Experimental Investigation on the Effect of Silica fume and Pumice stone in Developing Light Weight Concrete

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Abstract. The major challenge in the recent construction sector is to design the building with the cost effective manner. In order to address this issue, self weight of the structural member has to be reduced considerably, and then simultaneously the dimensions will be minimized. This will be only by means of introducing light weight concrete (LWC). Different light weight aggregates are used by the past researches to reduce the density. This study is planned to achieve the properties of LWC in considering the importance to enhance the strength factors. Hence, in this experimental investigation, the influence of the silica and pumice stone is studied on the various partial and full replacement levels. The specimens are casted based on the arrived mix proportion and tested against compression, split tension and flexure. The test result shows 0.6 to 0.7 times the strength achieved of the conventional concrete for this developed LWC mix proportion. A considerable improvement is seen in the strength parameters by the presence of 5 % silica fume.

1. Introduction
A prime concern in the construction industry is to bring down the cost of the buildings in a feasible ways but without the negotiation its mechanical and performance properties. In this regard, it is only probable by reducing the dead loads of the structures and thereby some savings in the foundations, materials and reinforcements in reducing the dimension of the columns, footings and other load bearing elements [1,2,4,6,7,11]. This necessitate is to be addressed in the light weight concrete (LWC). The density of the LWC is considerably made low than the conventional concrete and it is in the limit of 1200 kg/m$^3$ - 1850 kg/m$^3$ with incorporating the light weight aggregate either partially or completely [4,5,8,9,12]. The various researchers used expanded shale, clay, slate, foamed slag, sintered fly ash, vermiculite, expanded perlite, pumice stone, expanded glass, polystyrene beads etc as light weight aggregates in the concrete [2,6,8,9,12]. Out of that aggregates, pumice stones has greater advantage in performing better in the properties like thermal conductivity, freezing/thawing, non-toxic and acoustical [2, 6, 12]. In many research studies, shows that the LWC might have strength only 45 % to 55 % compressive strength. Hence it is important that the properties of LWC should be attained with some increase in the strength factor with the use of eco-friendly pumice stones. Therefore, in this paper an attempt is made to develop the light weight concrete and also to enhance the strength properties by adding 5 % silica fume content along with the different replacement levels of coarse aggregate by pumice stones.

2. Materials Used
The following materials were used for this experimental study:

2.1. Cement
Ordinary Portland cement (OPC) of 43 grade confirming to the standards of IS: 8112-2013. Its specific gravity is 3.12.
2.2. **Fine Aggregate**
M-Sand is used as a fine aggregate with the specific gravity of 2.88. It is related to zone II of IS 382 – 2016. Its fineness modulus is 2.76.

2.3. **Coarse Aggregate**
Coarse aggregate of size 12.5 mm with a specific gravity of 2.8 is used. Its fineness modulus is 4.6.

2.4. **Fly ash**
Class C flyash with a specific gravity 2.76 obtained from Tuticorin Thermal Power Station is used for the replacement of cement in different levels.

2.5. **Pumice stones**
Pumice stones of gravity 0.92 g/cm$^3$ are used and its specific gravity is found to be 0.95.

2.6. **Admixture**
Silica fume of specific gravity 2.34 is used as a mineral admixture.

2.7. **Water**
Potable drinking water is used for mixing LWC and curing purpose.

3. **Experimental Study**
The mix design arrived for this experimental study is 1 (C) : 1.37 (FA) : 2.24 (CA) : 0.42 (W/c). The experimental investigation involves in evaluating the mechanical characteristics of the developed light weight concrete based on the coarse aggregate replacement levels in 25%, 50%, 75% and 100% by pumice stones along with 5% silica fume in the arrived mix design. 18 Cube specimens of standard dimension of 150 mm (length), 150 mm (breadth) and 150 mm (depth) were casted as per the mix ratio for the compression test, 18 cylinder specimens of size 150 mm (diameter) and 300 mm (height) for split tension test and 18 prism specimens of size 100 mm (breadth), 100 mm (Width) and 500 mm (length) for flexure test were casted and allowed in water curing as shown in figure 1. The cube specimens and cylinder specimens were tested for the 28 days strength in the CTM. The prisms specimens were tested in the UTM under two point loading.

