Study on POP Waste & Fibrofor Fiber in Conventional Concrete

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Abstract - *This work will be centred on testing the Mechanical properties of concrete with variable proportions of Fibrofor fibre and also substituting some cement content with Plaster Of Paris waste up to 15 percentage as per the study accompanied by V.N.Kanthe, India, which will help in maintaining the mechanical properties of concrete without disturbing the strength of concrete and also help in waste management of Plaster Of Paris waste which are being discarded in ponds during Ganesh festival in form of statues which in turn helps in protective ponds and Surroundings.*

Tests are done for Tensile, Compression, Flexure and Workability properties of concrete and finding out the optimal percentage of Fibrofor fibres for 15 percentage of Plaster of Paris waste which will help in improving the bonding properties of concrete, thereby improving the overall strength and load carrying capacity of concrete in Compression, Tension and flexural tests of concrete. Different parameters of concrete has been tested and are tabulated in this report and are compared to the standards results as per Indian Standards.

Based on the tests conducted it is found that with Cement replaced up to 15 percentage by POP waste, the percentage of Fibrofor fibres with 0.5 percentage yields good results in all the mechanical properties of concrete tested as per the codal requirements.

***Key Words*: Fibrofor fibres, Plaster of Paris waste, Mechanical properties, Tests, Optimal Percentage.**

1. INTRODUCTION

Ever since the introduction of cement in 1824 by Joseph Aspadin, there has been a continual development in the field of concrete technology by improving and perfecting the various parameters of concrete day by day.

Concrete with higher strength and workability has been used on construction of buildings such as Tall Structures, Dams, Bridges etc. but the Mass houses/Apartments in slum development boards cannot use High Strength concrete which will not be feasible in economic viewpoint, Hence alternate methods to achieve such Similar property concrete has to be made by widespread research.

We all know that Concrete is feeble in tension but it is good in Compression so to increase the strength of concrete in tension investigators found that use of fibres in concrete supports in increasing the tensile strength carrying capability of concrete efficiently, so the use of fibres has been combined in this thesis work to attain satisfactory strength in both Compression and Tensile properties of Concrete.

Professors, Specialists and Researchers has used different fibres in the concrete in both their natural and artificial form, which helps in reducing the major weakness of concrete i.e., tensile strength of concrete. Some researchers has proved that use of fibres in concrete has improved the tensile properties of concrete and also the Crack resistance by their extensive research.

Fibrofor Fibre is a revolutionary product introduced by Brugg Contec, Swiss Company which has a positive engineering history of over 30 years. They have also developed numerous fibres over the years most prominent types are Fibrofor fibres and Concrix fibres. The industrial process of manufacturing fibres takes place in very sophisticated and advanced plant which is approved by European Standards for building materials.

Fibrofor fiber is a microfibers or High performance fiber which is bundled, fibrillated construction with 3D fibernet aids in guaranteeing fast and constant spreading & linking of concrete and fiber through the concrete mass.

2. LITERATURE REVIEWS

1) V N Kanthe (Professor, India, March 2013) :

Tests were done with POP waste collected from rivers and lakes and then use if in form of replacement of cement by varying their percentage.

Compression tests were done for a total of 30 cubes of different ratios with standard mixing and casting procedure as specified by IS code books and curing were done for rapid setting time as per specifications provided in IS 9013(1978) which recommended curing of cubes in boiled water at a temperature of 100 degrees for 3.5 hours which is then removed and air cooled for 2 hours, then it is finally taken for compression test. The results were tabulated for 28 days as per the formula provided in IS 9013(1978).

After the tests it was concluded that Compressive strength of concrete is maximum in the range of 5% to 15% of POP waste can be utilized in concrete.

2) Karishma Syed et.al (Professor, India, Dec 2016):

In this report, textile fiber made of cotton yarn were collected from mills as this fibers were available in abundance in India, Advantage and Disadvantages of using both POP and Textile waste in concrete were discussed.

Testing's were done for density, water content, Compressive strength and net area of concrete voids etc.

