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Study on Behavior of Fibrillated Polypropylene Fibers Reinforced Concrete

Manohara K N[1], Nithish Nayaka Y B[2], Sharanappa[3], Veeresha K V[4], Darshan M K[5]

[1,2,3,4]*B.E. Student, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, India*

[5]*Assistant Professor, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, India*

***Abstract*: Concrete is made up of cement, fine aggregates, coarse aggregate, water and admixtures if necessary. Aggregate is one of the main ingredients in producing concrete covering up to 75% of total concrete mix. Strength of concrete produced is dependent on properties of concrete. Concrete will gives better durability and also its cost during construction as well as maintenance are very low when compared to other construction materials. As we know that concrete is strong in construction and weak in tension and tends to fail because of its deficiencies such as low tensile strength, low strain at failure. Based on Experimental investigation for M-20 grade of concrete, this paper provides result data of the compressive strength, and split tensile strength of fibrillated polypropylene fiber reinforced concrete (PFRC) containing fibers of 0%, 0.25% and 0.5% volume fraction by weight of cement (V_f) without admixture. For compression test, cube (15cm x 15cm x 15cm) were used. For splitting Test, Cylinders (15 cm diameter and 30 cm length) were used. For permeability test, the cub (15cmx15cmx15cm) were used. A result data obtained has been analyzed and compared with a control specimen characteristics of concrete by using polypropylene fiber reinforced. (0%, 0.25% and 0.50% fiber). A relationship between Compressive strength vs. days, and tensile strength vs. days represented graphically and permeability at end of 28 days. Result data clearly shows percentage increase in7, 14 and 28 days Compressive strength, and Tensile strength for M-20 Grade of Concrete. The aim of this project is to determine the strength and durability.**

Keywords: fibrillated polypropylene fibers, reinforced concrete.

I. Introduction

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement which hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. However, road surfaces are also a type of concrete, asphalt concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer.

In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily moulded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Often, additives are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

Famous concrete structures include the Hoover Dam, the Panama Canal and the Roman Pantheon. The earliest large-scale users of concrete technology were the ancient Romans, and concrete was widely used in the Roman Empire. The Colosseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforcsed concrete dome. Today, large concrete structures (for example, dams and multi-storey car parks) are usually made with reinforced concrete.

After the Roman Empire collapsed, use of concrete became rare until the technology was redeveloped in the mid-18th century. Today, concrete is the most widely used man-made material (measured by tonnage).

Concrete is world’s most widely used construction material. The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world.

Concrete is characterized by quasi-brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (polypropylene fiber) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc.

Fiber: Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend upon the efficient transfer of stress between matrix and the fibers, which is largely dependent on the type of fiber, fiber geometry, fiber content, orientation and distribution of the fibers, mixing and compaction techniques of concrete, and size and shape of the aggregate. Fiber reinforced concretes (FRC) exhibit property improvement caused by the fibers.

Fibrillated Polypropylene fibers have great influence on the spalling behavior of concrete under fire loading. Fibers of Fibrillated Polypropylene form a mesh or net type structure which binds the coarse aggregates in it, resulting in good workability and less bleeding of concrete. They also lower the permeability of concrete Fibrillated Polypropylene fibers give very good impact resistance strength to the concrete matrix. This property is very well utilized in concrete pavement successfully. Fibrillated Polypropylene fibers actually inhibit the formation of cracks in concrete matrix, whereas steel mesh only has functional value after the concrete has cracked. These materials are an excellent option for use as external reinforcing because of their light weight, resistance to corrosion, and high strength. Fibrillated polypropylene fibers are slit and expanded into an open network thus offering a larger specific surface area with improved bond characteristics.

