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Study on Partial Replacement of Aggregate by Pumice Stone in Cement Concrete

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Abstract:
Construction activities have increased phenomenally for the past two decades. With these construction activities going up, we are falling short of the construction materials, especially aggregates. So, finding an alternate resource is the need of our project. In concrete production aggregate is the cheaper material as compared to cement and maximum economy is obtained by using as much aggregate as possible. Aggregates also improve the volume stability and the durability of the resulting concrete. Light weight concrete has become more popular in recent years owing to the tremendous advantages it offers over the conventional concrete. Even Light concrete but at the same time strong enough to be used for the structural purpose. The present study deals with natural light weight pumice aggregate. The study aims at finding out the sustainability of pumice stone as a construction material, its cost effectiveness and the reduction in density produced by using it as a replacement of coarse aggregate partially in concrete. The research work mainly consist of two parts. In the first part, trial mixes were conducted for the conventional concrete M20, M25 and M30. In the second part, partial replacement of pumice stone with concrete with certain percentages of 10%, 20% and 30%. The results after the test are compared to the IS code requirement.

Keywords: *Pumice, Pumice stone, Light weight concrete, Light weight aggregate, Replacement of aggregate with pumice stone.*

1. Introduction

In concrete production aggregate is the cheaper material as compared to cement and maximum economy is obtained by using as much aggregate as possible. Aggregates also improve the volume stability and the durability of the resulting concrete. A good aggregate should produce the desired properties in both the fresh and hardened concrete. Concrete is very variable material having a wide range of strength and the constituent materials are cement, fine aggregate, coarse aggregate and water. Based on research using pumice stone as replacement material. Pumice is a natural material of volcanic origin produced by the release of gases during the solidification of lava. Pumice is used both as structural lightweight and some times as ultra-lightweight aggregate. It is lighter in coloured of lower density, and more lightly cellular than scoria and cinder. The cellular structure of pumice is created by the formation of bubbles or air voids when gases contained in the molten lava flowing from volcanoes become trapped on cooling. Pumice is also said to be lightweight aggregate. Replacing pumice stone with coarse aggregate is said to be structural lightweight concrete solves weight and durability problems in buildings and structures. One of the most significant of the advantages of pumice aggregate concrete is its lightweight quality—up to one-third lighter than conventional sand-and-gravel concrete. Pumice stone is lightweight aggregate of low specific gravity. Its water absorption is as high as 50% because it is highly porous material while comparing other materials. We use Pumice as coarse aggregate by replacing it and sand as fine aggregate. Construction material is becoming increasingly important as more attention is being paid to energy conservation and to replace with natural resource. Pumice is a colour less or light grey coloured coarse aggregate, which floats on water. The density of pumice is 0.25 g/cm^3. Pumice is also fire resistant with a high melting point and has low specific gravity.

2. Literature Review

T. Parhizkar, M. Najimi and A.R. Pourkhorshidi investigated on the properties of volcanic pumice lightweight aggregates concretes. To this end, two groups of lightweight concretes (lightweight coarse with natural fine aggregates concrete, and lightweight coarse and fine aggregates concrete) are built and the physical/mechanical and durability aspects of them are studied. The results of compressive strength, tensile strength and drying shrinkage show that these lightweight concretes meet the requirements of the structural lightweight concrete. Also, the cement content is recognized as a paramount parameter in the performance of lightweight aggregate concretes. The compressive strength of lightweight concrete is 20% to 40% lower than control concrete, whereas they are about 30% lower than control concrete. To this end, the physical/mechanical properties and durability of volcanic pumice lightweight aggregates concretes are investigated.

I.Uger investigated on pumice lightweight concrete characteristics generally depend on the aggregate watrer content prior to mixing. Excessive water content causes lack of adherence between the aggregate and mortar, while low aggregate water content causes the aggregate to soak up part of the mortar water, thus causing a cement sub-hydration and consequent reduction of the concrete shape alteration capacity. Both cases result in lower resistance characteristics than when the aggregates are moderately soaked just prior to concrete preparation. The pre-soaling time chosen for pumice aggregate 30 minutes has said to give the best results as to resistance and workability characteristics.

lightweight concrete aggregate, although it has mainly been restricted to dry mixes such as for block making and masonry use. There are both advantages and drawbacks connected with the material as an aggregate. Its compressive strength is low, between 5 and 7 MPa for usual pumice material of normal gradation. Therefore, high strength constructional concrete is not to be expected. Lightweight concrete is generally a concrete with specific gravity 800-1800 kg/m. it can be lowered either by using porous, therefore light aggregate instead of ordinary one or introducing air into the mortar or removing fine fraction of aggregate and compacting concrete only partially. The lightweight aggregate is by far the simplest and most commonly used method of making a lightweight concrete and oumice is the most widely used lightweight aggregate especially from lightweight structural concretes. The specific gravity of the concrete is about to 900 – 1600 kg/m^3.