Textile fiber was used from ratio varying from 0% - 2% by cement quantity with POP waste replaced up to 10-20% provided good results.

3. SCOPE AND OBJECTIVE OF WORK

3.1 Scope of work

During Ganesh Festivals, As per the Annual Municipal solid waste report of Karnataka state pollution control board in the year 2013-2014, Around 1.68 -1.80 lakh of idols are submerged in lakes, pond and nearby water sources in Karnataka in festival season around 2 months.

We all know that POP idols when immersed in water, it will not be dissolved in water the idols remain in one piece even after several months when compared to clay idols which is capable of dissolving in 30-45 minutes

POP in water experiences exothermic response in water i.e. it discharges heat when it interacts with water, which makes it sink and harden in the bed level of aquatic bodies, once it hardens further most important problems like reduction in dissolved oxygen content of water which in turn terminates the nearby aquatic life such as fishes, frogs, and other reptiles etc.

It is also to be noted that POP waste are also entering the municipal solid waste in the form of waste False ceilings, Plaster Cornices, Plaster boards, Plaster mouldings etc. Since POP is Non-Biodegradable, there is a need to reduce the amount of POP waste hence the current method used by BBMP is to use the POP waste in form of Landfills.

Lastly we the Public and the Government overlook the damaging effects of POP waste in water contamination and its risky result on us. So to evade the contamination by excess of POP, we have to turn away surplus POP waste into valuable and usable.

3.2 Objective of work

- To use the POP discarded in lakes, rivers and Sea into useful material.
- To minimize, the water contamination by removing and using POP waste from water sources.
- To improve the strength of concrete with 15% replacement of cement by POP waste by adding fibres (Fibrofor fiber).
- To make concrete Cost effective for use in large scale production.
- To find the optimum percentage of fibrofor which will provide adequate strength and also concrete should be workable.
- To improve the resistance of concrete to form micro cracks by addition of Fibrofor fiber.
- To improve the tensile strength carrying capacity of concrete by introducing fibers.

4. METHODOLOGY

By referring the research paper published by V N Kanthe in the year 2013, it showed that there is an increase in POP idols being discarded into lakes and rivers which caused environmental imbalance. Hence the use of POP waste as a useful replacement of cement in Concrete works. The above said works consist of only Compression strength characteristics of various percentages of POP waste in concrete. As per the works done previously by V N Kanthe, it is stated that up to 15% of Cement can be replaced by POP waste, so by confirming the results achieved in our lab it was similar to the results obtained by him. Hence I've used 15% of POP waste as constant I my all trials and Varying the % of Fibrofor Fibres by 0%, 0.5%, 1%, 1.5%, 2%, 2.5% & 3% to find the Optimal % of Fibrofor fiber for 15% replacement of waste POP in cement.

As per the works done by A. Senthilkumar in year 2014, when Textiles fiber were used it helped in reduction of formation of micro-cracks of concrete as the ratio of fiber increased , hence Fibrofor fiber has been used for different proportions.

Hence in this project, comprehensive works were done to analyse the feasibility of concrete with POP waste and Fibrofor fibres in all the mechanical properties of concrete such as Compressive Strength test, Split Tensile test, Flexural Strength test, so that it can implemented in a greater scale for use in building's and different concrete constructions.

4.1 Material used and their Properties:

4.1.1 Fine Aggregate

River sand was used for the experiments which is confirming to Zone 2 as per IS :383-1970.

Table -1: Properties of Fine aggregate used for tests

No	Experiment	Observed results	Acceptable limits
1	Specific gravity of fine aggregate	2.55	2.50-3.0
2	Specific gravity of Coarse aggregate	2.61	2.50-3.0
3	Sieve Analysis of fine aggregate	Zone 2 (Well Graded)	IS :383-1970

4.1.2 Coarse aggregate

Aggregate used for the experiments should be compact, tough & clean without any debris or unwanted harmful materials in them. The shape of the aggregates should be cubical which will provide more surface area which will help in providing good bond and aggregate should also conform to IS: 2838 (part 1).

