Rishik Sarkar,2021, 9:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Experimental Study on the use of Pumice as Coarse Aggregate in Structural Concrete

Rishik Sarkar, Ridul Saud
School of Civil Engineering (SCE),
Vellore Institute of Technology,
Tamil Nadu, India.
rishiksarkar.98@gmail.com, ridulsaud97@gmail.com

Abstract-Applications of Lightweight Concrete for development works is rapidly growing because of their various advantages over conventional concrete [9]. This experimental study is undertaken by utilizing Pumice as coarse aggregate. One major demerit of conventional concrete is its high self-weight. This substantial self-weight will make it somewhat an uneconomical construction material [10]. Lightweight concrete results in a decrease of dead load and an increase in thermal insulation [9]. In this investigation, an attempt has been undertaken to find out whether pumice lightweight concrete can be used as structural concrete. This is carried out by comparing conventional concrete and lightweight aggregate concrete using the M30 mix [1]. Lightweight concrete is prepared by partial replacement of coarse aggregate with various percentages of pumice, viz., 25%, 50%, 75% and 100%. This project is undertaken to determine the mechanical and durability properties of lightweight aggregate concrete, i.e., Compressive Strength, Split Tensile Strength and Acid Resistance, after 7 and 28 days of curing and hence find the suitable replacement concerning the above-mentioned replacement percentages [4]. The results indicate reduced mass without significant change in acid resistance, whilst maintaining adequate strength. The different engineering properties of pumice aggregate concrete were compared to that of conventional concrete.

Keywords: -Lightweight concrete, Pumice aggregate, Pumice concrete, conventional concrete

I. INTRODUCTION

In India, the development of smart cities, along with the dependence of several industries on concrete, including housing and real estate, has provided a large enhancement to the sector. Thus, opportunities have been opened for the development and use of several different types of special concretes ["Project Monitor", 2018]. One of the most important among these is Lightweight Concrete.

Recently, application for Lightweight concrete construction works is being widely used for both structural and non-structural purposes due to its various advantages over ordinary concrete ["Hess Pumice", n.d.].

For the same volume of conventional concrete, the mass or weight of lightweight concrete is less. Thus, the density of lightweight concrete is also less as compared to conventional concrete and lies between 320 to 1920 kg/m^3 [2].

The main reason for the rising demand for Lightweight Concrete over conventional concrete in the construction sector is because it has strengths comparable to conventional concrete, whilst also being 25% to 50% lighter ["Pumice-Wikipedia", n.d.]. Lightweight concrete is mainly used for Structural purposes due to the reduction of dead loads or constant loads that the structure pertains to, as the load from walls, beams, columns, and slabs ["Nevada Ready Mix", 2019]. This, in turn, decreases the

International Journal of Science, Engineering and Technology

An Open Access Journal

effective surcharge pressure on the soil and so structures can also be constructed in that soil without the need for Ground Improvement Techniques, making the overall project much more economical ["Hess Pumice", n.d.]. It is also used extensively in top floors of high-rise buildings, long-span bridges, steel structures, marine structures and proves very advantageous in seismic zone regions because of its lightweight compared to normal concrete [5].

Commonly used Lightweight Concrete is made of lightweight aggregate coming mainly from natural sources. Pumice is one such lightweight aggregate and is almost 66% lighter than the conventional coarse aggregate [9].

This trait contributes to a decrease in structural steel costs and simultaneously job costs too. A larger quantity of concrete can be handled using lighter equipment with less wear and tear for the equipment and thus economically feasible. Pumice stone is a lightweight mixture that is formed when molten volcanic matter cools.

Pumice is framed by the course of a volcanic eruption of thick magma, particularly siliceous unpredictable constituents and water vapour. These characteristics contribute to voids in pumice stone ["Pumice-Wikipedia", n.d.].

II. METHODOLOGY

The behaviour and properties of pumice stone as coarse aggregate were studied and literature reviews were collected. The most common and important tests were performed on cement, coarse aggregate, fine aggregate and pumice stone to check their suitability as concrete ingredients [10].