Nurhayat Degimenci investigated to evaluate the possibility of using granular pumice as an alternative to fine aggregate in production of lightweight cement mortar. The cement/pumice fine aggregate ratio is 1:3 for pumice aggregate mortar. The water content is determined by flow table test, Compressive and flexural strength, freeze-thaw resistance, sulphate resistance, water absorption and dry unit weight of the mortar are determined. Mortar using 100% pumice as fine aggregate developed strength in excess 13MPa and had an oven dry density of 1140-1146 kg/m^3 would satisfy the requirement for lightweight mortar and it can be used as in cast in place walls, load bearing and non- load bearing structures. Pumice aggregate mortar is about % lighter than Portland cement control mortar due to the replacement of comparatively heavier standard sand by lighter pumice aggregate. The pumice aggregate mortar exhibits a higher frost resistance due to existence of voids in pumice aggregate. Pumice aggregate mortar showed better performance showing higher residual strength at high temperature compared Portland cement mortar. The residual compressive strength reduction of pumice aggregate mortar is higher than that of Portland cement mortar exposed to freeze-thaw cycles. The use of pumice aggregate as sand provides the resistance to sulphate attack.

3. Experimental Investigation

The experimental investigation consists of casting and testing of 9 sets along with control mix. Each set comprises of 9 cubes for determining compressive and split tensile test respectively. Pumice stone is used in the study with different percentages as a partial replacement to natural weight coarse aggregate. Cube section dimension is of 15cm × 15cm × 15cm, cylinder section dimension is 15cm × 30cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes and cylinders are moved to the curing tank carefully.

3.1. Materials

The constituent materials used in this study are (i) Cement, (ii) Fine aggregate, (iii) Coarse aggregate,
(iv) water.

3.1.1. Cement

The cement used was ordinary Portland cement of 53- grade conforming that concrete mix design, for concrete M-20 and above grades a saving of 8 to 10 % of cement may be achieved with the use of 53 grade OPC. The OPC 53 grade has a higher strength cement to meet the needs of the consumer for higher strength concrete. As per BIS requirements the minimum 28 days' compressive strength of 53 Grade OPC should not be less than 53 MPa. For certain specialized works, such as pre-stressed concrete and certain items of precast.

3.1.2. Fine Aggregate

Fine aggregate is the inert or chemically inactive material, most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material. The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and considerably increases its strength. Usually, natural river sand is used as a fine aggregate. However, at places, where natural sand is not available economically, finely crushed stone may be used as a fine aggregate.

3.1.3. Coarse Aggregate

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel etc. Maximum coarse aggregate size used is 20 mm and the minimum coarse aggregate size used is 12 mm. Coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. Coarse aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. After harvesting, aggregate is processed: crushed, screened, and washed to obtain proper cleanliness and gradation.

3.1.4. Light Weight Coarse Aggregate (PUMICE STONE)

Pumice stone is a colour less or light grey coloured coarse aggregate. It is powdered or dust form and a volcanic rock that consists of highly vesicular rough textured surface. pumice stone specific gravity is 1.04 and the constituents are silica (70%) and alumina (14%), along iron oxide as 2.5%, calcium oxide as 1%, and sodium oxide as 9%.

Figure 1: Pumice stone

3.1.5. Water

Water available in SRM University is used for the study. Almost any natural water that is drinkable and has no pronounced taste or odour may be used as mixing water for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but can also cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability.

3.2. Test Procedure for Concrete Cubes

3.2.1. Compressive Strength

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^2 per minute is applied on test specimen for curing days of 7, 14 and 28 days. Ultimate load at which the cubical specimen fails is noted down from dual gauge reading. This ultimate load divided by the area of specimen gives the compressive strength of each cube.