Polypropylene fibers are hydrophobic, that is they do not absorb water. Therefore, when placed in a concrete matrix they need only be mixed long enough to insure dispersion in the concrete mixture. The mixing time of fibrillated or tape fibers should be kept to a minimum to avoid possible shredding of the fibers. The type of polypropylene fiber recommended by manufacturers for paving applications is the collated fibrillated fibre. The length of fiber recommended is normally tied to the nominal maximum size of aggregate in the mixture. Manufacturers recommend that the length of the fiber be greater than twice the diameter of the aggregate. This would be consistent with past experiences with fibrillated polypropylene fibers and also with current theories on fiber dispersion and bonding". Hence this study explores the feasibility of fibrillated polypropylene fiber reinforcement; aim is to do parametric study on compressive strength and tensile strength study etc. with given grade of concrete, proportions and percentage of fibers.

II. Literature Review

Review of work done by various researchers discusses the mechanism of fibre-matrix interaction, where various models are used to compute the bonding between the fibres and cement matrix. As the bonding of fiber and the matrix plays a major role in the composite behavior. Furthermore, this chapter also presents a review of literature relevant to the investigation and tests done for fibre reinforced concrete in general with a prominence of civil engineering application. Fiber reinforced concrete was successfully used in variety of engineering applications, because of its satisfactory and outstanding performance in the industry and construction field. However, most of the engineers and researchers have thought that how and why the fibers perform so successfully. So, to recognize the usage of fibers in concrete, in these last four decades, most of the research was done on mechanical behavior of fiber reinforced concrete and the fibers itself.

Balaguru (1988) the uniaxial compression test is normally used to evaluate the behavior of concrete in compression. This produces a combination of shear failure near the ends of the specimen with lateral swelling of the unconfined central section accompanied by cracking parallel to the loading axis when the lateral strain exceeds the matrix cracking strain in tension. Fibers can affect these facets of uniaxial compressive behavior that involve shear stress and tensile strain. This can be seen from the increased strain capacity and also from the increased toughness (area under the curve) in the post-crack portion of the stress-strain curve.

Khajuria and Balaguru, (1989) .in some instances, if more water is added to fiber concrete to improve its workability, a reduction in compressive strength can occur. This reduction should be attributed to additional water or due to an increase in entrapped air, not fiber addition.

Alhozaimy, A.M., Et Al (1995) carried out experimental investigations on the effects of adding low volume fractions (<0.3%) of calculated fibrillated polypropylene fibres in concrete on compressive flexural and impact strength with different binder compositions. They observed that polypropylene fibres have no significant effect on compressive (or) flexural strength, while flexural toughness and impact resistance showed increased values. They also observed that positive interactions were also detected between fibres and pozzolans.

Bentur, (2007). (Hasan Et Al., 2011 Roesler Et Al. (2006), the addition of polypropylene fibres does not have a significant effect on the direct tensile cracking strength (Bentur, 2007). However, in moderate volume replacements (0.33-0.5%) the addition of macro-synthetic polypropylene fibres showed a 10 to 15% increase in splitting tensile strength.

Priyanka study shows the effect of partial replacement of natural sand by manufactured sand on the compressive strength of cement mortar of proportion 1:2, 1:3 and 1:6 with water cement ratio as 0.5 and 0.55. The results are compared with reference mix of 0% replacement of natural sand by manufactured sand. The compressive strength of cement mortar with 50% replacement of natural sand by manufactured sand reveals higher strength as compared to reference mix. The overall strength of mortar linearly increases for 0%, 50% replacement of natural sand by manufactured sand as compared with reference mix. Manufactured sand has a potential to provide alternative to natural sand and helps in maintaining the environment as well as economical balance.

Singh S.P. (2010) has evaluated the strength and flexure toughness of Hybrid Fibre Reinforced Concrete (HyFRC) containing different combinations of steel and polypropylene fibres. The specimens incorporated steel and polypropylene fibres in the mix proportions of 100-0%, 7525%, 50-50%, 25-75% and 0-100% by volume at a total volume fraction of 1.0%. The results indicate that concrete containing a fibre combination of 75% steel fibres + 25% polypropylene fibres can be adjudged as the most appropriate combination to be employed in HyFRC for compressive strength, flexural strength and flexural toughness. A maximum increase in compressive strength of the order of 18% over plain concrete was observed in case of concrete containing 75% steel fibres + 25% polypropylene fibres. In case of static flexural strength tests, a maximum increase in flexural strength of the order of 80%, centre point deflection corresponding to peak load of the order of 84% was observed for HyFRC with 75% steel fibres + 25% polypropylene fibres. The results obtained in this investigation indicate that, in terms of flexural toughness, concrete with fibre combination of 75% steel fibres + 25% polypropylene fibres gives the best performance.