The mix proportions of ingredients of conventional concrete of M30 grade were determined by casting cubic moulds of size 100 mm x 100 mm x 100 mm and cylindrical moulds of size 100 mm x 200 mm. Casted samples were tested after 7 days and 28 days of curing. Compressive strength Test, Split Tensile Strength Test and Acid Resistance Test was performed using the casted concrete specimens. A total of 2 trials were conducted for all the above-mentioned tests for each type of concrete cube, i.e., percentage replacement of coarse aggregate by pumice (25%, 50%, 75% and 100%) in each cube. The average of the two values for all the tests was taken. Results were obtained and specific conclusions were drawn.

III. MATERIALS

1. Cement:

The cement used in this experimental study was Ordinary Portland Cement (OPC) Grade 53 [3]. Theimportant properties of this cement are as per Table 1.

Table 1. Important Cement Properties.

Property	Test results	Limiting value
Specific Gravity	3.13	Around 3.15
Standard Consistency value	29%	Between 25% to 30%
7 days Copressive Strength (N/mm^2)	38.92	Not < 37 N/mm^2 as per IS:12269 (1987)
28 days Copressive Strength (N/mm^2)	54.61	Not < 53 N/mm^2 as per IS:12269 (1987)
Initial Setting Time (mins.)	50	Not < 30 mins. as per IS:12269 (1987)
Final Setting Time (mins.)	505	Not > 600 mins. as per IS:12269 (1987)

2. Fine Aggregate:

Dry sand according to grading Zone I of IS:2386 (Part 1), was used for this study [6]. The water absorption, specific gravity and fineness modulus of the sand were 1.04%, 2.65 and 2.85 respectively.

3. Coarse Aggregate:

Granite Aggregate with specific gravity 2.72 and nominal size 20 mm was used in this study [2]. Its fineness modulus was 6.82 and water absorption 0.54%.

4. Lightweight Aggregate:

Pumice stone or breccia was used as a lightweight aggregate in this study, as shown in Fig. 1 [4]. The average size of the pumice stones was 20 – 25 mm bearing a specific gravity of 0.7 and water absorption of 28.68%, as per Table 2.

Table 2. Water Absorption of pumice aggregate.

Weight of oven dried Pumice Aggregate (g)	1000
Weight of saturated surface dried Pumice Aggregate (g)	1286.82
Water Absorption (%)	28.68

Fig 1. Pumice Aggregate.

IV. MIX DESIGN

In this study, M30 grade of concrete was used and the method of Volume Batching was adopted because the nominal size of pumice aggregate was not comparable to the nominal size of conventional coarse aggregate.

The total amount of all the elements was taken according to weigh batching method i.e., according to their respective weights then the coarse aggregate was replaced by respective amount of pumice (25%, 50%, 75%, 100%) by volume.

The mix was prepared for 0.001 m^3 and 0.00157 m^3 for cubes and cylinders respectively by taking the water cement ratio as 0.43, as per Table 3.

Table 3. Mix Proportion.

Mix Symbol	Cement (Kg)	Conventional Coarse Aggregate (Kg)	Fine Aggregate (Kg)	Water (ml)	Pumice content (% by volume) w.r.t total volume of coarse aggregate
$P_{0\%}$	0.45	1.09	0.71	193	0
$P_{25\%}$	0.45	0.82	0.71	193	25
$P_{50\%}$	0.45	0.55	0.71	193	50
$P_{75\%}$	0.45	0.27	0.71	193	75
$P_{100\%}$	0.45	0	0.71	193	100

V. TESTING PROGRAMME

1. Compressive Strength Test:

The Compressive Strength of Concrete cube Specimens were tested after 7 days and 28 days of curing in water maintained at a temperature of around 25°C. The test was performed using Universal Testing Machine, according to IS:516 (1959) [8].

The Compressive Strength of each concrete Cube is calculated as below equation.

Compressive Strength of concrete cube (N/mm²) = Load at failure (N)/Cross Sectional Area (mm²)

2. Split Tensile Strength Test:

The Split Tensile Strength of Concrete cylinder Specimens were tested after 7 days and 28 days of curing in water maintained at a temperature of around 25°C. The test was performed using Universal Testing Machine, as per IS:5816 (1999) [4].

The Split Tensile Strength of each concrete Cube is calculated as per the below equation.