Figure 2: Compressive strength testing machine

4. Casting and Testing Specimen

All trial batches were prepared by using a mechanical mixer confirming to the requirements. The mortar mixtures were cast into molds 15cm×15cm×15cm and compacted in accordance with the provision. After the compaction with vibrator table procedure the specimens were left in the molds for 24 hours at room temperature of 20^0C. Following this period, thee specimens were removed from the molds and kept in lime saturated water at a temperature 20^0C for 7, 14, 28 days. Compressive strength measurements were carried out using a hydraulic press with a capacity of 3000 kN. Strength tests were carried out at 7, 14 and 28 days. The compressive strength results indicated the average of three values.

Conventional reading (N/mm²)	No. of days	Replacement %	Reading after replacement of Pumice stone (N/mm²)
13.21	7 days	10%	12.87
		20%	11.5
		30%	10.9
18.56	14 days	10%	14.74
		20%	13.68
		30%	12.93
23.92	28 days	10%	19.75
		20%	18.97
		30%	17.98

Table 1: M20 Grade Test result for pumice stone at 7, 14 and 28 days

Conventional reading (N/mm²)	No. of days	Replacement %	Reading after replacement of Pumice stone (N/mm²)
17.28	7 days	10%	16.2
		20%	15.9
		30%	15.68
21.71	14 days	10%	20.45
		20%	18.52
		30%	19.47
28.72	28 days	10%	23.34
		20%	22.27
		30%	22.42

Table 2: M25 Grade Test result for pumice stone at 7, 14 and 28 days

Conventional reading (N/mm²)	No. of days	Replacement %	Reading after replacement of Pumice stone (N/mm²)
22.03	7 days	10%	19.80
		20%	18.90
		30%	20.89
24.86	14 days	10%	22.58
		20%	20.93
		30%	21.32
33.84	28 days	10%	31.51
		20%	30.40
		30%	29.77

