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A Study of Structural Concrete Using Pumice and Sintered fly ash Aggregates

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Abstract:
Lightweight aggregates have low density, high permeability than conventional coarse aggregates. One of the most commonly available natural lightweight aggregate is Pumice aggregate (PA) and Sintered fly ash aggregate (SFA) is from artificial source. In general, Lightweight aggregates are used as replacement of coarse aggregate (CA) to produce Light weight concrete. This paper presents an experimental study on Lightweight aggregate concrete (SLWAC) using pumice and Sintered fly ash as partial replacement for coarse aggregates. The mechanical and durability properties of SLWAC using different percentages (25%,50%,75%,100%) of pumice and sintered fly ash aggregates, (by 50%replacement) were evaluated by conducting comprehensive series of tests and then concluded that the pumice concrete at 50% replacement has sufficient strength and adequate density to be accepted as structural lightweight aggregate concrete as per ASTM standards. When the coarse aggregate is completely (100%) replaced by pumice aggregate non-structural lightweight concrete will be achieved. The mix are designed for M_{25} grade concrete and the results are then compared with M25 grade conventional or normal concrete (CC/NC).

Keywords: *Pumice aggregate, Sintered fly ash aggregate, lightweight aggregate concrete*

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I. INTRODUCTION

Concrete is a combination of coarse aggregate (CA) and fine aggregate (FA), together with cement paste which hardens over the time. It is generally utilized as a development material for different kinds of construction works because of sturdiness and high strength properties. Its utilization by networks across the globe is second just to water. The properties of concrete rely upon the kind of ingredients utilized. Startling misuse of substantial rock masses has driven avalanches of sensitive and vertical mount slopes. The dread of about the fatigue of natural coarse aggregate has a result on environment and made to think toward unnaturally formed (from squander materials) aggregates as an option in contrast to the common rock aggregates and also some of other natural sources. In a total about 60-70% of concrete is filled with aggregate, so instead of using conventional aggregate, lightweight aggregates have been used in this study, now-a-days a wide range of lightweight aggregates are available. Pumice aggregate (natural resource) and Sintered fly ash aggregate (artificial resource) have been used as a replacement of normal coarse aggregate in this study.

Pumice aggregate (PA) is a natural lightweight aggregate which is formed by the rapid cool down of molten volcanic matter. Pumice is formed during the volcanic ejection of viscous magma contains mostly siliceous. The cell design of pumice is made by the arrangement of air pockets or air voids when gases contained in the liquid magma moving from volcanoes become caught on cooling. The cells are extended and corresponding to each other and are here and there interconnected. Volcanic pumice (VP) has been utilized as total in the creation of lightweight concrete in numerous nations of the world[1]. Currently the raising consideration to the environmental & sustainable management are noticeable and promote on utilizing porous concrete. This concrete can be a fruitful means in addressing a number of environmental issues and aiding sustainable development. Although having a lower strength, the porous concrete with a high porosity is used for many applications, like permeable pavement, purifying water, heatreducer, and sound absorber. Porous concrete has been widely applied for rainstorm water and has been rewardingly used for filtering the water and decrease pollutant loads that enter into the streams, ponds, and rivers [2].Concrete in which pumice aggregate is incorporated shows lower mechanical properties, higher thermal conductivity and water permeability than those of normal concrete[3]. The water absorption rate of pumice aggregate is significantly high than normal coarse aggregate which might effect the uniformity of experiments during mixing and fresh concrete test, so, pre-soaking of lightweight aggregate should be performed[4]. In this study, structural lightweight aggregate concrete (SLWAC) can be produced by incorporating the pumice aggregate as replacement of coarse aggregate in different percentages. Light weight concrete (LWC) which ranges from 500 to 1850kg/m^3 can be achieved when CA is completely replaced with PA.

