

Permeability Characteristics of Waste Plastic Fibre Reinforced Concrete

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Abstract - In this study, plastic obtained from waste plastic flush doors are cut into fibres of 5mm width and used in M30 grade concrete in five aspect ratios namely 30,50,70,90 and 110 in volume fractions of 0.25%, 0.5%, 0.75 %, 1.0%, 1.25% and 1.5% of concrete. Specimens are cured in water for 28 days and later the standard methods are adopted for testing the permeability, Sorptivity and rapid chloride penetration values. Results are compared with reference specimens cast without fibre. The results showed that waste plastic fibres up to 0.5% by volume of concrete can be used in concrete for making it impermeable. Among all the aspect ratios adopted, aspect ratio 50 proved to be optimum.

Key Words –Aspect Ratio, Fibre Reinforced Concrete, Permeability, , Rapid Chloride Penetration test(RCPT), Sorptivity, Rapid Chloride Penetration test(RCPT), Waste Plastic Fibre

I. INTRODUCTION

Permeability is the property of the material which allows the fluids to pass through it. It may be due to pressure head or capillary action. The factors that affect the permeability are the viscosity of the fluid, pore structure of the concrete, age of concrete, type and duration of curing, admixtures used, use of fibres etc. some of the standard methods of testing the permeability are

- Sorptivity test for water absorption by capillary action as per ASTM C 1585 – 2004
- Water permeability to check the water flow under standard pressure head as per code DIN: 1048 Part (V) – 1987
- Rapid Chloride Penetration test (RCPT) to check the chloride ion flow as per ASTM C 1202- 2003

Sorptivity is the measure of absorption of water through capillary action. It is a good measure to evaluate the pore structure and their interconnectivity. It is an easy method of measuring the absorption where increased weight of the specimen indicates the porous structure. Water permeability is a measure of fluid ingress under a pressure head maintained over duration. Depth of water penetration is an easy method of determining the water permeability. RCPT is a measure of amount of charges passed (Coulombs) through a cylindrical specimen of standard size for a duration of 6 hours. Based on the coulombs passed, concrete is graded from excellent to poor

II. LITERATURE REVIEW

Durability of concrete is mainly governed by permeability of concrete. A dense impermeable concrete does not allow the ingress of fluid and will last long. Several researchers have studied the permeability characteristics of concrete with various parameters. Steel fibres of 3 aspect ratios and 3 weight fractions were used by A. P. Singh and Dharendra Singh [1] to check the water permeability after 7, 14, 28 and 60 days. The coefficient of permeability was determined for 1, 2 and 4 % of fibres at aspect ratios of 65, 85 and 105 using Darcy's law. It was observed that permeability decreases with increase in percentage of fibres at all aspect ratios. Similar study was conducted by Prahallada. M.C. et al [2] using waste plastic fibres indicated that the coefficient of permeability was least at 0.5% of waste plastic fibres. Rapid Chloride permeability test is based on ASTM C 1202-97 and American Association of State Highways and Transportation Officials, AASHTO-277-83. The RCP testing method was given in detail by Bruce Supernant [9] in his article. Kribanadan Guruswamy Naidu [3] reviewed the applicability of RCPT for durability compliances. His review concluded that RCPT should merely be used to check the homogeneity of concrete from penetration point of view. But since RCPT is a widely accepted method, several researchers have adopted this method. Chandramouli K et al [4] used CemFil anti crack glass fibres of 35mm length in different percentages by weight of cement. RCP values were checked at 90, 180, 365 and 720 days. The results showed that the RCP values reduced with addition of CemFil fibres. This was attributed to the discontinuity of pores created by fibres.

Polypropylene fibres in the concrete also found to reduce the permeability in the study conducted by M Tamilselvi et al [5]. H SudarsanaRao et al [6] used combination of rubber latex, metakaoline along with steel fibres in various percentages and various water cement ratios to check the RCP values. The results showed a decrease in permeability values with 0.5% rubber latex and 1% steel fibres. Polypropylene fibres and steel fibres also found to reduce permeability when incorporated in concrete in a study conducted by Abhishek Kumar Singh et al [7]. Sorptivity studies were conducted by M K Maroliya[8] proved that reactive powder concrete is dense and reduce sorptivity.