Table -2: Properties of Coarse aggregate used for tests

No	Experiment	Observed results
1	Specific gravity of Coarse aggregate	6.22

4.1.3 Cement

Birla Super 53 Grade Ordinary Portland cement based on IS: 12269 is use for the experiments, following tests are done to verify property of cement.

Table -3: Properties of cement used for tests

No	Experiment	Observed results	IS CODE
1	Fineness test	% of residue in BIS 9 is 4.30 %	IS :4031 (Part 3)
2	Consistency test	P=29.5% with 118 ml of water	IS :4031 (Part 4) 1988
3	Initial setting time	12 minute 50Seconds at 0.85P=25.075%	IS :4031 (Part 5)1988
4	Compression test	53 N/mm^2	IS :4031 (Part 6) 1988
5	Specific gravity of cement	3.15	IS :2720 (Part 3)

4.1.4 Plaster of Paris

Since POP waste collected from lakes was used in this project work some precautionary measures has to be taken, they are as follows:

- All visible inert materials like lake weeds should be removed POP waste.
- Since POP waste are from idols, some fibres like coconut, jute will be present in them, it should also be carefully removed as it will decay over time when in concrete.
- POP waste collected should be air dried for 24 hours.
- POP waste lumps will be crushed to obtain a Particle size less than 90 micron which will held in easy blending of particles with Cement.

Table -4: Properties of Waste POP used for tests

No	Experiment	Observed results	Acceptable limits
1	Specific gravity of Waste POP	1.08	1-1.8 (IS :2542-1978)
2	Initial setting time test of POP	11 minutes	<15 minutes (IS :2542-part 1)
3	Initial setting time test of 15 % POP with Cement	15minutes 30 second	NA

4.1.5 Steel

Steel used is conforming to IS code 1786-(2008) with a grade of Fe 500, bars used for experiments were 12mm and 8mm in diameter.

4.1.6 Mix Design as per IS 10262-2009

Grade Designation = M20
Form of Aggregates = Angular
Slump =50mm, Exposure condition = Mild
Concrete Placement = By Hand
Grade of supervision = Good
Fine aggregate: Specific gravity=2.55 , Zone= 2
Coarse aggregate: Specific Gravity=2.61
Plaster of Paris: Specific gravity= 1.08

Target mean Strength:

$f'_{ck} = f_{ck} + 1.65\ s = 20+(1.65*4) = 26.60$ Mpa.

Selection of water cement Ratio:

Max. Water cement ratio=0.55
Take on water cement ratio as 0.50

Water content Calculation:

Water content essential for 50mm Slump: 186 litre

Calculation of Cement content and POP:

Water/Cement Ratio: 0.50
Cement Content with POP = 186/0.5 = 372 kg/m^3 > least Cement content=300 kg/m^3 .Therefore OK.

Cementatious Material =372 x 1.15= 427.8 kg/m^3

Water Content = 186 litre
POP at 15% of Total Cementatious Material = 427.8 x 15% = 64.17 kg/m^3
Cement = 427.8-64.17 = 363.63 kg/m^3
Cement Saved by using POP = 64.17 kg/m^3

Volume of Coarse Aggregate & Fine Aggregate Proportion:

From Table 3 of IS 10262 : 2009, Volume of coarse aggregate corresponding to 20 mm D/S Coarse aggregate & Fine aggregate, *For Zone 2 with W/C ratio of 0.5 is 0.62.*
Volume of Coarse aggregate = 0.62.
Volume of fine aggregate =1-0.62 = 0.38.

Mix calculations:

