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Prediction of Strength Parameters for Cellular Light Weight Concrete by using Fly ash as Partial Replacement of Cement

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Abstract:- Cellular lightweight concrete is a lightweight concrete that contains numerous, evenly distributed air bubbles throughout the concrete mixture. These air bubbles make the concrete lighter in weight than traditional concrete. On the other hand, cellular lightweight concrete provides less, strength compared to traditional concrete due to the presence of pores. Utmost control is very much needed during its production and onsite supervision. There are no such Codal provisions available for the preparation and testing of the physical and mechanical properties of foamed concrete. The focus of the study is to add of foaming agent and fly ash as a partial replacement of cement to fill the pore spaces to improve the strength of cellular lightweight concrete. In this study, different percentage of fly ash has been added and the result has been discussed. The optimum strength is achieved with 25 to 30% replacement of cement with fly ash.

I. INTRODUCTION

Conventional concrete made with coarse and fine aggregates has a high density with a range of 2200 – 2600 kg/m^3 imposing a high dead load on the structure. Lightweight foam concrete (LWFC) using foaming agents has a density of 2000 kg/m^3 or less and is a class of aerated concrete. Cellular lightweight concrete (CLWC) provides a strong mechanical key uniting the concrete masonry backing and plaster finish in a strong permanent bond. The Romans first introduced it in the second century when the Pantheon was constructed using pumice. It was made using natural aggregates of volcanic origin such as pumice, scoria, etc. The performance of CLWC in terms of density and compressive strength is investigated. Foamed lightweight concrete can be added to the list of green building materials. This material has good thermal and acoustic properties, low water uptake, fire resistance, high early 28-day compressive strength, and freeze/thaw resistance, and is available in a wide variety of products. The use of huge quantities of aggregate will be no longer available and the deficit has to be made up by importing materials from other places. A new direction toward CLWC in building and civil engineering construction is highly necessary. The study is aimed at identifying and optimizing the salient parameters that influenced the mixture proportions of CLWC with and without fly ash and its curing methods.

➢ *Objective*

The major objectives of this study are

- *To determine the compressive strength and elasticity of LWFC with different percentages of fly ash as sand replacement*
- *Characterization of physical properties of the samples*
- *Optimization of mix design for the formulation of FC*
- *Addition of accelerators to decrease the setting time of FC*
- *Evaluation of FC to determine the suitability for construction projects*
- *To assess the impact of fly ash on FC*

II. MATERIALS

➢ *Cement*

Cement is an extremely ground material having adhesive properties that provide a binding medium for discrete ingredients. An ideal selection complying with Indian standards is 53 grade OPC conforming to IS 12269. The basic ingredient for Portland cement consists of lime reach materials such as limestone, seashells, marl, chalk, clay, shale, fly ash or sand to provide silica and alumina, iron ore, and mill scale to provide the iron or ferriferous component. The properties of cement are listed in Table 1.

Table 1 Properties of OPC

Sl NO	Properties	Value
1	Fineness	98%
2	Specific gravity	3.13
3	Normal Consistency	29%
4	Initial setting time	105 min
5	Final setting time	350 min

➢ *Fine Aggregate*

Sand is used to produce FC for practical reasons with a dry density in excess of 1200 kg/m^3. In this study, natural river sand conforming to IS 383 is used. River sand is primarily composed of finely divided particles of quartz, granite, and other minerals. The sand used in this experimental work was free from reactive elements which create excessive expansion in concrete The tests were performed to find the properties of sand as per the provision of the Indian Standard code. The properties of sand are mentioned in Table 2.

Table 2 Properties of Fine Aggregate

Sl No	Properties	Value
1	Zone	III
2	Fineness modulus	3.027
3	Specific gravity	2.63

➢ *Coarse Aggregate*

Aggregates retained on the 4.75 mm IS sieve are the coarse aggregates. For the production of cellular lightweight concrete, 10 mm to 20 mm size particles are used. These are due to the natural disintegration of rocks or the artificial crushing of rock or gravel. The properties of the coarse aggregate confirming IS 383-1970 are mentioned below in Table 3.

Table 3 Properties of Coarse Aggregate

Sl No	Properties	Value
1	Specific gravity	2.76
2	Water Absorption	3 %

➢ *Fly ash*

Fly ash contains oxides of calcium, aluminium, and silicon. The important advantage of fly ash in concrete is the reduction of thermal cracking thereby increasing the durability of concrete. Fly ash may be used as an additive or in-part replacement for sand. Various previous research works concluded that cement can be partially replaced by fly ash. It also proved that the fly ash improves workability, durability and also lowers the overall cost of concrete. The use of fly ash in concrete decreased the environmental impact due to cement manufacturing. The Properties of fly ash are listed in Table 4.

