregate. In a 24-hour absorption test, they generally absorb 5 to 20% by mass of dry aggregate, which is depending on the pore structure of the aggregate

Increasing exploitation of lightweight materials in civil structuring applications is making pumice stone a very important raw material as a lightweight rock. Due to its having a good capability for making the different products based on its physical, chemical and mechanical properties, the pumice aggregate finds a large useful in civil industry as a construction material. In the initial stage of a building project, the construction material properties should be well evaluated. Therefore, the need arises to evaluate the materials to be used in construction experimentally in detail. Pumice stone has been used for centuries in the world. Pumice aggregate can be found in many places around the world where volcanoes are situated. Although it has been used successfully in many countries. But finding new and improved ways to use pumice is little bit slowly. When structural lightweight concrete with pumice is used in construction and maintenance of civil engineering structures, the resultant benefits of reduced overall costs, better heat and sound insulation and better resistance to fire can be realized. Although its lower compressive strength and lower modulus elasticity, pumice concrete can be potentially used in many kinds of structural elements

GGBS means the ground granulated blast furnace slag is a by-product of the manufacturing of pig iron. Iron ore, coke and Lime-stone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500oC to 1600oC. The molten slag has a composition close to the Chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of a glassy granulate. This glassy granulate is dried and ground to the required size, which is known as ground granulated blast furnace slag (GGBS).

II. METHODOLOGY AND OBJECTIVES

A. *Objectives:*

The specific objectives of the present investigations are as listed below:

- To conduct the possibility study of producing light weight aggregate pumice concrete with GGBS admixture.
- To investigate the mechanical properties of pumice aggregate concrete, such as, compressive strength, tensile strength, flexural strength.
- To investigate the flexural behavior of the pumice Light Weight Aggregate Concrete beam.

- To study the effect of various types replacements (25% and 35%) of natural aggregate by light weight aggregate(pumice) and the replacement of cement by an admixture (GGBS) in different percentages, (5%,10%,15%, 20%, 25%,and 30%) on 7, 28,90 days compressive strength.
- To study the effects and behaviour of various replacements (25% and 30%) of natural aggregate by light weight aggregate(pumice) and replacement of cement by an admixture (GGBS) in different percentages, on 7, 28,days split tensile strength
- To study the effect of various replacements (25% and 30%) of natural aggregate by light weight aggregate(pumice) and replacement of cement by an admixture (GGBS) in percentages on 7, 28, days flexural strength (fs) .

B. Methods of Making Light Weight Concrete

Basically, there is only one means of making concrete light- by including air in its composition. The inculcation of air can however be accomplished by the following three ways

- By omitting i,e finer sizes from the aggregate grading, thereby creating the so called 'No-fines concrete'.
- By replacing the gravel or crushed rock by a hollow, cellular or permeable aggregate which s includes air in the mix.
- By creating gas bubbles in a cement slurry - 'Aerated Concrete'.

III. MATERIALS & PROPERTIES

A. Cement:

The cement used was ordinary Portland cement of 53-grade conforming to IS 12269. The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible.

Physical properties	Zuari 53 grade	IS: 12269-2013
Fineness (m^2/kg)	290	>225
Soundness (mm)	1.0	<10
Initial Setting Time Final Setting Time	160 260	>30 <600
Compressive Strength 28 days (MPa)	60	>53
Speccific Gravity	3.18	3.15
Fineness modulus	0.9	1.20

Table 1: Physical Properties of OPC 53 grade cement based on IS: 12269-2013

B. Fine Aggregate

The locally available natural river sand is procured and is found to be conformed to grading zone-II

Specific Gravity : 2.66
Fully compacted density : 1670 kg/m^3
Partially compacted density: 1500 kg/m^3
Fineness Modulus : 3.20

C. Coarse Aggregate:

The Machine Crushed granite aggregate confirming to IS 383-1970 consisting 20 mm maximum size of aggregate has been obtained from the near or local quarry. It has been tested for Physical and Mechanical Properties such as Specific Gravity.

Specific Gravity : 2.61
Fully compacted density : 1690kg/m^3
Partially compacted density: 1466kg/m^3
Fineness Modulu : 9.09

D. Pumice Stone:

Pumice is a natural sponge-like (absorb) material of volcanic origin which was composed from molten lava rapidly cooling and trapping millions of small air bubbles.

