# EXPERIMENTAL INVESTIGATION ON LIGHTWEIGHT SELF – COMPACTING CONCRETE USING POLYPROPYLENE FIBER

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***Abstract:*** This project presents the experimental study to determine the simultaneous effects of polypropylene fiber on the mechanical properties of light weight self-compacting concrete using pumice powder. Mixes with different fiber volume fractions (0.0, 0.2, 0.4 and 0.6%) at different levels of fly ash (0.0, 10, 20 and 30%) as a replacement by weight of cement were prepared. Concrete offers many advantages regarding mechanical characteristics; the brittle behavior of the material remains a larger handicap for the seismic and other applications where flexible behavior is essentially required. Reinforcement with randomly distributed short fibers presents an effective approach to the stabilization of the crack and improving the ductility and tensile strength of concrete. Polypropylene (PP) fiber reinforcement is considered to be an effective method for improving the shrinkage cracking characteristics, toughness, and impact resistance of concrete materials. Also a variety of materials are added to concrete so as to improve its mechanical behavior.The mechanical properties were conducted by comprising the compressive, splitting tensile & flexural strengths at 14 days , 21 days and 28 days. All mixes achieve self-compacting properties using polypropylene fiber up to 0.4% fiber content. The Light Weight Self Compacting Concrete mixes have a slump flow in the range of 610–690 mm. However applying these fibers at their maximum percentage volume fraction determined through this study, increased the tensile strength and the flexural strength.

***Key words*–Polypropylene fiber,flyash,pumice powder.**

## I. INTRODUCTION

Lightweight concrete has been used for a number of applications and is also known for its good performance and durability. In structural applications, the self weight of the concrete structure is important since it represents a large portion of the total load, the reduced self weight of lightweight concrete will reduce gravity load and seismic inertia mass, resulting in reduced member size and foundation force. The development of new types of high performance concretes, such as self-compacting concrete (SCC) and lightweight concrete (LWC) responds to some of the urgent needs of the construction sector . The development of SCC has been perceived by many specialists as a giant step towards achieving high performance cement- based materials . It offers also limitless advantages in terms of durability, cost efficiency, and job site productivity. On the other hand, lightweight concrete can decrease the self weight of structures which can result in reduced members' sections and simplify construction. Therefore, lightweight concrete can save overall construction costs. Conventionally, lightweight aggregate concrete is mixed and produced in a similar manner as conventional concrete. This manufacturing method is usually associated with segregation problems in the mixture due to the low density of the aggregate used. In contrast, with a reduced aggregate content, self-consolidating concrete can be manufactured with a large volume of powders. This usually results in a concrete having an enhanced viscosity at the fresh stage and higher compressive strength at it hardens. Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort and which is at the same time cohesive enough to be handled without segregation or bleeding . SCC was originally developed at the University of Tokyo, Japan in 1986 by Prof. Okamura and his team to improve the quality of construction and to overcome the problems of defective workmanship . It is used to facilitate and ensure the proper filling and good structural performance of the restricted areas and heavily reinforced structural members. SCC can also provide a better working environment by eliminating the vibration noise . Self-compacting lightweight aggregate concrete (SCLC) is a kind of high-performance concrete developed from self-compacting concrete (SCC). SCLC combines the favourable properties of lightweight aggregate concrete (LWAC) and SCC, needs no external vibration, and can spread into place, fill the formwork and encapsulate reinforcement without any bleeding or segregation . On the other hand, the use of chemical admixtures is always necessary when producing SCC in order to increase the workability and reduce the segregation. The content of coarse aggregate and water to binder ratio in SCC are lower than those of normal concrete. Therefore, SCC contains large amounts of fine particle such as, fly ash in order to avoid gravity segregation of larger particles in the fresh mix. The wide variety of the lightweight aggregate source result in distinguishing behaviour among the SCLCs. Thus, properties of SCLCs have to be examined individually .Achievements in modern concrete technology have led to the introduction of light-weight concrete (LWC) and selfcompacting concrete (SCC) as structure mass reducing and workable materials. The relation between cement paste and aggregates is very important in the mix design of concrete. SCC has a higher paste amount than conventional concrete and LWC to facilitate the flowing of aggregates to fill any voids inside the formwork. Paste coating of aggregates to reduce the friction and direct touching between aggregates can improve the flowability of fresh concrete. Controlling the water to cement ratio, results in a denser and stronger concrete. In LWSCC, this problem is even more obvious due to insufficiencies in the initial energy of lightweight aggregates in relation to moving along with the light weight aggregates in the cement paste . To keep the balance among the proportions of LWSCC is therefore important to achieve the required flowability in the fresh state and the planned density and high quality in the hardened state. Packing density theory is a method of concrete mix design which has been successfully used in LWSCC by determining the optimum mortar to aggregates packing voids ratio. The main steps to attain the LWSCC mix design in this method are: (a) minimizing the voids volumes related to the coarse aggregate, (b) minimizing the water to cement ratio, (c) maximizing the density of the cementitious materials and (d) optimizing the flowability and requirements of the fresh concrete.