1) Concrete Volume = 1m^3.
2) Cement Volume $= \frac{Cement\ Mass}{Specific\ Gravity\ of\ Cement} * \frac{1}{1000}$
$= \frac{363.63}{3.15} * \frac{1}{1000}$
= 0.115 m^3.
3) Volume of POP $= \frac{POP\ Mass}{Specific\ Gravity\ of\ POP} * \frac{1}{1000}$
$= \frac{64.17}{1.08} * \frac{1}{1000}$
=0.059 m^3.
4) Water Volume $= \frac{Water\ Mass}{Specific\ Gravity\ of\ Water} * \frac{1}{1000}$
$= \frac{186}{1} * \frac{1}{1000}$
= 0.186 m^3.
5) All in Aggregates Volume = { (1) - (2 + 3 + 4) }
= 1 - (0.115+0.059+0.186)
= 0.64 m^3.
6) Mass of Coarse Aggregate = (5) x Coarse aggregate Volume x Coarse Aggregate Specific Gravity x 1000
= 0.64 x 0.62 x 2.61 x 1000
= 1110 kg.
7) Mass of Fine Aggregate = (5) x Fine aggregate Volume x Fine Aggregate Specific Gravity x 1000
= 0.64 x 0.38 x 2.55 x 1000= 579 kg.

PROPORTIONS OF MIX:

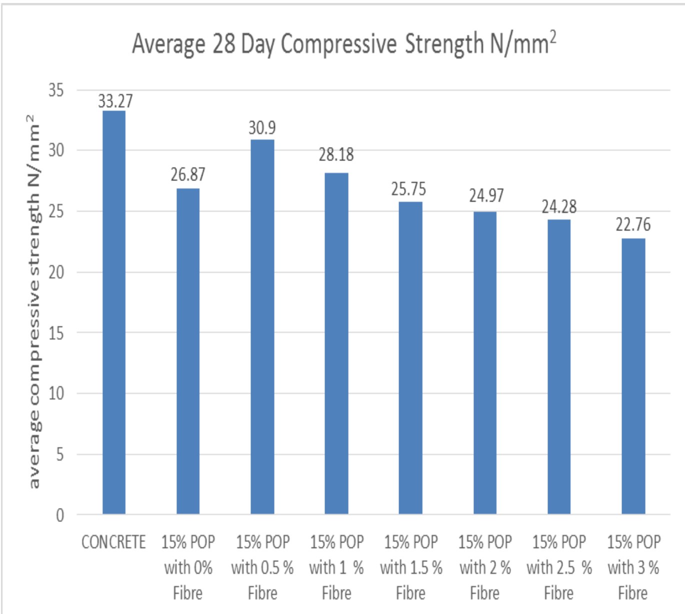
- **Cement** = 363.63 kg / m^3
- **POP** = 64.17 kg / m^3
- **Water** = 186 kg / m^3
- **Fine Aggregate** = 579 kg / m^3
- **Coarse Aggregate** = 1110 kg / m^3
- **Water to Cement Ratio** = 0.50.

Design Mix Ratio = 1 : 1.51 : 2.88

5. TEST RESULTS AND DISCUSSIONS

5.1 Compression Strength Test of Cubes (As per IS 516-1959)

Fig -1: Compression strength test of cubes



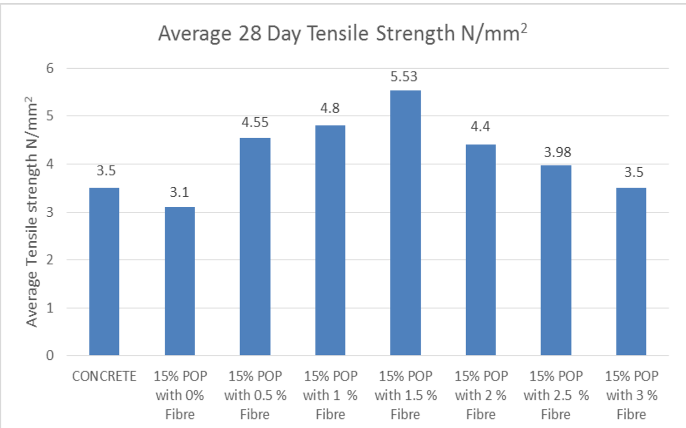
Graph -1: Compressive strength of concrete for 28 days

5.1.1 DISCUSSIONS:

1. The maximum compressive strength of concrete with 15% POP waste and 0% fiber is lesser than conventional concrete mix.
2. The Maximum compressive strength was achieved for Mix with 15% POP waste and 0.5% Fibrofor fiber.
3. It can be observed from Graph -1, as the fiber content increases the strength of concrete also increases for both 0.5% and 1% Fibrofor fiber, then further increase in fiber contents reduced the workability and strength characteristics of concrete.
4. The percentage of strength decrease in concrete with 15% POP waste and 0.5% fiber when compared to conventional concrete is 7.12% but the minimum target strength for 28 days is achieved satisfactorily.