Fig. 1:

Specific Gravity : 0.82
Fully compacted density : 85kg/m^3
Loose density : 140kg/m^3
Size of Pumice : 20mm

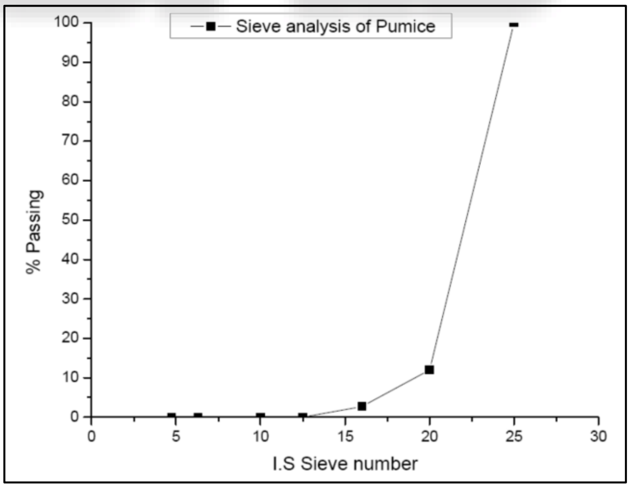

Fig. 2: Sieve Analysis of Pumice

E. Ground Granulated Blast Furnace Slag:

Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag is rapidly chilled by immersion in water. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like port land cement. The specific gravityof GGBS is 2.85.

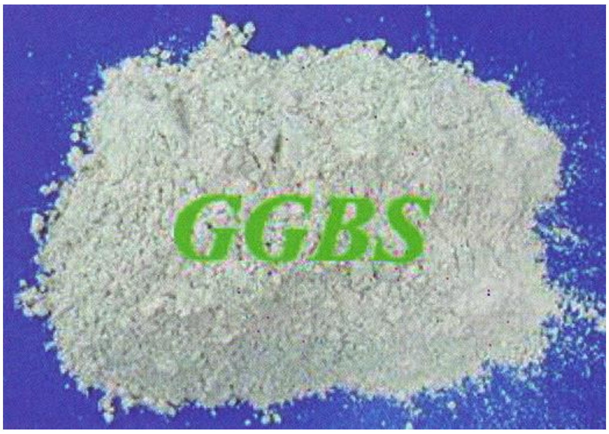

Fig. 3:

CHEMICAL PROPERTIES OF GGBS	RESULTS
Fineness(m^2/kg)	276
Soundness(mm)	11
Initial setting time(min)	240
Insoluble residue	1.7%
Magnesia	15%
Sulphur	2.60%
Loss of ignition	3.5%
Manganese	3%
Chloride	0.2%
Moisture	1%
Glass	67%
Compressive strength at 7 days(MPa)	12
Compressive strength at 28 days	32.7
Specific gravity	2.89

Table 2: Chemical Properties GGBS

F. *Water:*

In this research potable water free from organic substance was used for mixing as well as curing of concrete.

IV. TESTS & DISCUSSIONS

A. *Process of Manufacture of Concrete:*

1) Batching:The measurement of materials for making concrete isknown as Batching.
2) Weigh Batching: Weigh is the correct method of measuring the material. Use of weight system is batching, facilitates accuracy, flexibility and simplicity
3) Measurement of water: When weigh batching is adopted, the measurement of water must be done accurately. Addition of water by graduated bucket in terms of liters will not be accurate enough for the reason of spillage of water etc.

B. *Preparation of Concrete Cubes:*

Metal moulds, preferably steel or cast iron, strong enough to prevent distortion is required. They are made in such a manner as to facility the removal of the moulded. Specimen without damage and are so maintained that, when it is assembled, the dimensions and internal faces are required to be accurate within the following limits.

1) Compacting

The testing cube specimens are made as soon as possible after mixing and in such a manner to produce full compaction of the concrete with neither segregation nor excessive bleeding.

2) Curing

The test specimens are stored in a place free from vibration in moist air of at least 90% relative humidity and at a temperature of 27^0C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds.

C. *Testing:*

1) Compressive Strength

After 28 days curing, cubical specimens are placed on compression testing machine having a maximum capacity of 3000 KN and a constant rate of loading of 40 kg/m^2per minute is applied on test specimen. Ultimate load at which the cubical specimen fails is noted down from dial gauge reading. This ultimate load divided by the area of specimen gives the compressive strength of each cube.