Split Tensile Strength of Concrete Cylinder (N/mm²) = 2P / ΠLD

3. Dry Density Test:

After curing, the concrete cubes were surface dried and then oven dried for 24 hrs. at a constant temperature of 105°C. The oven dried masses of the specimens were noted, and the volumes were also calculated. Consequently, density values were found out.

4. Acid Resistance Test:

After curing the specimens for 28 days, they were taken out and kept under atmospheric conditions for 24 hrs. Next, the specimens were immersed in 10% Sulphuric acid solution and kept for 28 days. The pH value was regularly monitored and maintained at 1 [7][4]. Subsequently, the specimens were taken out of the acidic solution and washed in running water and kept in the atmosphere for 24 hrs. Finally, the compressive strength of each cube was found.

VI. RESULTS AND DISCUSSIONS

1. Compressive Strength:

The compressive strength for concrete specimens is found to be maximum for $P_{0\%}$ (conventional concrete), i.e., 0% replacement of coarse aggregate by pumice. The value is found to decrease for $P_{25\%}$, increase for $P_{50\%}$ and again decrease subsequently for $P_{75\%}$ and $P_{100\%}$ as shown in Table 4 and Chart 1. As per the tests conducted on the specimens with minimal manual error, $P_{50\%}$ can be said as the most favourable replacement of coarse aggregate by pumice as this value is quite comparable to that of $P_{0\%}$.

Table 4. Compressive Strength Values.

Mix Symbol	Compressive Strength after 7 days (N/mm^2)	Compressive Strength after 28 days (N/mm^2)
$P_{0\%}$	24.37	36.92
$P_{25\%}$	16.83	26.85
$P_{50\%}$	21.19	32.10
$P_{75\%}$	14.30	22.80
$P_{100\%}$	10.48	16.72

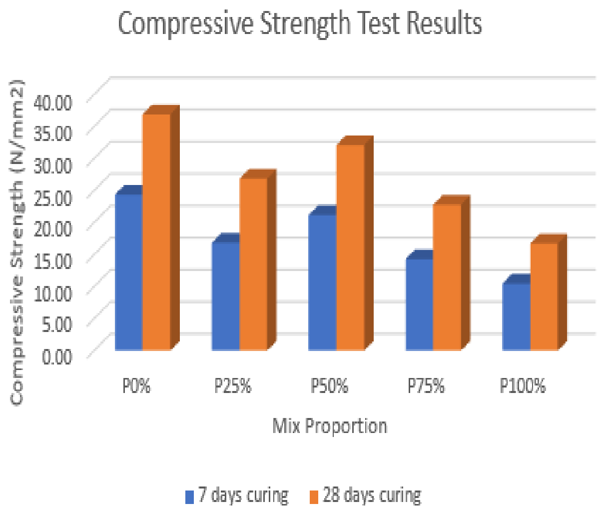

Fig 2. Compressive strength at 7 and 28 days.

2. Split Tensile Strength:

The trend for Split Tensile Strength was found to be similar to that of Compressive Strength. The largest value being 3.53 N/mm^2 for $P_{0\%}$ followed by 3.15 N/mm^2 for $P_{50\%}$, as shown in Table 5 and Chart 2.

Table 5. Split Tensile Strength Values.

Mix Symbol	Split Tensile Strength after 7 days (N/mm^2)	Split Tensile Strength after 28 days (N/mm^2)
$P_{0\%}$	2.35	3.53
$P_{25\%}$	1.81	2.71
$P_{50\%}$	2.10	3.15
$P_{75\%}$	1.55	2.32
$P_{100\%}$	1.34	2.01

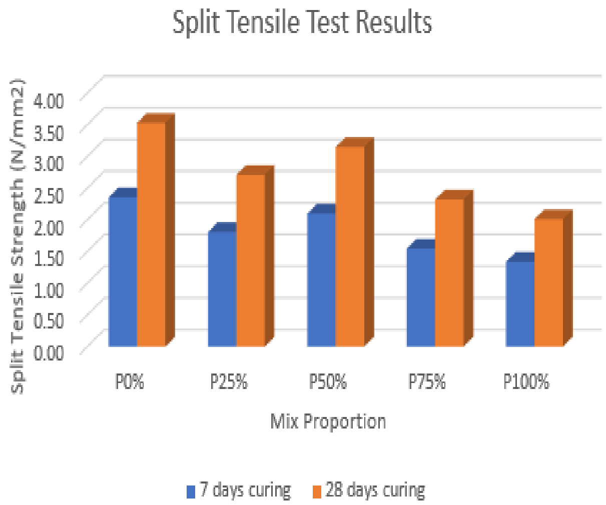

Fig 3. Split Tensile strength at 7 and 28 days.