Use of mechanical squanders as development material is a reasonable practice to utilize the waste and monitor the accessible assets for people in the future. Flyash is a by-product of coal based nuclear energy stations. If not appropriately discarded, flyash can cause water and soil pollution thusly interferes with the natural cycles. China, USA and India together burn-through around 70% of the complete coal utilization around the planet[5]. Sintered flyash lightweight aggregate(SFA) is one of such possible materials to make concrete lighter than the traditional aggregate concrete. Sintered flyash lightweight aggregate were created by sintering the combination of flyash, semi plastic earth/clay as bindermaterial and coke breeze at a specific extent and sintering them at a temperature between 1200 ^oC and 1300 ^oC in a Laboratory Chain Grate Sintering System by the DownDraft Sintering TechniqueTo avoid the functionality issues related with LWA, it is broadly received to utilize immersed LWAs during the concrete production. Studies have indicated that the utilization of immersed LWA makes the concrete performance usual to conventional concrete, though the utilization of dry LWA improves the concrete exhibition better than immersed LWA just as the ordinary aggregates[6] .In this study, M25 grade Structural Lightweight Aggregate Concrete (SLWAC) is produced by replacing CA with PA in different percentages(25%, 50%,75%,100%), SFA by 50% replacement of CA and a combination of both lightweight aggregates have been produced and their mechanical properties (flexural strength) and durability properties (Acid attack, Sulphate attack tests) are studied and compared.

1.1 OBJECTIVES

- To determine whether pumice stone and sintered fly ash aggregate concrete can be used as structural lightweight aggregate concrete(SLWAC).
- To develop the mix design for producing M25 grade concrete using pumice (PA) and sintered fly ash aggregate (SFA).
- To compare the mechanical properties and durability properties of structural concrete with conventional/normal concrete (CC/NC).

1.2 MATERIALS USED

The test specimens have been prepared by using following materials:

- Cement (OPC 53 grade)
- Coarse Aggregate size- 12.5mm passing
- Pumice Aggregate size- 10mm passing
- Sintered Flyash Aggregate size- 10mm passing
- River sand as fine aggregate- 4.75mm passing
- Water

1.3 EXPERIMENTAL PROGRAM

1.3.1 SPECIMEN SPECIFICATIONS:

500mm x 100mm x 100 mm size prisms have been casted and subjected for testing the flexural strength.100mm x100mm x 100 mm dimensions cubes have been casted for acid attack test , sulphate attack test and this testing has been carried out after the curing period of 28 days.

1.3.2 Material Properties:

Ordinary Portland Cement (OPC), sand (as FA), pumice aggregate (as CA), sintered fly ash (as CA), Potable water have been used for casting cubes and prisms in M25 mix design.

- **Cement:**

Ordinary Portland cement (BrilaA1 cement) of 53 grade confirming to IS: 296-1989 has been used. Physical properties of Ordinary Portland Cement are given below in table.1.

Table.1 Properties of cement

S.NO	PROPERTY	TEST RESULTS
1.	Consistency of cement	32%
2.	Specific gravity	3.14
3.	Initial setting time	24 mins
4.	Final setting time	268 mins

- **Coarse Aggregate:**

Coarse aggregate (CA) of size 10 mm was used for this investigation, aggregate taken from the local quarry confirming to IS: 383:1970. The specific gravity of CA is 2.77 and bulk density is 1752.6 Kg/m^3.

- **Lightweight Aggregates:**

The physical properties of pumice aggregate and sintered flyash aggregate are shown in table.2. and fig.1

Table.2 Properties of pumice aggregate

S.No	Physical Properties	Pumice aggregate	Sintered flyash aggregate
1.	Maximum size	10mm	10mm
2.	Fineness modulus	2.705	2.275
3.	Specific gravity	1.05	1.785
4.	Bulk density	724 Kg/m^3	903.6 Kg/m^3
5.	Water absorption	18.81%	17%

Fig.1 Pumice and Sintered fly ash aggregates

- **River sand as Fine Aggregate:**

The locally existing sand confining to zone II was used in accordance with IS: 383-1970. Physical Properties of Fine Aggregate are shown in table.3

Table.3 Properties of Fine aggregate

S.No	Physical properties	Test results
1.	Fineness modulus	3.085
2.	Bulk density	1285Kg/m^3
3.	Specific gravity	2.5

II. MIX DESIGN FOR SLWAC

Manu S. Nadesan and P.Dinakar have proposed a new mix design specification for SLWAC. Using the concept of mix design for SLWAC proposed by Manu S. Nadesan and Dinakar mix design is done for M_{25} grade concrete.Flexure strength,Acid attack and Sulphate attack tests have been carried out for various samples.