Table 4 Properties of Fly ash

Sl No	Properties	value
1	Colour	Grey
2	Bulk density	0.994
3	Specific gravity	2.027

➢ *Water*

Water used for foamed concrete should be portable. The criterion of portability of water is not absolute. Water with PH 6-8 which is not tested saline or brackish is suitable for use. Natural water that is slightly acidic is harmless but water containing humic or other organic acids may adversely affect the hardening of concrete.

➢ *Superplasticizer*

Superplasticizers are high range water reducing agents which is a chemical admixtures used to increase workability, reduction in water content, and increase the fluidity characteristics of concrete without affecting the optimum strength. Superplasticizers have a strong water-reducing effect in the w/c ratio of a concrete mix preparation resulting in high-performance and high-strength concrete due to reduced permeability and improved durability. Properties of superplasticizers are mentioned in Table 5.

Table 5 Properties of Superplasticizer

Sl No	Properties	Value
1	Colour	Brown
2	Specific gravity	1.053

➢ *Foaming Agents*

Foaming agents in concrete are chemical compounds that are used to introduce air bubbles or voids into the concrete mixture. These air bubbles create a cellular structure within the concrete, resulting in a material known as foamed concrete or lightweight concrete. Foaming agents are commonly used in construction to produce lightweight concrete with reduced density and improved insulation properties. Properties of the Foaming agent are listed in Table 6.

Table 6 Properties of the Foaming Agent

Sl No	Properties	value
1	Colour	Blue
2	pH	8.43
3	Specific gravity	1.027

➢ *Methods*

The foamed concrete is also called cellular lightweight concrete prepared by the addition of a foaming agent in conventional concrete. The resulting concrete mixture has a large portion of tiny air bubbles, which makes the concrete low density and gives an excellent thermal insulating property. The details design procedure is given below. Three pairs of concrete mixes were prepared by using fly ash and foaming agents. To determine the compressive strength of concrete three sets of (150 x 150 x 150) mm cubes were prepared as per the guideline set by IS 516-1959. The cubes were tested in a compressive testing machine with having capacity of 2000 KN in 7, 14, and 28 days respectively. Similarly, three sets of 150 mm diameter and 300 mm length cylinders were prepared by confirming IS 5816:1999. The three sets of cylinders were tested in 7, 14, and 28 days respectively.

- PCI Sand mix:
- Plastic Density: D = Cement + Water + Sand
- Water content: W = (Water Cement Ratio) x Cement
- Sand content: S = Plastic Density - Cement - [(water-cement ratio) x Cement]
- PC/PFA/Sand mix:
- Plastic Density: D = Cement + Water + Sand + Fly ash
- Sand Content: S = Plastic Density – Cement – Fly ash - [(water-cement ratio) x (Cement + Fly ash)]
- Water content: W= (Water cement Ratio) x (Cement + Fly ash)
- PFA content: F = % of replacement to cement

Table 7 Details of Mix

Type of mix	Cement (kg/m³)	Sand (kg/m³)	w/c + FA	Water (lit)	Foaming Agent (lit)	Fly ash (kg/m³)
PCS_{1400}	500	750	0.3	150	4.5	-
$PCPFS_{1400}$	356	650	0.5	250	7.5	144
PCS_{1600}	500	950	0.3	150	4.5	-
$PCPFS_{1600}$	378	819	0.45	243	7.29	160
PCS_{1800}	500	1150	0.3	150	4.5	-
$PCPFS_{1800}$	420	960	0.4	240	7.2	180

III. RESULTS AND DISCUSSIONS

- *Compressive Strength*

The results of compressive strength at 7 days, 14 days, and 28 days for Lightweight foam concrete specimens with and without partial replacement by fly ash are shown in Fig 1, Fig 2, and Fig 3. The cube strengths are calculated for the normal curing condition at 25°C – 27°C. The maximum strength is achieved in the case of a density of 1800 kg/m³ in comparison to other mixes in both cases. From experimental observation in accordance with the literature reviews it's observed that an optimum percentile i.e., 28-30% of fly ash replacement hasn't shown any significant variation in strength.