Ezeokonkwo, J. Cet. have examined the use of polypropylene fibres to improve the compressive strength of sandcrete blocks. This involved the reinforcement of sandcrete blocks with twisted polypropylene fibres of length 50mm, 75mm and 100mm respectively at 5 different volume fractions of 1 per cent, 2 per cent, 3 per cent, 4 per cent and 5 per cent, and 5 different water/cement ratios of 0.4, 0.5, 0.6, 0.7 and 0.8. Analyses of the results showed that, addition of fibre increased the compressive strength from 2.236 per cent to 35.783 per cent and it is dependent on the length, volume fraction of fibre and water/cement ratio.

Patel PritiAet. (2012) hasexplored properties such as compressive strength, flexural strength, split tensile strength and shear strength of polypropylene fibre reinforced concrete. Triangular shaped polypropylene fibre of 12 mm length and having density 1400 kg/m3, with fibre volume fractions 0%, 0.5%, 1%, 1.5% and 2 % were used in the experiments. The compressive strength of material increases from 8% to 16% for PFRC with increasing fibre content. The splitting tensile strength due to polypropylene fibre addition enhanced from 5% to 23%. The flexural strength increased with increasing fibre content. The maximum increase in flexural strength of PFRC was 36%.

Vairagade Vikrant S.(2012,) have studied the compressive strength, flexural strength and tensile strength of fibrillated polypropylene fiber reinforced concrete (PFRC) containing fibers of 0%, 0.25% and 0.4% volume fraction of fibrillated polypropylene fibers of 15mm, 20mm and 24mm length. It was observed that the compressive strength for M20 grade of concrete from three different cut length fibers at same volume fraction shows nearly same results with minor increase. By addition of 0.4%, 24 mm cut length fibrillated Polypropylene fibers showed maximum compressive strength. With same volume fraction, change in length of fiber result nearly minor effect on compressive strength of fiber reinforced concrete. For longer length fibers, the split tensile strength was higher. Used of 24 mm long fiber with same volume of fraction had given maximum split tensile strength over fiber 15 mm and 20 mm cut length.

RamujeeKolli.et. (2013) have made concrete samples with fine polypropylene monofilaments (Recron 3s) fibers of 12mm length, the amounts varies from 0%,0.5%,1%, 1.5% and 2.0%, to determine the compressive strength and splitting tensile strengths after 28 days of curing period. It was observed that the cube compressive strength increased up to 1.5% fiber content there after strength was decreased at 2.0% fiber content.

Scope of the Work:

The aim of this project is to determine the strength and durability characteristics of concrete by using polypropylene fiber.

Objectives:

It would be a milestone achievement for the local construction industries. Therefore, the main objective of this research is to determine and prove the feasibility of using polypropylene fibers.

- To determine the compressive strength, tensile strength and co-efficient of permeability for PRFC and that of normal concrete.
- To compare the value, Obtained by addition of fibers with different percentage.
- To check the obtained results by addition of fibers with 0.25%& 0.5% will satisfy the results of Balguru.

III. Experimental Programme

A. *Materials Required*

The constituent materials used in this investigation were procured from local sources. These materials are required by conducting various tests. Due to these results we were define what type of materials are used. The materials are listed below:

1) Cement
2) Fine Aggregate
3) Coarse Aggregate
4) Polypropylene fibres
5) Water

1. Cement:

In the most general sense of the word, cement is a binder, a substance which sets and hardens independently, and can bind other materials together. The word “cement” traces to the roman’s, who used the term “opuscaementicium” to describe masonry which resembled concrete and was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives which were added to the burnt lime to obtain a hydraulic binder. Cement used in construction are characterized as hydraulic or non-hydraulic. The most important use of cement is the production of mortar and concrete the bonding of natural use of aggregates to from a strong building material which is the face of normal environmental effects.