## II. PROPERTIES OF POLYPROPYLENE FIBER

- Specific Gravity - 0.91
- Tensile Strength - 500-700 Mpa
- Young's modulus (E) - 3.5-.8 GN/m²
- Elongation at failure - 21%
- Melting point - 160-170º C

## III. SCOPE AND OBJECTIVE

- To study the properties of the polypropelene concrete
- To study the mechanical properties of light weight self compacting concrete using polypropylene fibres.
- To compare the strength and durability of normal concrete and LWSC Concrete using polypropylene fibres.
- The function of the polypropylene fibre mixed into concrete is to avoid the creation of micro cracks in the concrete. Polypropylene fibres are used in concrete to obtain a much better, more stable surface and more resistant piece of concrete. It reduces the danger of micro cracks dramatically.

## IV. MATERIALS USED

### A. Ordinary Portland Cement:

The cement used for the entire experiment is Ordinary Portland cement of 53 grade conforming to IS 12269. The cement was tested for fineness and specific gravity. Specific gravity of the cement obtained as per the test was 3.15. The cement used is fresh and without any lumps. It is the basic ingredient of concrete, mortar and plaster.

### B. Fine Aggregates:

They are aggregate most of which passes 4.75mm IS Sieve. M Sand is used as the fine aggregate. Sieve analysis is carried out and as per sieve analysis it comes under Zone-II. The limits for each zone as per IS: 383 – 1970.

### C. Coarse Aggregates:

Aggregate most of which is retained on 4.75mm IS Sieve and containing only so much finer material as is permitted for the various types described in this standard. As per IS: 10262 – 1982 clause 3.6 explaining the combination of different coarse aggregate fractions two different sizes, 20mm and 12.5mm size coarse aggregates were used which results in an overall grading conforming to Table 2 of IS: 383 - 1970.

### D. Chemical Admixture (Super Plasticizer):

Super plasticizer (normal) 4% by the weight of cement is used in the concrete for improving the workability condition of the concrete.

### E. Pumice stone powder:

Pumice is a natural material of volcanic origin produced by the release of gases during the solidification of lava, and it has been used as the aggregate in the production of lightweight concrete in many countries around the world. So far, the use of pumice was dependent on the availability and limited to the countries where it is locally available or easily imported.The use of pumice as aggregate or mineral additive in the production of self-compacting concrete may be a good approach for the production of lightweight, easy workable, economic and environmentalist concrete.

**Fig-1.1 Pumice powder**

**F. Fly ash:**

FA as fine powder form was used with surface area of 22,000 cm2/gm and at different levels namely: 0.0, 10, 20 and 30% as a partial replacement by weight of cement content. The chemical composition of cement and fly ash are reported in Table 1.2.

**Fig-1.2 Fly Ash**

**G. Viscosity Modifying Agent:**

VMA was used at level 0.4% by weight of cement content in all mixes.

**H. Water:**

Clean tap water, with water-binder ratio (w/b) equal to 0.45 was kept fixed in all mixes in this study.

**I. Polypropylene fibers:**

PPF was used in this study at different fiber volume fractions namely: 0, 0.2, 0.4 and 0.6.

**Fig-1.3 Polypropylene fiber**

**3.1Experimental Investigation**

**Determination of Specific gravity of Cement:**

Volume of sample taken as 50g.

Table 3.1 specific gravity of cement

| S.G 1 | S.G 2 | S.G 3 | Average |
|---|---|---|---|
| 3.04 | 3.14 | 3.15 | 3.15 |

$$\text{Specific Gravity} = \frac{(W2-W1)}{((W2-W1)-(W3-W4)X0.79)}$$


**Fig – 3.1 Specific Gravity Test on Cement**

**3.2 Specific Gravity Test on Fine Aggregate**

Volume of sample taken as 1000g.

| Sl.No | Weight Of Pycnomter In Gms (W1) | Weight Of Pycnomter + Sand In Gms (W2) | Weight Of Pycnomter + Sand + Water In Gms (W3) | Weight Of Pycnomter + Water In Gms (W4) |
|---|---|---|---|---|
| 1. | 630 | 830 | 1623 | 1503 |
| 2. | 630 | 830 | 1620 | 1504 |
| 3. | 630 | 830 | 1624 | 1500 |

$$\text{Specific Gravity} = \frac{(W2-W1)}{(W2-W1)-(W3-W4)}$$

**Table 3. 2. Specific Gravity of Fine Aggregate**

| S.G 1 | S.G 2 | S.G 3 | Average |
|---|---|---|---|
| 2.65 | 2.60 | 2.61 | 2.65 |