S.NO	Mix Designation	Compressive Strength(MPa)		
		7days	28days	90days
	0%NA	29.25	38.35	44.5
	0% GGBS25%LWA	24.04	35.11	40.64
	5% GGBS25% LWA	25.04	35.85	41.25
	10% GGBS 25 LWA	25.77	37.48	42.58
	15% GGBS 25% WA	26.51	37.93	42.64
	20% GGBS 25% LWA	28.29	38.25	43.24
	25% GGBS 25% LWA	25.04	34.96	40.15
	30%GGBS25%LWA	23.07	32.15	39.52

Table 3: Variation of compressive strength at different age for 25% LWA

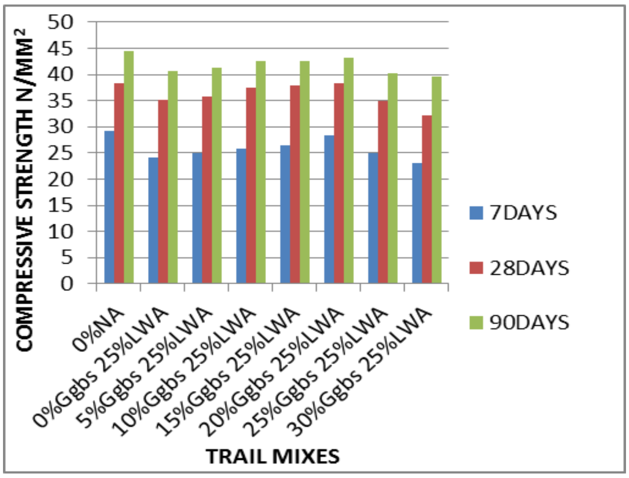

Fig. 4: Variation of compressive strength at different age for *25%LWA*

S.NO	Mix Designation	Compressive Strength (MPa)		
		7days	28days	90days
1	0%NA	29.25	38.35	44.5

2	0% GGBS35%LWA	23.25	34.28	40.35
3	5% GGBS35%LWA	24.36	34.85	40.24
4	10% GGBS 35%LWA	24.78	36.48	41.58
5	15% GGBS 35% LWA	25.51	36.93	41.23
6	20% GGBS 35% LWA	27.48	37.25	42.25
7	25% GGBS 35% LWA	24.04	33.96	39.15
8	30%GGBS 35%LWA	22.36	31.12	36.8

Table 4: Variation of compressive strength at different age for 35% LWA

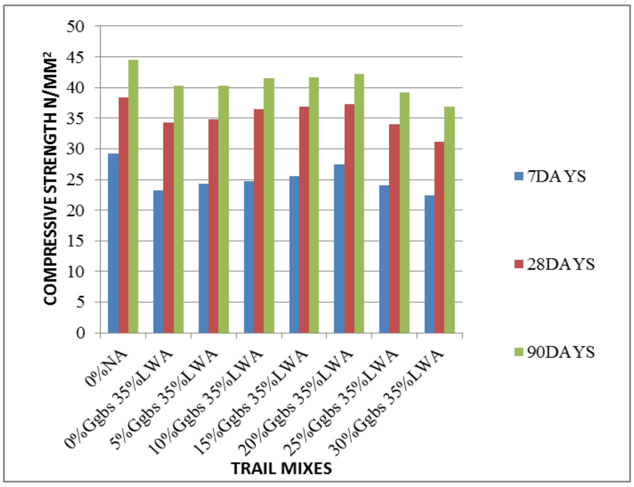

Fig. 5: Variation of compressive strength at different age for *35%LWA*

From above table 3&4 and graph 2&3

It is observed that for the mixes prepared with 35% replacement of light weight aggregate when cement was replaced by GGBS with 0%, 5%, 10%, 15%, 20%, 25 %and30%.Higher compressive strengths are observed for the 20% GGBS s for all ages

2) Tensile Strength:

After 28 days curing, cylinder specimens are placed on tensile testing machine having a maximum capacity of 1000 KN and a constant rate of loading of 40 kg/m^{2}per minute is applied on the test specimen by placing two steel plates below and above the cylinder in the horizontal direction. Ultimate load at which the cylindrical specimen fails is noted down from dial gauge reading.