Table 3: M30 Grade Test result for pumice stone at 7, 14 and 28 days

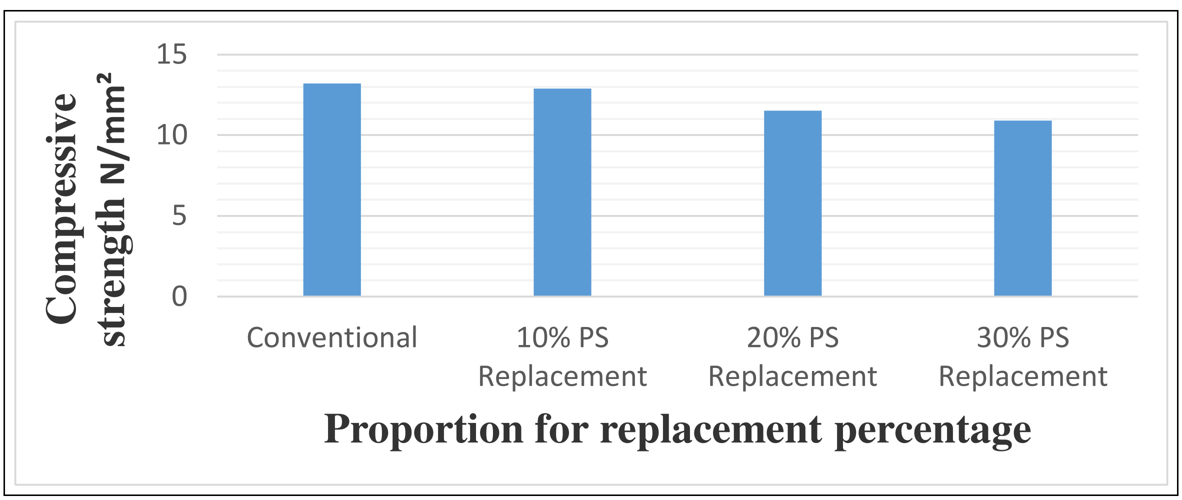

Figure 3: Compressive strength for M20 grade 7 days result of pumice stone

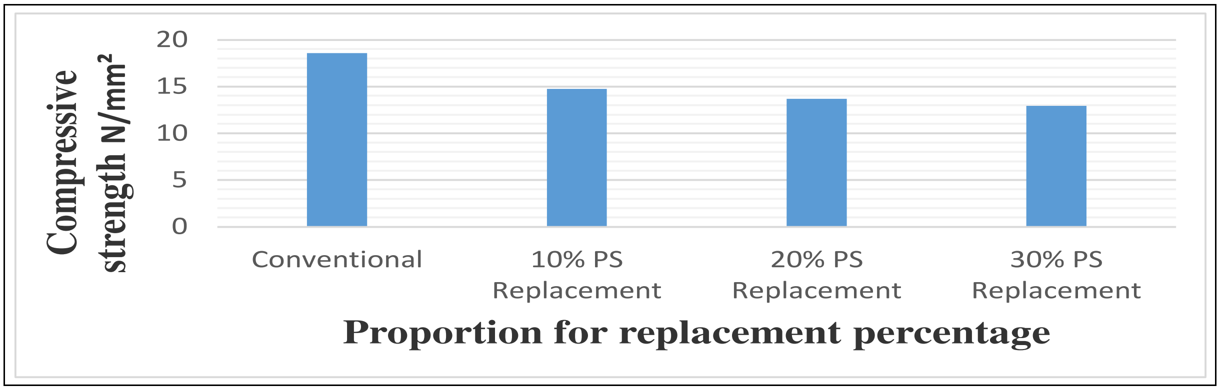

Figure 4: Compressive strength for M20 grade 14 days result of pumice stone

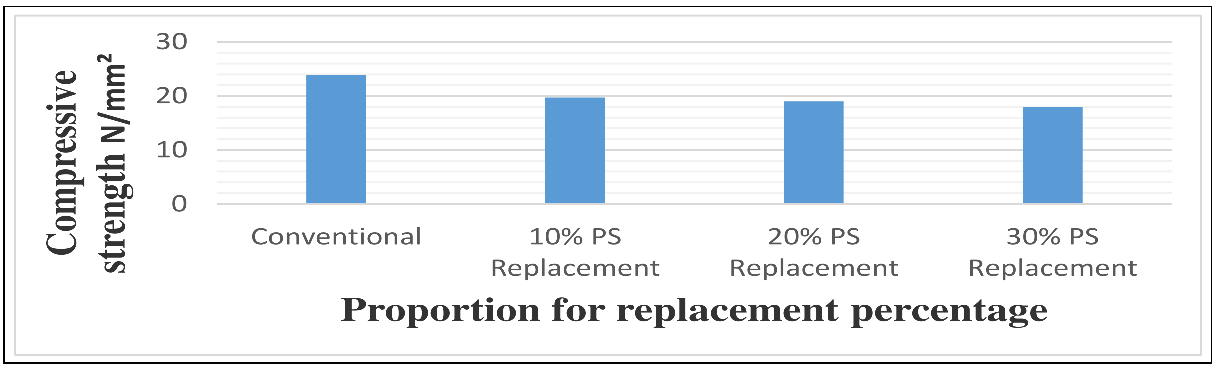

Figure 5: Compressive strength for M20 grade 28 days result of pumice stone

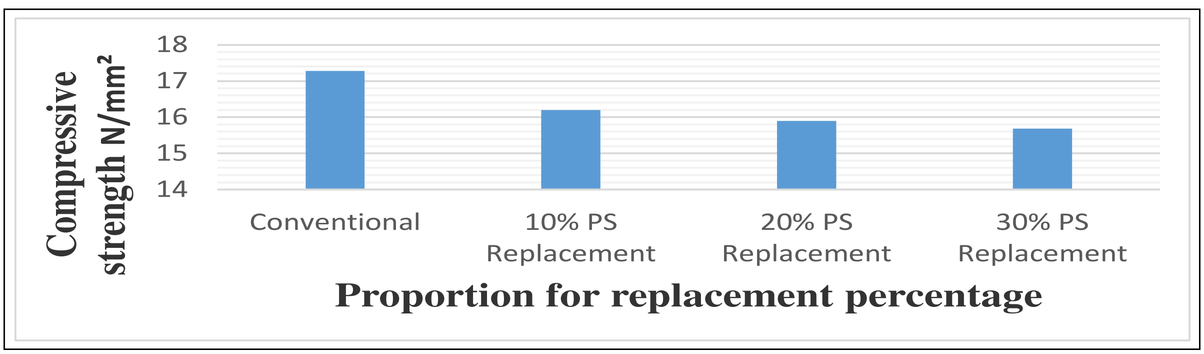

Figure 6: Compressive strength for M25 grade 7 days result of pumice stone

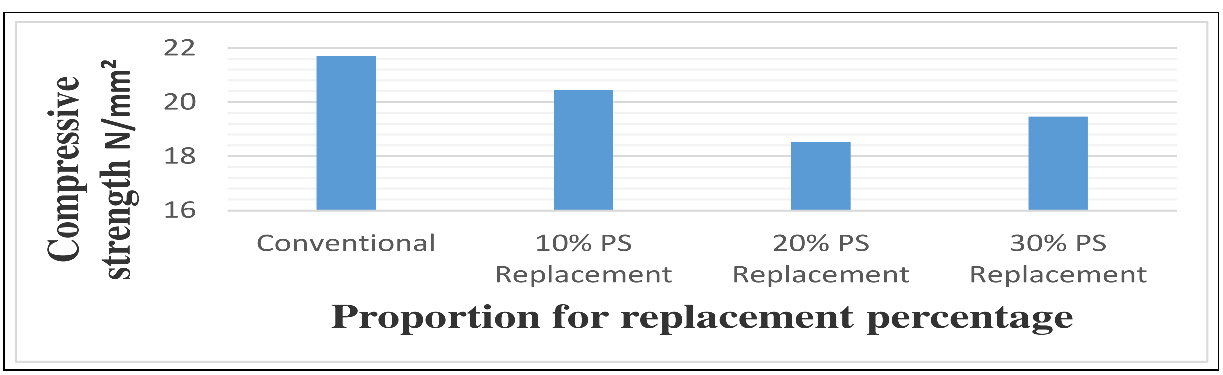

Figure 7: Compressive strength for M25 grade 14 days result of pumice stone

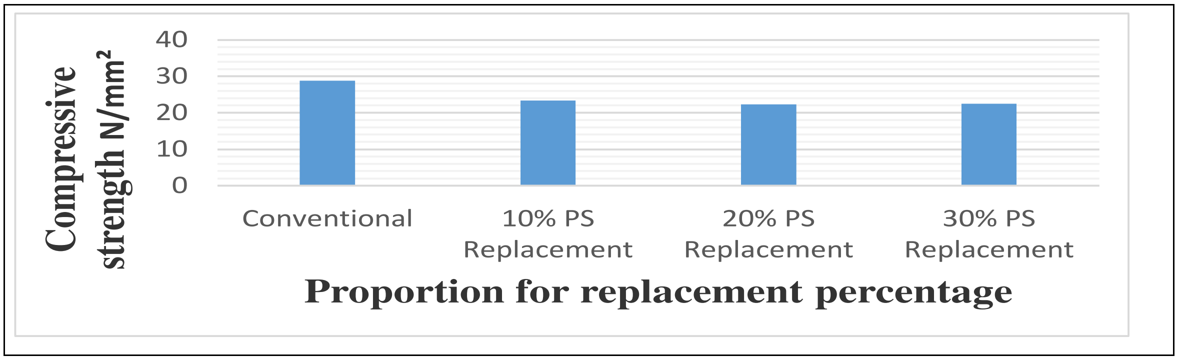