**Fig – 3.3. Specific Gravity on Fine Aggregate**

**3.3 Specific Gravity Test on Coarse Aggregate**

Volume of sample taken as 1000g.

| Sl.No | Weight Of Pycnomter In Gms (W1) | Weight Of Pycnomter + Coarse Aggregate In Gms (W2) | Weight Of Pycnomter + Coarse Aggregate + Water In Gms (W3) | Weight Of Pycnomter + Water In Gms (W4) |
|---|---|---|---|---|
| 1. | 630 | 958 | 1593 | 1234 |
| 2. | 468 | 988 | 1570 | 1234 |
| 3. | 468 | 951 | 1590 | 1234 |

$$\text{Specific Gravity} = \frac{(W2-W1)}{(W4-W1)-(W3-W2)}$$

**Limitations:** Specific gravity of coarse aggregate should be 2.5 – 3.0

**Table 3.3.Specific Gravity of Coarse Aggregate**

| S.G 1 | S.G 2 | S.G 3 | Average |
|---|---|---|---|
| 2.81 | 2.83 | 3.07 | 2.64 |


**Fig 3.3 Specific Gravity on Coarse Aggregate**

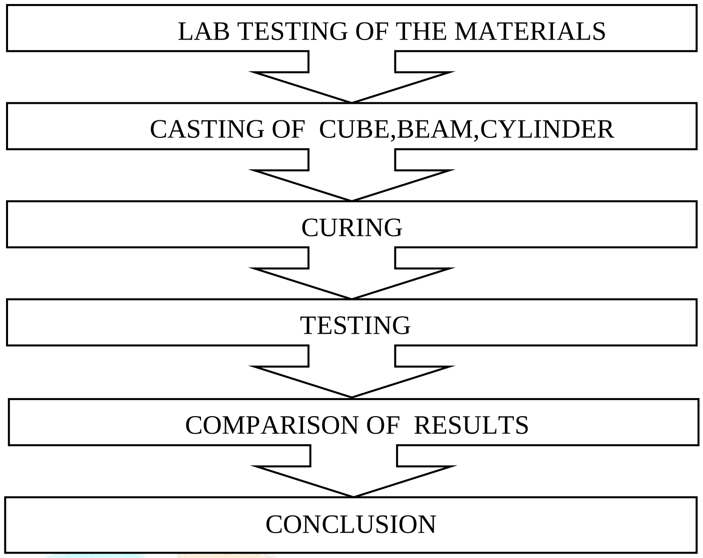
**3.4 Setting Time**

The initial setting time and final setting time to be determined by Vicat Apparatus. The following procedure is adopted. Take 500gm. Of cement sample and guage it with 0.85 times the water required to produce cement paste of standard consistency. The paste shall be gauged and filled into the Vicatmould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement. The temperature of water and that of the test room,at the time of gauging shall be within 27º C ± 2ºC.Lower the needle gently and bring it in contact with the surface of the text block and quickly release. Allow it to penetrate to the test block.The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35mm from the top is taken as initial setting time. Replace the needle of the Vicat apparatus by a circular attachment. The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle make an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5mm

**Table 3.4. Properties of OPC**

| Test | Result Obtained | As per IS 4031 -1998 |
|---|---|---|
| Consistency | 33 | - |
| Initial Setting time | 90 minutes | Not less than 30 min |
| Final Setting time | 5 hours | Not less than 600 min |
| Specific gravity | 3.15 | - |

## I. METHODOLOGY




### 3.1Mix Proportion

A rational mix-design method for self-compacting concrete using a variety of materials is necessary. The coarse and fine aggregate contents were fixed so that self compact ability could be achieved easily by adjusting the water binder ratio and super plasticizer dosage. For the experiments, 16 series of self-compacting concrete mix represent the main variables were mixed: Three different levels of polypropylene fiber volume fractions 0.2, 0.4 and 0.6 and three levels of fly ash, 10%, 20% and 30% as a partial replacement of cement by weight of cement were used in this work, in addition to control mix with no fiber and 0% fly ash. Also the dosage of viscosity modifying agent (VMA) of 0.4% was used. The water binder ratio (W/B) was kept constant and equal to 0.45, for all mixture.