5.2 Split Tensile Strength Test of Cylinders (As per IS 516-1959)

Fig -2: Split Tensile test of cylinders



Graph -2: Tensile strength of concrete cylinders at 28 days

5.2.1 DISCUSSIONS:

The Maximum Tensile strength of concrete with 15% POP waste and 0% fiber is lesser than conventional concrete mix.
The Maximum Tensile strength was achieved for Mix with 15% POP waste and 1.5% Fibrofor fiber.

It can be observed from Graph -2, as the fiber content increases the Tensile strength of concrete also increases for relatively with increase in Fibrofor fiber content upto 1.5%, then further increase in fiber contents reduced the workability and strength characteristics of concrete.

As seen from the experiment, the use of Fibrofor fiber will help in increasing the Tensile strength carrying capacity of concrete.

The percentage of strength increase in concrete with 15% POP waste and 0.5% fiber when compared to conventional concrete is 36.70%.

5.3 Flexure Test of Beams (As per IS 516-1959)

5.3.1 Beam Design:

$$\frac{Xu}{d} = 0.46$$

$$\frac{Xu}{d} = \frac{0.87 \times fy \times Ast}{0.36 \times fck \times b \times d}$$

$$0.46 = \frac{0.87 \times 500 \times Ast}{0.36 \times 20 \times 150 \times 175}$$

Ast =299.86mm²

$$M= 0.87 \times fy \times Ast \times d \times \left(1 - \frac{Ast \times fy}{fck \times b \times d}\right)$$

$$0.87 \times 500 \times 299.86 \times 175 \times \left(\frac{199.6 \times 500}{20 \times 150 \times 175}\right)$$

M= 13.50 kN-m.

Mu=*13.50 * 1.50 =* ***20.25 kN-m*** < $\frac{1.5 \times w \times l}{3}$ ***Hence OK.***

Maximum Bending Moment for 3 point loading,

$$M= \frac{1.5 \times w \times l}{3}$$

For Under Reinforced Section:

Ast =*299.86 mm²*.

No of Bars = 2-12 mm **Dia** ***= 226.19mm² < Ast Hence OK.***

Shear Reinforcement:

$$\frac{100 \times Ast}{b \times d} = \frac{100 \times 226.19}{150 \times 175} = 0.86$$

Table -5 Interpolation table for τ_c value

$\frac{100 \times Ast}{b \times d}$	τ_c N/mm²
0.75	0.56
0.86	0.5816
1.00	0.62

$$V_{us}=V_u - (\tau_c * b * d)$$

$$= (1.5*25*1000) - (0.5816*150*200)$$

$$V_{us}=14.23 \text{ kN}$$

Taking 2 Legged 8mm Dia bars as Shear reinforcement

$$\frac{0.87 \times fy \times Asv \times d}{Vus} = \frac{0.87 \times 500 \times \frac{2 \times \pi \times 8^2}{4} \times 175}{14.23 \times 10^3} =$$