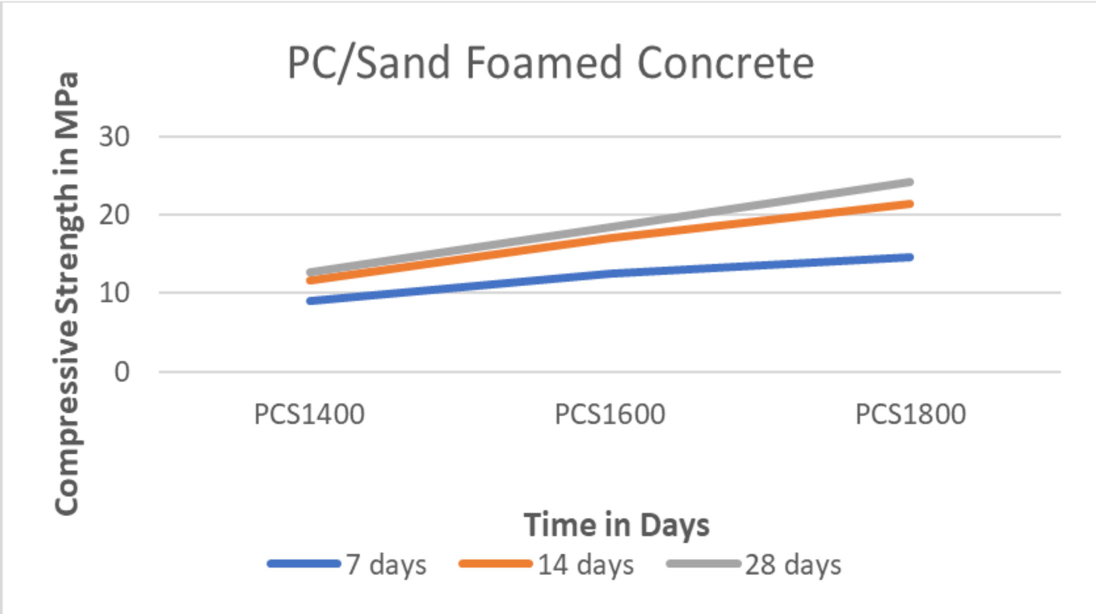

Fig 1 Compressive Strength of PCS Concrete

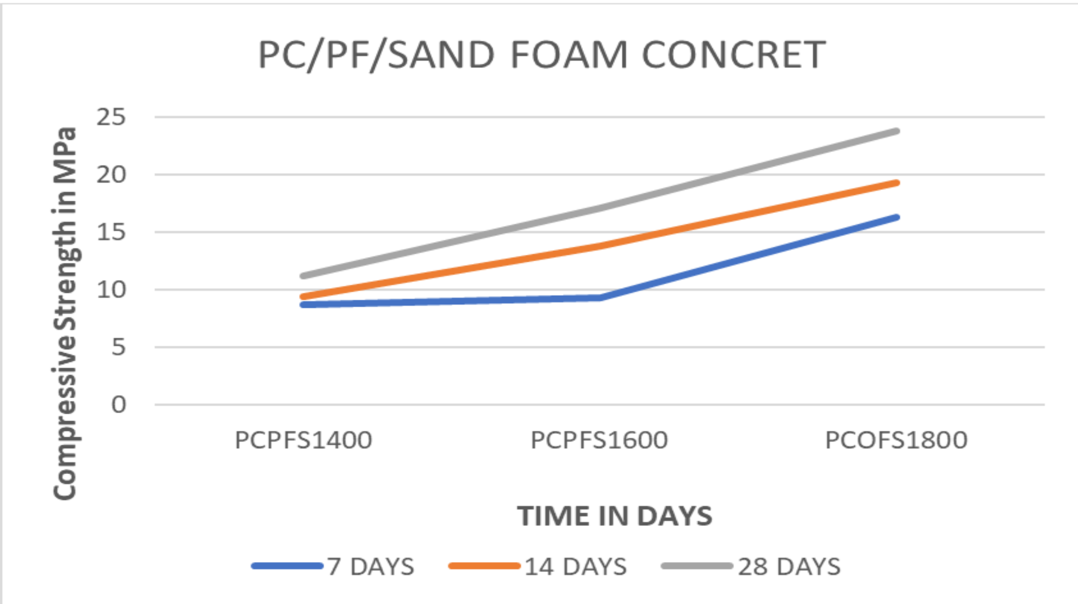

Fig 2 Compressive Strength of PCPFS Combination

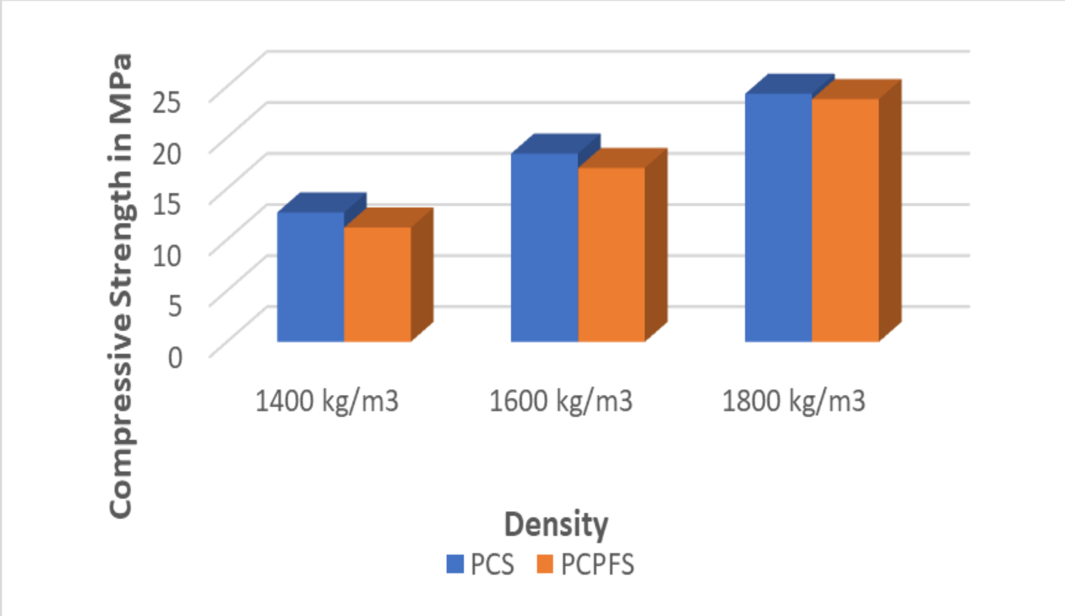

Fig 3 Comparison of Compressive Strength

➢ *Split Tensile Strength:*

The result of split tensile strength at 28 days for LFC concrete specimens is shown in Fig 4. The split tensile strength is calculated for the normal curing regimen condition. The results show that the maximum strength achieved by the PCS_{1800} compression to other mixes. The maximum is observed to be 2.52 MPa. The results show similar characteristics to compressive strength analysis. A little reduction in strength due to binder replacement has been encountered. A maximum variation of 24 % and a minimum of 11% were encountered for a plastic density of 1600 kg/m^3 and 1800 kg/m^3 respectively. The figure shows the splitting tensile strength compression between two different mixes: PC/SAND and PC/PFA/SAND