3. Oven Dry Density:

Density values follow a uniform and regular trend, decreasing with the increase of pumice content in concrete. The maximum and minimum density values for 28 days of curing are 2398.41 Kg/m^3 and 1586.19 Kg/m^3 respectively, as shown in Table 6 and Chart 3.

Table 6. Density Values.

Mix Symbol	Density of specimen after 7 days (Kg/m^3)	Density of specimen after 28 days (Kg/m^3)
$P_{0\%}$	2376.59	2398.41
$P_{25\%}$	2151.87	2171.85
$P_{50\%}$	1923.56	1959.85
$P_{75\%}$	1727.41	1772.98
$P_{100\%}$	1575.26	1586.19

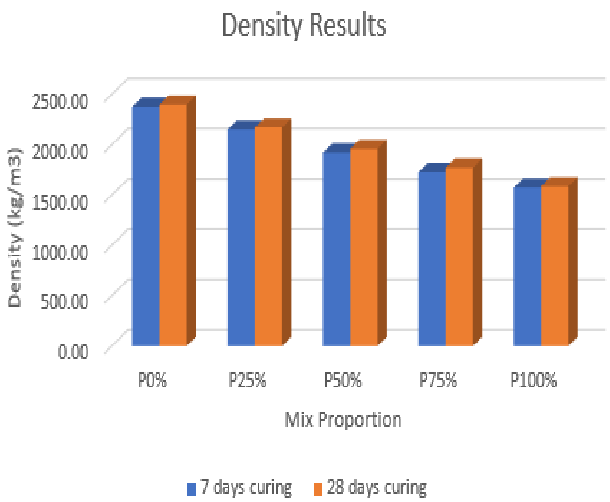

Fig 4. Density Values.

The density of specimens subjected to 28 days of curing are found to be greater than those subjected to 7 days of curing because of the acceleration of the hydration process in the later stages, which produces calcite, making the material denser.

4. Acid Resistance:
The compressive strength values of the specimens exposed to acidic conditions decreases significantly as compared to that of concrete specimens under normal conditions, both cured for 28 days.

The percentage decrease in compressive strength increases with the increase of pumice content in concrete.

From $P_{0\%}$ to $P_{50\%}$, the percentage decrease in compressive strength is comparatively less significant but it increases significantly for $P_{75\%}$ and further for $P_{100\%}$, as per Table 7 and Chart 4.

Table 7. Acid resistance test values (28 days).

Mix Symbol	Compressive Strength (N/mm^2)	Percentage (%) decrease in Compressive Strength
$P_{0\%}$	31.28	15.28
$P_{25\%}$	22.16	17.47
$P_{50\%}$	25.52	20.50
$P_{75\%}$	16.88	25.96
$P_{100\%}$	11.45	31.52

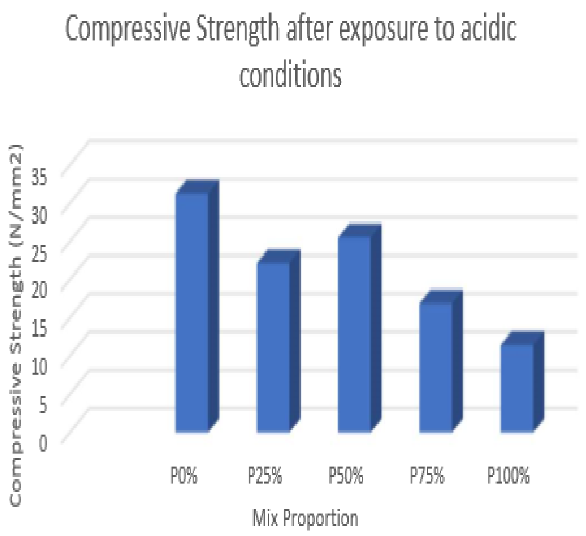

Fig 5. Acid Resistance Test Result.