![Figure 1](linked_image)

**Figure 1.** (a) - (b) Casting of specimens (c) Specimens under curing
4. Results and Discussions

Table 1 shows the test results conducted to examine the strength properties of compression, split tension and flexure of the developed light weight concrete in the various replacements levels from 0%, to 100% of pumice stones in the coarse aggregate content along with the 5% addition of silica fume. In this study, the average density of the conventional concrete is found to be 2600 kg/m$^3$ and it is distinct clear that, the average density is brought down to 1600 kg/m$^3$ by the significant effect of the pumice stones in different replacement levels in the coarse aggregate. For conventional concrete, the strength of compression, split tension and flexure is found to be 32.07 N/mm$^2$, 4.13 N/mm$^2$ and 8.21 N/mm$^2$ respectively. The presence of 5% silica fume in the cement proportion will slightly enhance the binding property of the concrete. Thereby the compressive strength is increase with a gaining factor of 7%. Similarly, both the strength of split tension and flexure is slightly increased by means of 5% in comparable with the conventional concrete.

The presence of 25% of pumice stone in the concrete, makes the reduction of average density (2300 kg/m$^3$) is 12% of the density of conventional concrete but it is still not come to the range of light weight concrete. However, in that instance, the compression strength had diminished to 30.60 N/mm$^2$, tensile strength reduced to 3.55 N/mm$^2$ and flexural strength reduced to 6.85 N/mm$^2$. Further if the presence of pumice stone is increased 50%, the density is in the border of light weight concrete and conventional concrete and reduction rate is around 20%. For this trial, there will be a further reduction in the strength parameters of 20% in compression and around 40% in flexure and split tensile test due to the consequence of improper bonding between the binding material and filler material. In replacement of coarse aggregate to pumice stones by 75% will results in bringing down the density level to around 1850 kg/m$^3$. This assures that, the corresponding trial is performing light weight concrete basic requirements in the reduction of density as 30%. The increase in the replacement levels of pumice stones is adversely affecting the strength of the concrete. The presence of pumice stones is showing the inverse proportional character to the strength parameters and proportional character to the declining level of density.

If the pumice stones are completely replacing the coarse aggregate (100%), the density is only 1600 kg/m$^3$ which assure that, it lies well within the range of LWC requirements in the reduction rate of around 40%. The declining trend in the strength parameters is continuing up to 45% for compressive strength and around 65% to 75% for split tensile and flexure strength. This may be owing to the influence of aggregate bonding nature and bonding strength in between cement paste and aggregates. The tensile strength ranges from 12% to 24% of its compressive strength for the conventional concrete and this ranges reduced to 12% to 24% for the lower density concrete (light weight concrete) as reflected in figure 3.
Table 1. Test results on hardened LWC for different replacements levels for Pumice stones

| Specimen | Replacements (%) | Avg. Density (kg/m$^3$) | Compression strength (N/mm$^2$) | Avg. Compression strength (N/mm$^2$) | Split tension strength (N/mm$^2$) | Avg. Split tension strength (N/mm$^2$) | Flexure strength (N/mm$^2$) | Avg. Flexure strength (N/mm$^2$) |
|----------|-----------------|-------------------------|-------------------------------|-----------------------------------|----------------------------------|-----------------------------------|-------------------------|-------------------------------|
| CC       | 0 0 0           | 2600                    | 3.24                          | 32.07                             | 4.13                             | 8.3                               | 8.21                    |                               |
| CC SF    | 5 0 0           | 2600                    | 33.78                         | 34.44                             | 4.45                             | 8.5                               | 8.71                    |                               |
| SF 25    | 5 25 2340       | 3.096                   | 30.79                         | 30.60                             | 3.5                              | 6.85                              | 6.85                    |                               |
| SF 50    | 5 50 2080       | 2.566                   | 25.66                         | 25.73                             | 2.54                             | 4.7                               | 4.7                     |                               |
| SF 75    | 5 75 1820       | 22.22                   | 22.67                         | 22.64                             | 2.06                             | 3.43                              | 3.44                    |                               |
| SF 100   | 5 100 1600      | 17.33                   | 19.92                         | 17.8                              | 1.59                             | 2.1                               | 2.05                    | 2.03                          |

Figure 3. Relationship between strength and replacement levels of pumice stones

5. Conclusions
The subsequent findings are arrived in this experimental investigation.
1. Addition of pumice stones yields the results of density as 1600 kg/m$^3$ which is 40% less than the conventional concrete (2600 kg/m$^3$) which confirms the development of lightweight concrete.
2. The additional content of 5% of silica fume shows increase on the strength parameters around 5% to 7% which will arrest the micro pores of concrete as filler material and helps in attaining better workability.
3. The developed lightweight concrete has compressive strength in the range of 60% to 70% of the conventional concrete strength. The reduction in the strength may be due to lacking of...
bonding strength between the cement paste and aggregate interface.

4. To increase the strength criteria for the light weight concrete, the addition of silica fume can be extended from 5% to 20%. If required, fly ash can be along with that.

Acknowledgements
Authors wishing to acknowledge the physical support given by Mr. R. Anand, Mr. S. Anand Ganesh and Mr. T. Arumugam throughout this experimental study.

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