S.NO	Mix Designation	SPLITTENSILE STRENGTH(MPA)	
		7DAYS	28 DAYS
1	0%NA	2.9	5.37
2	0% GGBS25%LwA	2.34	4.48
3	5% GGBS25%LwA	2.42	4.56
4	10% GGBS 25% LwA	2.54	4.68
5	15% GGBS 25% LwA	2.61	4.78
6	20% GGBS 25% LwA	2.69	4.86
7	25% GGBS 25% LWA	2.32	4.36
8	30%GGBS 25%LWA	2.24	4.24

Table 5: Variation of Splitting Tensile strength at different age for 25% LWA

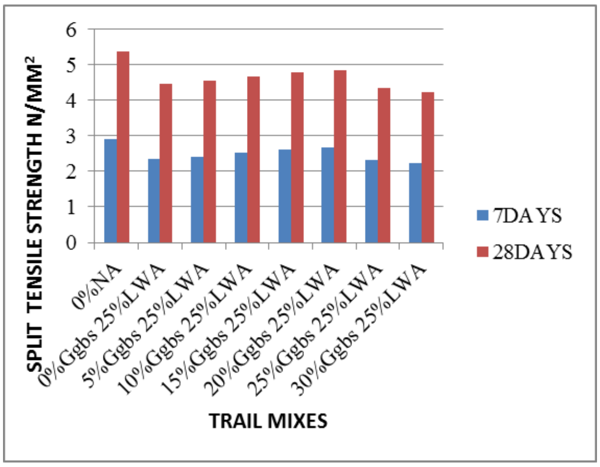

Fig. 6: Variation of Splitting Tensile strength at different age for *25%LWA*

From the above Table and Fig it is observed that for 25% light weight aggregate replacement in coarse aggregate and 20% GGBS replacement in cement then there is an increment of split tensile strength at 7 days later it is decreased.

From the above Table and Fig it is observed that for 25% light weight aggregate replacement in coarse aggregate and 20% GGBS replacement in cement then there is an increment of split tensile strength at 28 days later it is decreased.

S.NO	MIX DESIGNATION	SPLITTENSILE STRENGTH(MPA)	
		7DAYS	28 DAYS
1	0%NA	2.9	5.37
2	0% GGBS35%LwA	2.24	4.38
3	5% GGBS35%LwA	2.32	4.46
4	10% GGBS 35% LwA	2.44	4.58
5	15% GGBS 35% LwA	2.51	4.68
6	20% GGBS 35% LwA	2.59	4.76
7	25% GGBS 35% LWA	2.22	4.26
8	30%GGBS 35%LWA	2.14	4.12

Table 6: Variation of Splitting Tensile strength at different age for 35% LWA

Fig. 7: Variation of Splitting Tensile strength at different age for 35%LWA

From the above Table 6 and Graph 5it is observed that for 35% light weight aggregate replacement in coarse aggregate and 20% GGBS replacement in cement then there is an increment of split tensile strength at 7 days later it is decreased.

From the above Table 6 and Graph 5it is observed that for 35% light weight aggregate replacement in coarse aggregate and 20% GGBS replacement in cement then there is an increment of split tensile strength at 28 days later it is decreased.

3) Flexural Strength

After 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m ^{2} per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading.

S.NO	MIX DESIGNATION	FLEXURAL STRENGTH (MPA) 28 DAYS
1	0%NA	7.5
2	0% GGBS25%LwA	6.12
3	5% GGBS25%LwA	6.25
4	10% GGBS 25% LwA	6.32
5	15% GGBS 25% LwA	6.38
6	20% GGBS 25% LwA	6.47
7	25% GGBS 25% LWA	5.25
8	30%GGBS 25%LWA	5.02

Table 7: Variation of Flexural strength at 28 days For 25% LWA

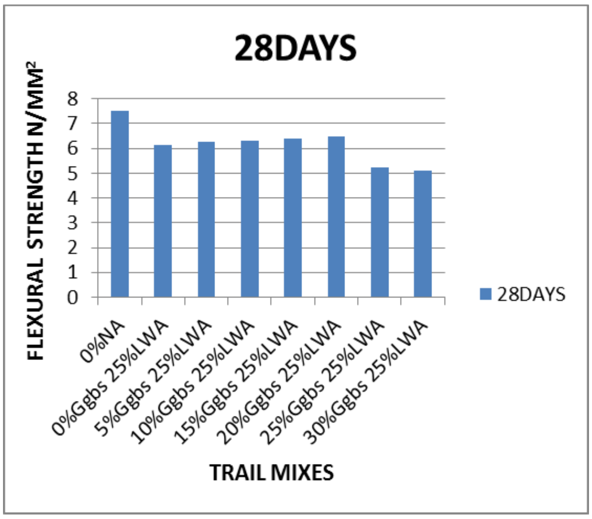

Fig. 8: Variation of Flexural strength at 28 days For *25% LWA*

From above table 7and graph 6 it is observed that for the mixes prepared with 25% replacement of light weight aggregate when cement was replaced by GGBS with 0%, 5%, 10%, 15%, 20%, 25 %and30%. Higher compressive strengths are observed for the 20% GGBS s for 28 days