VII. CONCLUSION

Based on the above test results, the following conclusions can be drawn:

- Compressive Strength and Split Tensile Strength of $P_{50\%}$ mix (50% replacement of coarse aggregate with pumice) is comparable to that of conventional concrete.
- $P_{50\%}$ mix is the optimum replacement of coarse aggregate with pumice, i.e., maximum value of strength is obtained for 50% replacement of coarse aggregate with pumice.
- Density of concrete specimens decrease (almost uniformly) with the increase of pumice content.
- Acid resistance of conventional concrete and $P_{50\%}$ mix does not differ largely suggesting that $P_{50\%}$ can be used as replacement to conventional concrete in areas where acid rain is more predominant.
- After 50%, the increase in percentage of pumice won't give satisfactory results on strength of concrete.
- $P_{25\%}$, $P_{75\%}$, $P_{100\%}$ mixes or any other percentage replacement of coarse aggregate with pumice can be used for non-structural purposes or for very lightweight structures.
- Acid Resistance of concrete specimens decrease with the increase of pumice content suggestingthe presence of more voids, leading to higher permeability.
- Henceforth, $P_{50\%}$ mix (50% replacement of coarse aggregate with pumice) can be effectively used for structural purposes because of its high strength and less vulnerability to acid attacks.

VIII. ACKNOWLEDGEMENT

The authors would like to extend their gratitude to Mr. Sadhan Kumar Ghosh (Professor – Department of Construction Engineering, Jadavpur University, Salt Lake Campus, Kolkata) and all the laboratory assistants of Jadavpur University Concrete Laboratory for giving them permission to work in the laboratory and helping them out with this study.

Further, it gives the authors immense pleasure to thank Dr. Sofi A (Associate Professor–School of Civil Engineering, VIT University) for her guidance and for granting them permission to work in Structural Engineering Laboratory, VIT University.

Last but not the least, the authors are also grateful to the fellow students of VIT: Somudra Kundu, Saurav Das, Ayush, Rohan Singh for helping them out with this work.

REFERENCES

[1] T. Parhizkar, M. Najimi, A.R. Pourkhorshidi (2012) 'Application of Pumice Aggregate in Structural Lightweight Concrete' Asian Journal of Civil Engineering (Building and Housing) Vol. 13, No. 1 Pages 43-54.

[2] Khandaker M, Anwar Hossain (2004) 'Properties of volcanic pumice-based cement and Lightweight Concrete' Cement and Concrete Research 34, pp. 283–291.

[3] Jihad Hamad Mohammed, Ali Jihad Hamad (2014) 'A classification of lightweight concrete: materials, properties and application review' International Journal of Advanced Engineering Applications, vol.7, Iss.1, pp.52- 57.

[4] R S Muralitharan, V Ramasamy (2015) 'Basic Properties of Pumice Aggregate' ISSN 0974-5904, Volume 08, No. 04.

[5] H. CelikOzyildirim (2011) 'Laboratory Investigation of Lightweight Concrete Properties' VCTIR 11-R17.

[6] Prof. Dr. Shakir A. Al-Mishhadani, Mays F. Al-Rubaie (2018) 'Utilization of Waste Glass as Mineral Admixture in concrete' The Iraqi Journal for Mechanical and Material Engineering, Special Issue (A).

[7] TakuKumatorJosiphiah, Amartey D Yusuf, Kassar T (2015) 'Effect of Acidic Curing Environment on the Strength and Durability of Concrete' ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.7, No.12.

[8] Lakshmi Kumar Minapu, M K M V Ratnam, Dr. U Rangaraju (2014) 'Experimental Study on Light Weight Aggregate Concrete with Pumice Stone, Silica Fume and Fly Ash as a Partial Replacement of Coarse Aggregate' ISSN: 2319-8753 Vol. 3, Issue 12, December 2014.

[9] MS Shetty, AK Jain (1982) 'Concrete Technology Theory and Practice' Revised Edition 2019.

[10] A. Suba Lakshmi, S. Karthick, Gasper Helden, M. Dinesh Boopathi, V. Balaji Pandian (2017) 'Experimental investigation on light weight concrete using pumice aggregate' International Journal of Innovative and Emerging Research in Engineering, Volume 4, Issue 3, 2017.