2.1 Mix Proportions for developed concrete:

The following are the different mixes for M25 grade of water/cement ratio 0.65 with their designations and proportions are shown in table.4

1. Normal/Conventional concrete (NC/CC).
2. Pumice aggregate concrete with different replacements ($P_{25\%}$, $P_{50\%}$, $P_{75\%}$, $P_{100\%}$).
3. Sintered fly ash aggregate concrete ($S_{50\%}$).
4. Combination of pumice and sintered fly ash aggregate ($PS_{50\%}$).

Table.4 Proportions of M_{25} grade Mix in Kg

Designation	Cement	Fine aggregate	Coarse aggregate	Pumice aggregate	Sintered fly ash aggregate	Water
NC	276.9	801	1084.73	0	0	180
$P_{25\%}$	276.9	801	813.55	102.795	0	180
$P_{50\%}$	276.9	801	542.36	205.59	0	180
$P_{75\%}$	276.9	801	271.18	308.38	0	180
$P_{100\%}$	276.9	801	0	411.18	0	180
$S_{50\%}$	276.9	801	542.36	0	349.5	180
$PS_{50\%}$	276.9	801	0	205.59	349.5	180

III. RESULTS AND DISCUSSION

3.1 Density:

The outcomes of the air dry and oven dry densities of all the SLWAC and conventional concretes (normal concrete) have been estimated and given in table.5. When CA is replaced with PA (at 75%, 100%), SFA (at 50%) light weight concrete is achieved.

Table.5 Density of concrete Kg/m^3

Designation	NC	$P_{25\%}$	$P_{50\%}$	$P_{75\%}$	$P_{100\%}$	$S_{50\%}$	$PS_{50\%}$
Air dry density	2686	2476	2354	2016	1825	2400	2033
Oven dry density	2665	2461.33	2320	1973.33	1786.66	2360	1985

3.2 Flexural Strength:

This test was done on Beam specimens to determine Flexural strength of concrete by using Universal Testing Machine (UTM). The test for flexural strength of concrete beams under two point loading has employed a beam testing machine which permits the load to be applied normal to the loaded surface of the beam. The specimen has been tested on its side with respect to its molded position. The beam was centered on the bearing supports. The dial indicator of the proving ring has been placed at the zero reading. The load has been applied at a uniform rate and in way to avoid shock. The load required to cause specimen failure has been acquired from the dial indicator's final reading.The flexural strength of concrete for 28 days is shown in table.6 and fig.2 shows the comparasion between P50%, S50%, PS50%.

Table.6 Flexural strength of concrete(28 days)

S.No	Designation	Flexural strength (N/mm2)
1	NC	5.97
2	P25%	4.87
3	P50%	5.17
4	P75%	5.04
5	P100%	4.67
6	S50%	5.78
7	PS50%	5.18