S.NO	MIX DESIGNATION	FLEXURAL STRENGTH (MPA) 28 DAYS
1	0%NA	7.5
2	0% GGBS35%LwA	5.28
3	5% GGBS35%LwA	5.34
4	10% GGBS 35% LwA	5.47
5	15% GGBS 35% LwA	5.67
6	20% GGBS 35% LwA	5.82
7	25% GGBS 35% LWA	4.89
8	30%GGBS 35%LWA	4.15

Table 8: Variation of Flexural strength at 28 days For 35% LWA

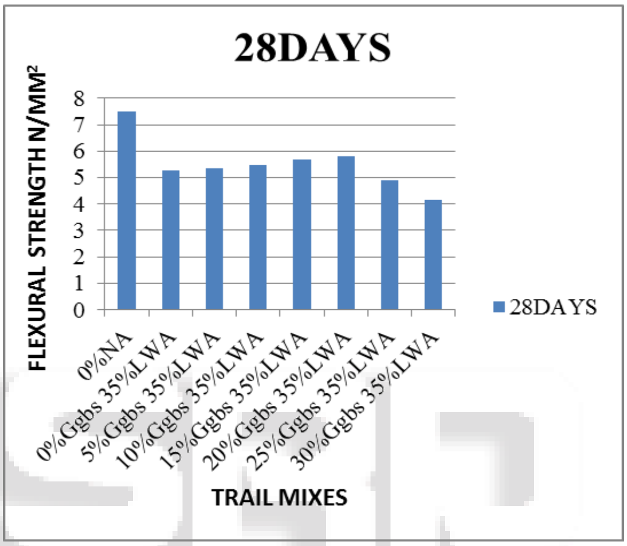

Fig. 9: Variation of Flexural strength at 28 days For 35% LWA

From above table 8 and graph 7 it is observed that for the mixes prepared with 25% replacement of light weight aggregate when cement was replaced by GGBS with 0%, 5%, 10%, 15%, 20%, 25 %and30%. Higher compressive strengths are observed for the 20% GGBS s for 28 days.

V. Conclusions

Based on the investigation, the following conclusions have been drawn.

- When compared to normal concrete the density of concrete is very much reduced so that the dead weight is also reduced
- Density is almost reduced to 695kg/m3 compared to normal concrete.
- The density of concrete is found to decreases with the increase in percentage replacement of natural aggregate by pumice aggregate.
- The workability of concrete is very better same as the normal concrete.
- The compressive strength of concrete is found to decreases with the increase in percentage replacement of natural aggregate by pumice content.
- 25% LWA replacement gives higher values for compressive, split and flexural strength.

- The results obtained with 25% light weight aggregate replacement in normal aggregate were studied with GGBS replacement in cement by 0%,10% 15% 20%, 25% and 30%. At 20% replacement of cement by GGBS the maximum compressive strength is observed for 25% and 35% LWA replacement in coarse aggregate.
- The split tensile strength at 28 days for 20% replacement of cement by GGBS 30% light weight aggregate replacement in normal aggregate it is observed as 4.86MPa and 4.76 Mpa.
- The Flexural strength at 28 days for 20% replacement of cement by GGBS and 35% light weight aggregate replacement in normal aggregate is observed as 6.47MPa and 5.82 Mpa.
- By using 20% of light weight aggregate as a partial replacement to natural coarse aggregates the compressive strength is promising..
- The compressive strength of concrete is found to decreases with the increase in percentage replacement of natural aggregate by pumice content.
- With the addition of mineral admixtures the compressive, split tensile and flexural strength of concrete is increased.
- Light weight aggregate is no way inferior to to natural coarse aggregate it can be used in construction purpose.
- This type of concrete is used in wall panels of non load bearing walls type for use in precast buildings.

A. *Scope for Future Study:*

- The similarly studies could be carried for different replacements of light weight aggregate.
- The similarly studied can be carried for different design mixes.
- An investigation can be made on pre-wetting of the light weight natural pumice aggregate for different mixes.
- Studies on fibrous (metallic, nonmetallic and natural) light weight aggregate (Pumice) concretes can be evaluated.
- The studies on SSC with light weight aggregate (pumice) can be evaluated)
- Behavior of the pumice aggregate concrete mixes with different mineral admixtures can be made.
- Durability studies can be conceded out by exposing to chloride sulphate and acidic environments.
- Elevated temperature studies, freezing, thawing and chloride permeability tests on this particular type of concrete can be studied.

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