Spacing, Sv = $537.8\ mm$

Sv>300mm

Sv>0.75d=0.75*175=132mm

Provide 2 Legged 8mm Dia @ 150mm C/C

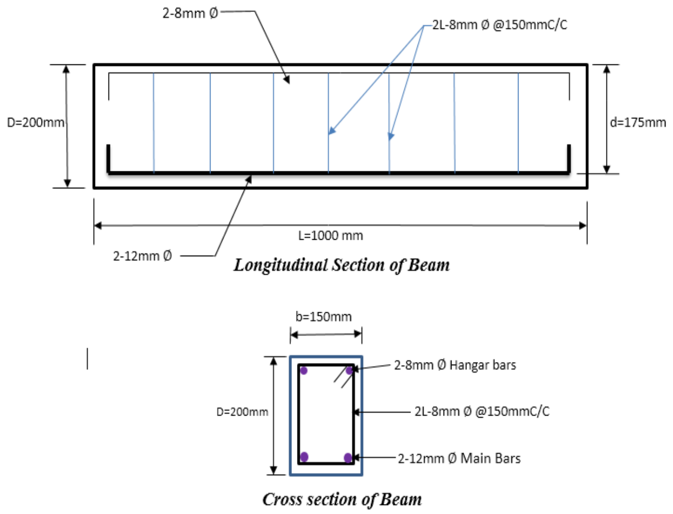
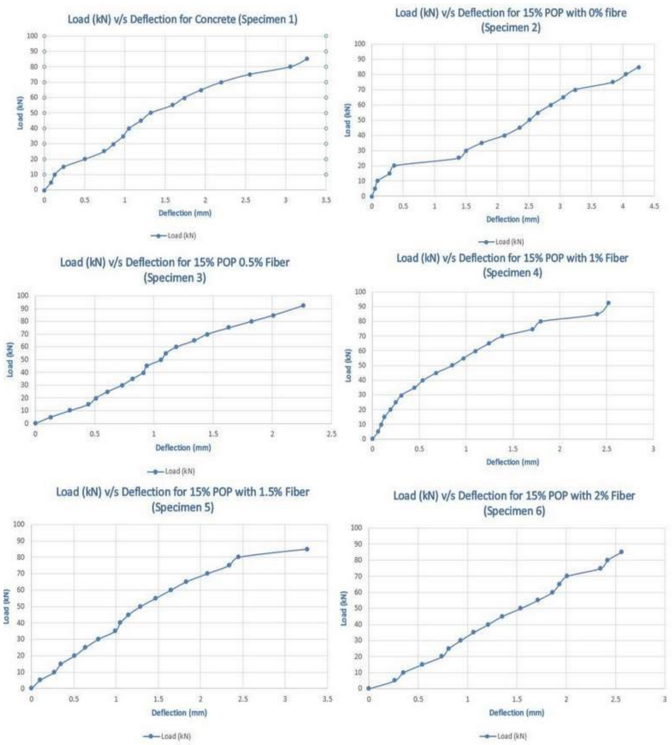


Fig -3: Longitudinal and Cross section of Beam

Fig -4: Reinforcement Bars for beam

Fig -5: Flexure test of beams



Graph -3: Load v/s Deflection of Beams at 28 days

5.3.2 Calculations and Graphs

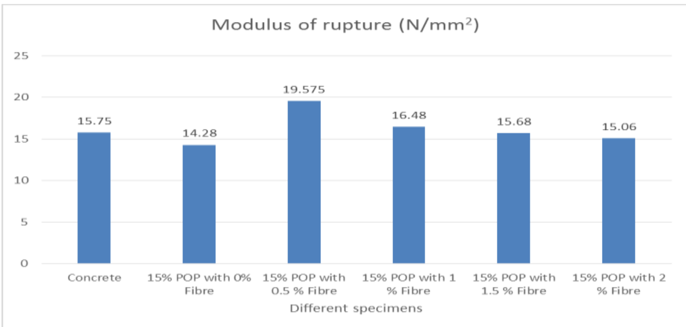
1) Moment of inertia = I = $\frac{B \times D^3}{12}$

$= \frac{150 \times 200^3}{12} = 100 \times 10^6$ mm^4.

2) Calculation table for Modulus of Rupture of Beam:

Table -6 Calculation table for Modulus of Rupture of beams

Sample No	Maximun Bending Moment = WL/6	Modulus of Rupture = M*y/I
1	15.75 kN-m	15.75 kN-m
2	14.28 kN-m	14.28 kN-m
3	19.575 kN-m	19.575 kN-m
4	16.18 kN-m	16.18 kN-m
5	15.68 kN-m	15.68 kN-m
6	15.06 kN-m	15.06 kN-m



Graph -4: Modulus of Rupture of Beams at 28 days

5.3.3 DISCUSSIONS:

The maximum Flexural strength of concrete beam with 15% POP waste and 0% fiber is lesser than conventional concrete mix.