III. EXPERIMENTAL WORK

3.1 Materials Used

A. Cement

Ordinary Portland cement of 53 grade of specific gravity 3.15 was used. Various tests conducted as per IS 4031 -1988 were specific gravity, normal consistency, setting time, fineness and soundness. The results were found to be within the allowable limits.

B. Fine Aggregate

Natural river sand is procured from nearby district Mandya for the present investigation. The sand is tested as per IS 383-1970. River sand used for the present work conformed to zone II, had a specific gravity of 2.54, water absorption of 0.6% and fineness modulus of 2.90.

C. Coarse Aggregate

Coarse aggregate obtained from local quarries, below 12mm size was used. It had a specific gravity of 2.53 and water absorption of 0.15%.

D. Waste Plastic Fibres

Waste flush door plastic was used in the current investigation. Fibres have a thickness of 0.7 mm and width of 5mm. The density of plastic was 1.152g/cm³. Length of the fibre was cut as per aspect ratios.

E. Chemical Admixture

Master Glenium SKY8233 was used to reduce the water content by 20%. Its specific gravity was 1.08, pH value > 6 and the optimum dosage was found to be 0.7% by weight of cement by trials.

F. Water

Ordinary tap water, free from organic matter and salts at room temperature is used in the present work.

3.2. Mix Design

Mix design is carried out for M30 grade of concrete as per IS 10262: 2009 for the test results obtained for moderate exposure condition for a slump of 100mm.

TABLE I MIX PROPORTION

Material	Mass
Cement	392Kg
Fine Aggregate(Zone-II)	934Kg
Coarse Aggregate(10mm down size)	827Kg
Water	177 lit
Super plasticizer	2.75Kg

C: FA: CA: W=1:2.39:2.11:0.45

3.3 Experimental Investigation

A. Water Permeability

The cube specimens of dimensions 150x150x150mm are subjected to constant hydraulic pressure head of 5kg/cm² on an area of 10 cm diameter for 72 hours (3 Days). Sides are sealed with leak proof material so that the water enters through testing surface area only. After 3 days, the specimens are taken out from the testing apparatus and split open under concrete testing machine. The distribution of water is observed and depth of penetration is measured using sliding caliper. The load required to break the specimen is also noted down.



Fig. 1. Specimen Tested for Water permeability

B. Sorptivity

In the present study, the cylindrical specimens of 100 mm diameter and 50 mm height are cored out from 150mm diameter and 300 mm height specimens which are water cured for 28 days. The curved surface and one flat surface of the specimen is sealed properly. Its weight is measured accurately for 0.01g accuracy. A large pan is filled with tap water to a height of 5 to 10 mm. Few supporting rods are kept at the bottom and prepared specimens are kept on the support taking care to see that bottom 3 to 5 mm of height of specimen is immersed in water and unsealed surface of the specimen is exposed to water. The mass of the specimen is recorded at the intervals of 1min, 5 min, 10 min, 20 min, 30 min, 60 min, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours and 24 hours apart after that upto eight days. Surface is dried with a blotting paper before the weight is taken and placed in water immediately after the weight is taken. Initially up to 10 minutes, the stop watch is stopped when the weight is being taken and started soon after the immersion. Sorptivity is given by the formula

$$I = m_1 / a \cdot d$$

Where 'I' is the capillary water absorption or sorptivity

'm₁' is the change of mass in specimen in grams in time t

'a' is the exposed area of sample in mm²

'd' is the density of water = 0.001g/mm³

Graphs are plot with absorption versus square root of time.



Fig.2 Prepared Sorptivity Specimens

C. Rapid Chloride Penetration Test

Cylindrical specimens of 100mm diameter and 50mm height are cored out from standard cylinders of size 150 mm diameter and 300 mm height.

The specimens are subjected to a 60VDC voltage for 6 hours using an apparatus as shown in Fig 3. One reservoir is filled with 3.0% NaCl solution and another reservoir with 0.3 M NaOH solution. The total number of charges passed are determined at intervals over the duration. Quality of concrete was determined as per the standard ratings.

A minimum of 3 samples have to be tested and the average value should be considered. However, as per code if the values differ by more than 29%, such values must be ignored. Total voltage passed can be calculated by the formula

$$Q = 900 [I_0 + 2I_{30} + 2I_{60} + \dots + 2I_{330} + I_{360}] / 1000$$

Where 'Q' is the current flowing through one cell

I₀, I₃₀, ... I₃₆₀ are the current readings in amperes in 0, 30 ... 360 minutes.