### 3.2 Compressive Strength Test

The Compressive Strength of concrete with lightweight self compacting concrete using polypropylene fiber was conducted on the Cubes of size 150mm, were tested as per IS 516 -1959 specifications and the experimental set up. The unit weight of the specimens was also determined at the same time. The Cubes were tested for compressive strength at the age of 14 days, 21 days and 28 days after curing.

### 3.3 Tensile Strength Test

The splitting tensile strength was determined at ages of 14 days, 21 days, 28 days on cylinders measuring 150-mm diameter and 300 mm height and cured in water until the date of test according the ASTM C496.

### 3.4 Flexural Strength Test

The flexural strength was determined according to ASTM C78. End capped 100 x 100x 500 mm prism specimens were cured in water and tested at ages of 14 days, 21 days and 28 days for different mixtures.

## IV. RESULTS AND DISCUSSION

### 4.1 Results of Cube, Beam, Cylinder Test on 28$^{th}$ day

The results of compressive strength of concrete cubes for various proportions of fly ash and 0.4% polypropylene fiber. The final 28 days strength is more than normal concrete mix.

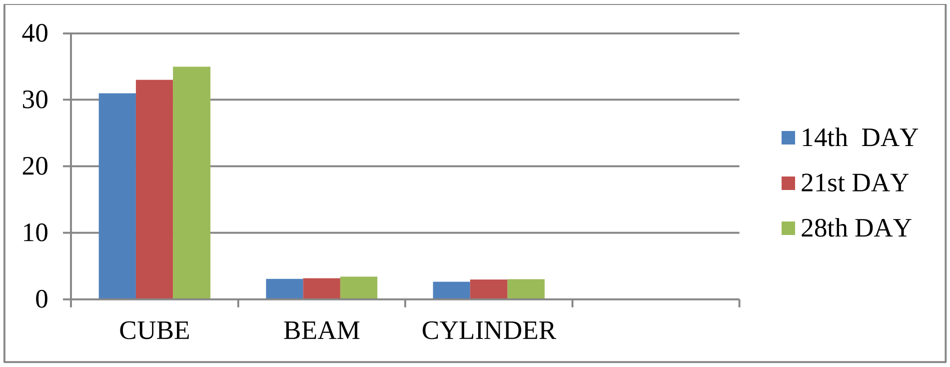



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**Fig 4.1. Discussion Of Result in MPa**

### 4.2 Conclusion

- The (SCFLWC) mixes suitable for structural applications were developed using locally available natural lightweight coarse and fine aggregates. The mixes developed had a compressive strength range of 25-35 MPa; density of 1700–2000 kg/m3; and a high degree of workability.
- The SCFLWC mixes developed. Splitting tensile strength developed was from 1.56, to 3.03 MPa. Flexural strength developed was from 1.98 to 3.4 MPa. The highest tensile and flexural strength was recorded in the SCFLWC with 0.4% polypropylene fiber. The compressive strength increased with a decrease in the percentage of the fly ash. In this way the maximum improvement in tensile strength is 14 % while the maximum improvement in flexural strength is 22%.
- Polypropylene fibers have no detectable effect on mechanical properties of hardened concrete at volume percent 0.2% volume ratios. Besides, addition of 0.4% Polypropylene fibers in concrete mixes has a negligible influence on compressive characteristics. However, 0.4% PP fibers increased both flexural strength and tensile strength to some extent. The improving effect of Polypropylene fibers is more recognizable in the mixes which do not contain fly ash. So, the minimum amount of polypropylene fibers to be used in SCFLWC to enhance flexural and tensile strength is about 0.4% by volume of concrete.
- Generally polypropylene fibers do not have an impact on the compressive strength of SCFLWC. The changes in qualities are irregular and insignificant as the volume percentage of polypropylene fibers is increased at 28 days.
- The Compression test also shows the PFRC have good resistance to controlling cracks.
- The Compressive Strength increases gradually in fiber reinforced concrete than concrete without fibers.

### V. ACKNOWLEDGMENT

We would like to express our sincere thanks to our Principal, **Dr.RAMESH P.L.N, B.Tech., M.Tech., Ph.D.,** Prathyusha Engineering College, Thiruvallur for providing the permission and College facilities for the successful completion of this Project.We feel grateful to **Mr.G.KUMARASEN M.E.,** Assistant Professor, Department of Civil Engineering, Prathyusha Engineering College, Thiruvallur, for his guidance, encouragement and support.

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**[3]** Equation for Mix Design of Structural LightWeight Concrete “EJSR” Volume-31 2009 Pg no:132-141.

**[4]**Codes Used:
Ordinary Portland cement Grade 53 : IS 12269 - 2013
Fly Ash : IS 3812 Part I
Fine aggregates : IS 383
Coarse aggregate IS 383
Admixtures : EN 934 – 2
VMA EN934 part II Table 1