2. *Ordinary Portland Cement:*

Is the most common type of cement in general use around the world, because it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulphate which controls the set time, and up to 55 minor constituents (as allowed by various standards).

- The cement used for our experimental work is OPC 53-Grade. Conformed to the quality provisions of Indian standard specification.
- Tests conducted on cement are specific gravity, standard consistency, fineness of cement, initial setting time.
- The specific gravity of the cement was 3.10

3. *Fine Aggregate:*

Well graded river sand passing through 4.75 mm was used as fine aggregate. The sand was air-dried and sieved to remove any foreign particles prior to mixing. We are conducting tests on fine aggregate are Specific Gravity, Bulking, sieve analysis, water content of fine aggregate.

4. *Coarse Aggregate:*

Coarse aggregates of maximum size 20 mm was used as coarse aggregate. We are conducting tests on coarse aggregate are fineness, specific gravity, water absorption, impact test.

5. *Water:*

This is the least expensive but most important ingredient of concrete. Water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc. In general, water which is fit for drinking should be used for making concrete and shall conform to the requirements of IS: 456-1978.

Water-cement ratio was taken as 0.45.

IV. Properties of Polypropylene Fiber

Specific gravity of PP fibre is 0.90 – 0.91 gm cm-3. Because of its low specific gravity, PP yields the greatest volume of fibre for a given weight. This high yield means that PP fibre provides good bulk and cover, while being lighter in weight. Polypropylene is the lightest of all fibres and is also lighter than water. It is 34 % lighter than polyester and 20 % lighter than nylon.

Polypropylene fibre has the lowest thermal conductivity of any natural or synthetic fibre. Polypropylene fibres retain more heat for a longer period of time. And, it remains flexible at temperatures around -55 °C. The melting point of polypropylene is about 165 °C and while it does not have a true softening point temperature, the maximum processing temperature of the fibre is approximately 140 °C.

Prolonged exposure to elevated temperatures will cause degradation of the fibre, but anti-oxidants are incorporated in polypropylene fibres to protect them during processing and at normal service temperatures. Nevertheless, this temperature is sufficiently high for the fiber to be processed satisfactorily in almost all normal manufacturing processes (Brown et al., 2001).

Fig. 1. Polypropylene fiber

Polypropylene has the best resistance of any common fibre to the action of most types of chemicals and is, alkalis, and salts. Polypropylene fibre is not affected by bacteria or micro-organisms. It is also moth-proof and rot-proof and is inherently resistant to the growth of mildew and mold affected only by the most aggressive acids and oxidizing agents. The fibre is unaffected by most acids (Brown et al., 2001).

Applications:

- Most small builder, cash sales and DIY applications
- Internal floor-slabs (retail stores, warehouses, etc.)
- External slabs (driveways, yards, etc.)
- Agricultural applications
- Roads, pavements, driveways, kerbs
- Shotcrete; thin section walling
- Overlays, patch repair
- Water retaining structures, marine applications

V. Basic Tests Conducted on Materials

Tests on Cement:

- Specific gravity
- Fineness of cement
- Standard consistency
- Initial setting time

Tests on Coarse Aggregates:

- Fineness modulus of coarse aggregates
- Specific gravity and water absorption test
- Coarse aggregate impact test

Tests on Fine Aggregates:

- Sieve analysis of fine aggregates
- Specific gravity of fine aggregates
- Bulking of fine aggregates
- Water content of fine aggregates

TABLE I
Comparisons of Results Obtained with Standard Results from IS-Codes

Tests conducted on fine aggregates	**Obtained results**	**Std. Value (IS 383:1970)**
Specific gravity	2.55	2.68
Water content	1.8%	
Sieve analysis (Finess Modulus)	3.57	4.75
Bulking	4%	5%

Mix Design:

The mix design for M20 grade concrete was done as recommended in IS 10262-2009 and according to IS 10262-2009 the following data was required for concrete mix design.