The Maximum Flexural strength of concrete beam was achieved for Mix with 15% POP waste and 0.5% Fibrofor fiber.

It can be observed from **Graph-3**, as the fiber content increases the flexural strength of concrete also increases for 0.5% and 1%, then further increase in fiber contents reduced the workability and strength characteristics of concrete progressively.

The specimen with only 15% replacement of POP waste ruptured under lesser loads when compared to other mixes. The percentage of strength increase in concrete with 15% POP waste and **0.5%** fiber when compared to conventional concrete is **19.54%.**

6. CONCLUSIONS

The Fine Aggregate tested comes under **Zone 2** classification and it is well graded as per IS: 383-1970, and Coarse Aggregate is up to the standards given in table 3 of IS: 383(1970).

The POP waste collected was and crushed to a size of < 90 micron and tested for Specific gravity, Initial setting time for Cement with 15% POP waste and also for POP waste individually and they are within the standards range specified in the IS: 2547(Part 1), and fit for use in concrete. During the Compressive strength test **(Graph-1)** it was observed that as the quantity of Fibrofor fiber increased, concrete mix was getting stiffer while mixing thereby reducing the workability of concrete mix and also it showed reduction in compressive strength of concrete as fiber increased, hence the concrete mix with **2.5 percentage and 3 percentage** of fibres was found to be undesirable and uneconomical for construction process.

There is a decrease in Compressive strength carrying capacity of concrete with 15% POP waste and 0.5% Fibrofor fiber when compared to conventional concrete of **7.12% (Graph-1)** but the mean target strength for 28 days is achieved satisfactorily.

From the Split tensile test result, it can be observed that the conventional concrete had more tensile strength than cylinder with 15% POP replaced specimen, and also when fiber has been introduced to the mix the tensile strength of the specimens increased progressively. The maximum tensile strength of concrete was achieved for sample with 15% POP waste and 1.5% Fibrofor fiber **(Graph-2)**.

There is an increase in Tensile strength carrying capacity of concrete with 15% POP waste and 0.5% Fibrofor fiber when compared to conventional concrete of **36.70% (Graph-2).**

Since the Aspect ratio of Fibrofor fiber is greater than other fibres such as steel and organic fibres it can be seen that Fibrofor fiber is increasing the bonding properties of concrete and also help in reduction of micro cracks in concrete formed during flexural tests, which helps in increasing the strength characteristics of concrete when compared to conventional concrete mix.

In Flexure tests of beams **(Graph–3)**, it can be observed that the load carrying capacity and maximum crack length was observed for (Specimen 2) concrete with 15% POP waste without fiber, (Specimen 2 with 15% POP waste) deformed at lesser loads than (Specimen 1 conventional concrete). It can also be observed that as the Fibrofor fiber content increased in the mix (Specimen 3, 4, 5 and 6) both load carrying capacity and resistance to cracks also increased respectively.

There is an increase in Flexural strength carrying capacity of concrete with 15% POP waste and 0.5% Fibrofor fiber when compared to conventional concrete of **19.54% (Graph-4).**

By testing the Concrete cubes, Cylinders and Reinforced beams with various proportions and mix ratios for Compressive, Tensile and Flexural strength test respectively; It was found that Concrete mix with ***15 percentage of waste POP and 0.5 Percentage of Fibrofor fibres*** achieved the maximum strength when compared to other mixes and it also achieved the target mean strength for **M20 grade concrete for 28 days.** Hence this mix can be recommended for use in Construction purposes as it is providing acceptable strength and Economy in construction as per the rate analysis.

So it is concluded that Fibrofor fiber can be used effectively with POP waste which helps in increasing strength of concrete by providing good bond between the Fibrofor fiber and Concrete mass as a whole and the use of POP waste can reduce the pollution created by immersing the idols in local rivers and lakes. Thus helping in providing healthy environment for humans and other living organism's specifically aquatic life, thereby helping in waste management of POP waste and protecting the Environment.

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