Figure 8: Compressive strength for M25 grade 28 days result of pumice stone

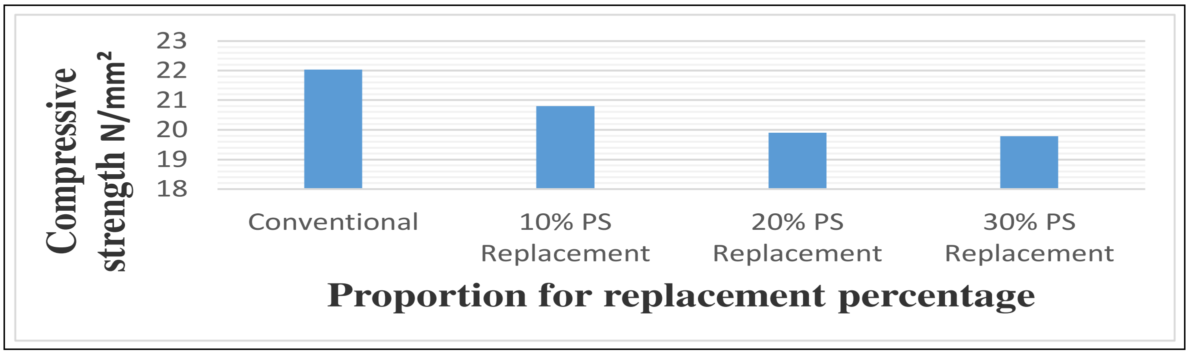

Figure 9: Compressive strength for M30 grade 7 days result of pumice stone

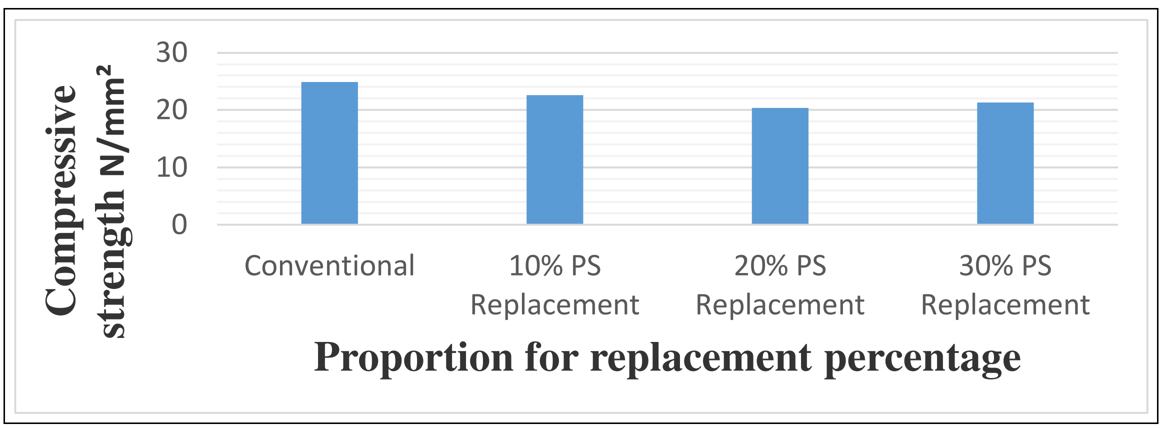

Figure 10: Compressive strength for M30 grade 14 days result of pumice stone

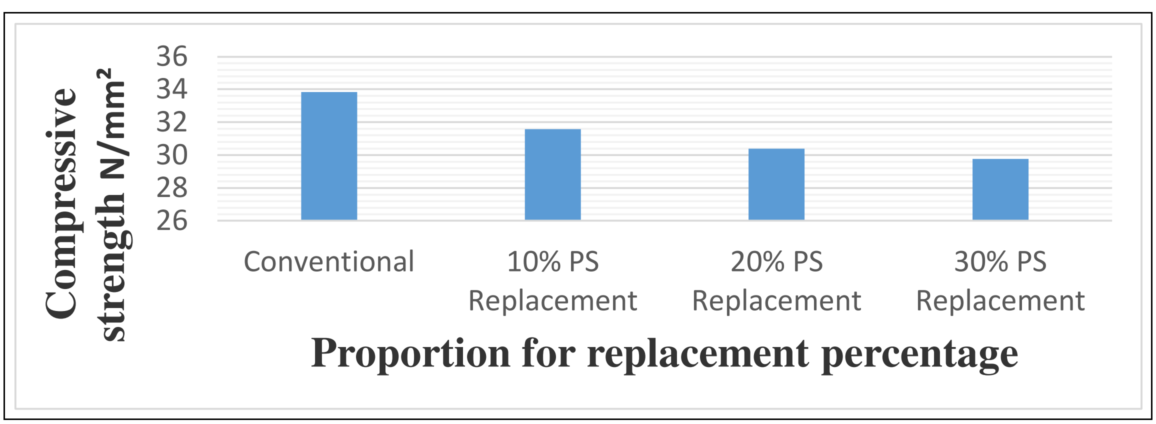

Figure 11: Compressive strength for M30 grade 28 days result of pumice stone

5. Conclusion

Based on the experimental study results obtained from this investigation the following conclusions are made:

1. Using pumice aggregate as coarse aggregate in mortar decreases the strength of the mortar. This was due to the replacement of strong standard coarse aggregate by relatively weak pumice aggregate. Mortar using pumice as standard light weight mortar and it can be used as in cast in place walls, load bearing and non-load bearing purposes.
2. The compressive stremgth of pumice light weight concrete is found to be at desired values for 10%, 20% ans 30% replacement.
3. The 30% replacement of the normal aggregate with the pumice aggregate gives least compressive strength with more reduction in weight of concrete.

Henceforth, M20, M25 and M30 grade of concrete used with replacement percentage 10% and 20% can be effectively used for structural purpose. Replacement of 30% can only be used for nonstructural purpose and optimum strength of replacement for 20% is effective.

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