a) Grade designation: M20

b) Type of cement: OPC 53 grade confirming to IS 8112

TABLE II
Mix Design

Material	**Quantity**
Cement	394 kg/ m3
Sand	670 kg/ m3
Coarse aggregate	1110 kg/ m3
water	197litrs
Polypropylene fiber	0.25% ,0.5% by weight of cement
Slump	75- 100 mm

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Cement: Water: Fine Aggregate: Coarse Aggregate

394	: 197	: 670	: 1110
1	: 0.5	: 1.7	: 2.82

Compressive Strength Determination:

General:

Test is carried out as per Indian Standard code IS 516: 1959 on plain concrete and concrete with polypropylene fiber and results are tabulated and conclusions are drawn.

TABLE III
COMPRESSIVE STRENGTH DESIGN

Tests	Obtained results	Std. Value
Coarse Aggregates		
Specific Gravity	2.65	2.80
Water Absorption	0.15%	0.68%
Sieve Analysis(F.M)	6.08	10%
Impact Value	27.94%	Less than 30%
Cement		
Finess of Cement	4.5 %	10%
Specific Gravity	3.10	3.16
Std. Consistency	33%	34%

A. *Curing of Specimens*

The test specimens are stored in place free from vibration, in moist air of at least 90% relative humidity and at a temperature of 27o+ 2o C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds and immediately submerged in clean fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged, are renewed every seven days and maintained at a temperature of 27o+ 2o C. The specimens are not allowed to become dry at any time until they have been tested.

B. *Method of Testing in CTM*

Specimens are tested at the ages of 7, 14, 28 days. The specimens to be tested are taken out from water and wiped to remove excess water and grit present on the surface. 3 specimens are tested for each type of mix at specific age. Dimensions of the specimens are measured with an accuracy of 0.1mm and tabulated. Cubes are placed on the compression testing machine of 100 tons capacity such that the marked face faces the observer and load is applied on the specimen and increased at the rate of 140kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. Maximum load applied to the specimen was recorded and compressive strength of the concrete is found out using the relation,

$$Compressive\ Strength = \frac{P}{B \times D}\ (\text{N/ mm}^2) \quad (1)$$

P=load in N.
B=breadth of cube in mm.
D=depth of cube in mm.

Fig. 2. Testing in CTM

TABLE IV
COMPARISON OF RESULTS OBTAINED

Days	Normal concrete (N/mm^2)	0.25% Polypropelene (N/mm^2)	0.50% Polypropelene (N/mm^2)
7th	23.86	24.20	24.910
14th	24.05	26.04	26.93
28th	25.4	27.51	28.35

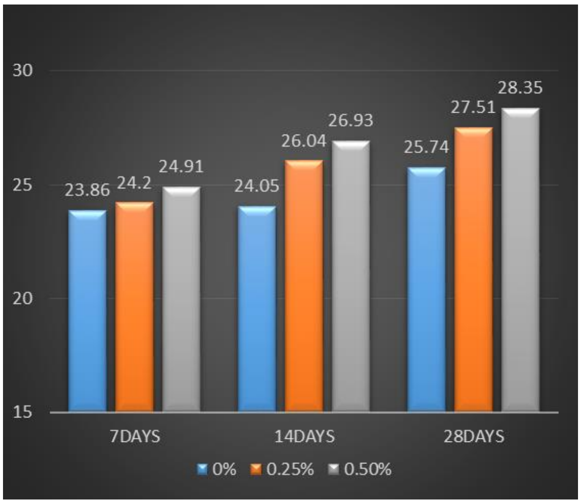

Fig. 3. Comparison of results obtained

VI. TENSILE STRENGTH DESIGN

A. *Method of Testing in CTM*

Specimens are tested at the ages of 7, 14, 28days. The specimens to be tested are taken out from water and wiped to remove excess water and grit present on the surface. 3 specimens are tested for each type of mix at specific age. Dimensions of the specimens are measured with an accuracy of 0.1mm and tabulated. Cylinders are placed on the compression testing machine of 100 tons capacity such that the marked face faces the observer and load is applied on the specimen and increased at the rate of 140kg/sq cm/min until the resistance of the specimen to the increasing load breaks

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down and no greater load can be sustained. Maximum load applied to the specimen was recorded and Tensile strength of the concrete is found out using the relation,

$$Tensile\,Strength = \frac{2P}{3.14 \times D \times L}\ (\text{N/mm}^2) \qquad (2)$$

P=load in N.
L=length of cylinder in mm.
D=Diameter of cylinder in mm.