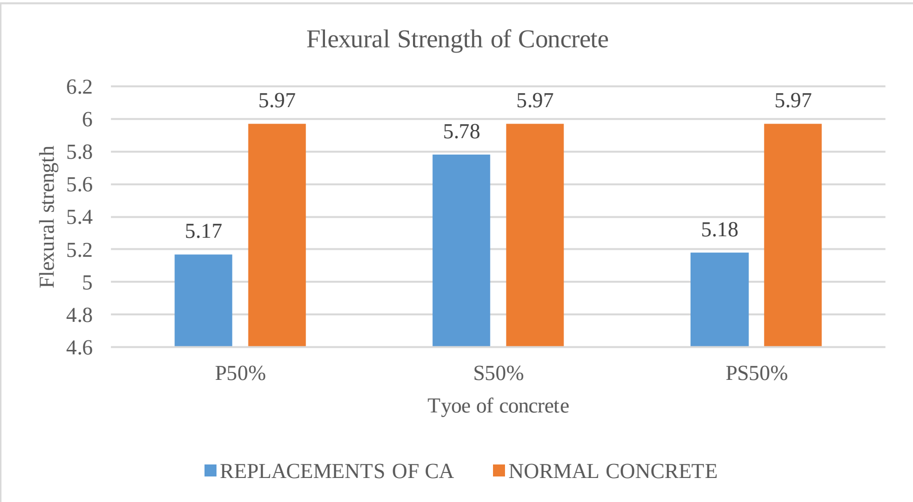

Fig.2 Flexural strength of concrete

3.3 Acid Attack Test:

Acid attack on concrete is to determine the resistance of concrete under chloride exposure. This test is carried out on 100 x 100 x 100mm size cube specimens dipped in water diluted with 5% by weight of sulphuric acid for 28 days for SLWAC (P50%, S50%,PS50%) and then compared with normal concrete(NC). After 28 days immersion in sulphuric acid solution change in weight and compressive strength of the cubes have been calculated and shown in table.7 and cubes subjected to acid attack test has been shown in fig.3.

Table.7 Acid Attack test on concrete (P50%, S50%, PS50%, NC)

Mix Designation	Weight before exposure(Kg)	Weight after exposure(Kg)	% Weight loss	Compressive strength before exposure(N/mm^2)	Compressive strength after exposure(N/mm^2)	% Reduction in compressive strength
NC	2.540	2.382	5.22	50.67	20.33	59.87
P50%	2.076	1.923	7.36	34.33	13.00	62.13
S50%	2.323	2.148	7.53	40.33	18.83	53.31
PS50%	1.976	1.845	6.63	27.00	12.50	53.70

Fig.3 Cubes after immersion in sulphuric acid solution

3.4 Sulphate Attack Test:

Sulphate attack on concrete was performed to determine the resistance of concrete when exposed to the sulphate, it involves number of chemical reactions between sulphate ions and hardened concrete components, as these reaction may lead to fragmentation, cracking or loss of strength of concrete. The sulphate attack has been carried out on 100 x 100 x100mm size cube specimens dipped in water diluted with 15% by weight of magnesium sulphate for 28 days for SLWAC (P50%,S50%,PS50%) and then compared with normal concrete (NC).after 28 days immersion in magnesium sulphate solution change in weight and compressive strength of cubes have been calculated and shown in tabe.8 and cubes subjected to sulphate attack test has been shown in fig.4.

Table.8 Sulphate Attack test on concrete (P50%, S50%, PS50%,NC)

Mix Designation	Weight before exposure(Kg)	Weight after exposure(Kg)	% Weight loss	Compressive strength before exposure(N/mm^2)	Compressive strength after exposure(N/mm^2)	% Reduction in compressive strength
NC	2.495	2.501	0.240	50.67	48.15	4.97
P50%	2.120	2.127	0.329	34.33	28.33	17.47
S50%	2.363	2.371	0.338	40.33	35.16	12.82
PS50%	1.946	1.52	0.308	27.00	22.37	16.04

Fig.4 Cubes after immersion in magnesium sulphate solution

IV. CONCLUSION

Based on the results and analysis the following conclusion are made. The flexural strength of pumice aggregate and sintered fly ash aggregate concrete at 50% replacement of CA is more comparable with normal concrete. On further increase in percentage of PA instead of CA, a decrease in strength was noticed. Structural lightweight aggregate concrete can be achieved by using both PA &SFA. It has been observed that M25 grade with SLWACs has higher resistance to sulphate attack than compared to acid attack.

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