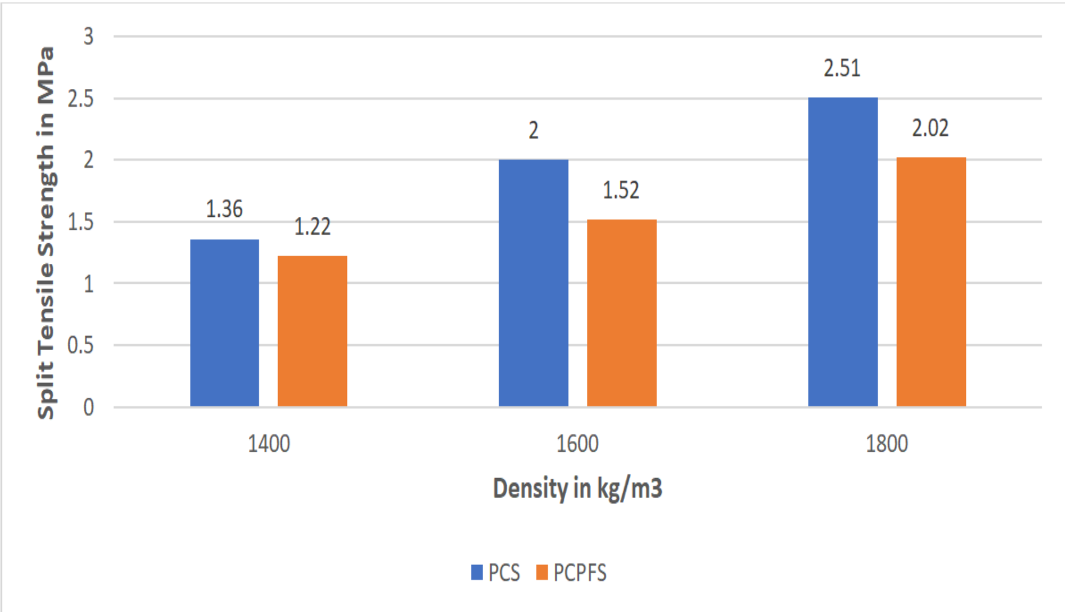

Fig 4 Comparison of Split Tensile Strength

IV. CONCLUSION

From the study, it is investigated that the formation of pores influences the mechanical properties of LFC. The addition of an excess quantity of foaming agent reduces the strength of concrete due to the formation of more pore spaces and also the amount of air content inside the material which leads to weak cell structure between pores and matrix. The addition of fly ash as a replacement for cement results in better compressive strength compared to other additives. Satisfactory results may be achieved in the compressive strength with 15 to 30% replacement of cement with fly ash. The optimum strength is achieved with 25 to 30% replacement of cement with fly ash. The results shown in the figures indicate that the addition of fly ash in the LFC mix reduced the size and amount of pores influencing the strength parameters of LFC.

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