Fig. 4. Tensile strength determination

TABLE V
COMPARISON OF RESULTS OBTAINED

Days	Normal concrete (N/mm^2)	0.25% Polypropelene (N/mm^2)	0.50% Polypropelene (N/mm^2)
7th	1.27	1.48	1.76
14th	2.10	2.20	2.37
28th	2.48	2.70	2.96

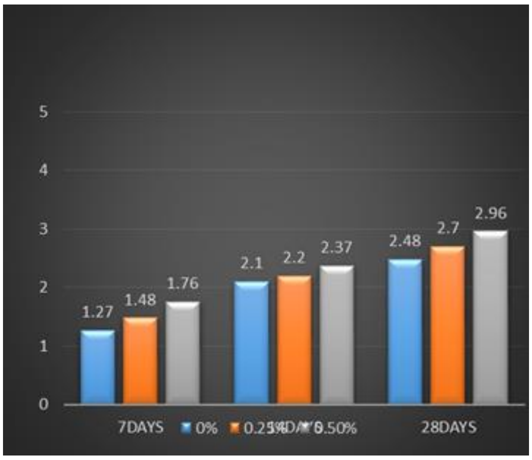

Fig. 5. Comparison of results obtained

VII. PERMEABILITY DESIGN

A. *Method of Testing in Permeability Testing Machine:*

Specimens are tested at the ages of 28days. The specimens to be tested are taken out from water and wiped to remove excess water and grit present on the surface. One specimens are tested for each type of mix at specific age. Dimensions of the specimens are measured with an accuracy of 0.1mm and tabulated. Cubes are placed on the permeability testing machine andload is applied at a rate of 150kg/cm^2.Note down the initial head in the permeameter and then allow the specimen for 24 hour in testing machine and note down the final head.

Fig. 6. Experimental setup

TABLE VI
COMPARISON OF RESULTS OBTAINED

Specimen (Cubes)	Wt. of block before test (Kg)	Wt. of block after test (Kg)	Initial Head (Cm)	Final Head (Cm)	Co-Efficient of Permeability
Normal	7.90	7.93	28.6	27.9	$1.58\text{x}10^{-6}$
0.25%	7.44	7.49	28.3	27.7	$1.25\text{x}10^{-6}$
0.50%	7.86	7.89	30.6	30.1	$1.13\text{x}10^{-6}$

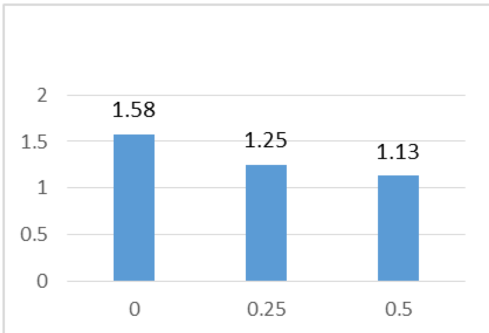

Fig. 7. Experimental setup

VIII. CONCLUSION

The study of the effects of fibrillated polypropylene fibres with different percentage can still be a promising work as there is always need to overcome the problem of concrete.

The following conclusion could be drawn from the present investigation:

- It is been observed that , the compressive strenth for M20 Grade concrete from three different percentage at same volume fraction shows nearly same results with minor increases
- By addition of 0.5%, shows maximum strength

- It was observed that , the spilt tensile strength increase by increase in percentage of polypropylene
- It was observed that the co- efficient of permeability decreases with increase in percentage of fibers.

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