Based on the coulombs passed, the concrete is classified as given in table II

TABLE II CLASSIFICATION OF QUALITY OF CONCRETE BASED ON RCPT RESULTS

Charges passed (Coulombs)	Chloride ion Penetrability	W/C ratio
>4000	High	>0.6 (Low strength Concrete)
2000-4000	Moderate	0.4 to 0.5 (Moderate strength)
1000 - 2000	Low	<0.4 High Strength
100 - 1000	Very Low	Polymer concrete Latex-modified concrete, Internally sealed concrete Microsilica concrete
<100	Negligible	Polymer concrete/polymer impregnated concrete

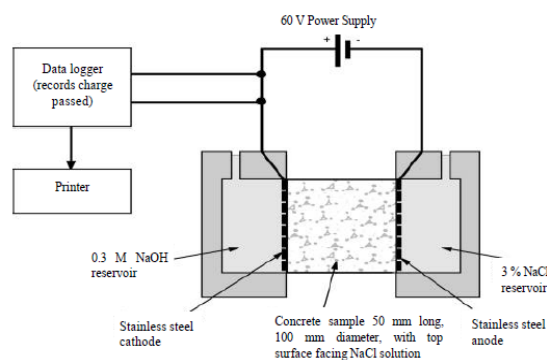


Fig. 3. RCPT Apparatus

IV. RESULTS AND DISCUSSIONS

TABLE III. PENETRATION (MM) DEPTH FOR VARIOUS PERCENTAGES OF FIBRES AND ASPECT RATIOS

%of Fibre	Aspect Ratio				
	AR30	AR50	AR70	AR90	AR110
0	24.68	24.68	24.68	24.68	24.68
0.25	24.22	19.44	23.52	25.88	27.89
0.5	22.91	14.09	22	25.59	26.38
0.75	33.93	23.3	39.48	43.47	47.2
1	45.32	29.38	48.25	54.34	58.75
1.25	65.6	39.53	67.33	75.65	81.36
1.5	78.31	56.93	79.03	89.01	92.2

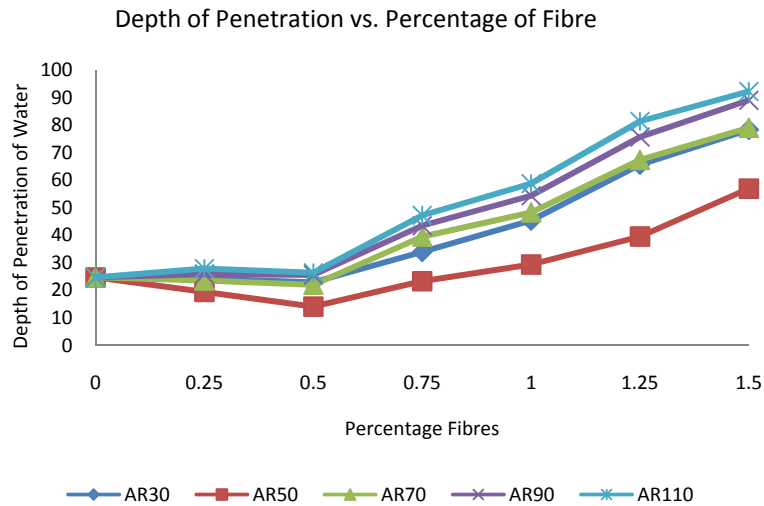


Fig. 4. Penetration Depth(mm) for various Percentage of fibres and aspect ratios

TABLE IV. FAILURE LOAD (KN) FOR VARIOUS PERCENTAGES OF FIBRES AND ASPECT RATIOS

% of Fibre	Aspect Ratio				
	AR30	AR50	AR70	AR90	AR110
0	121.43	121.4	121.4	121.4	121.43
0.25	125.4	130.6	130.6	124.9	123.86
0.5	131.32	139.5	131.1	130.2	128.94
0.75	113.01	120.8	114.1	112.8	111.13
1	106.34	115	106.3	103.5	105.1
1.25	102.85	107.5	101.6	99.95	98.63
1.5	94.03	89.3	91.06	86.96	76.5

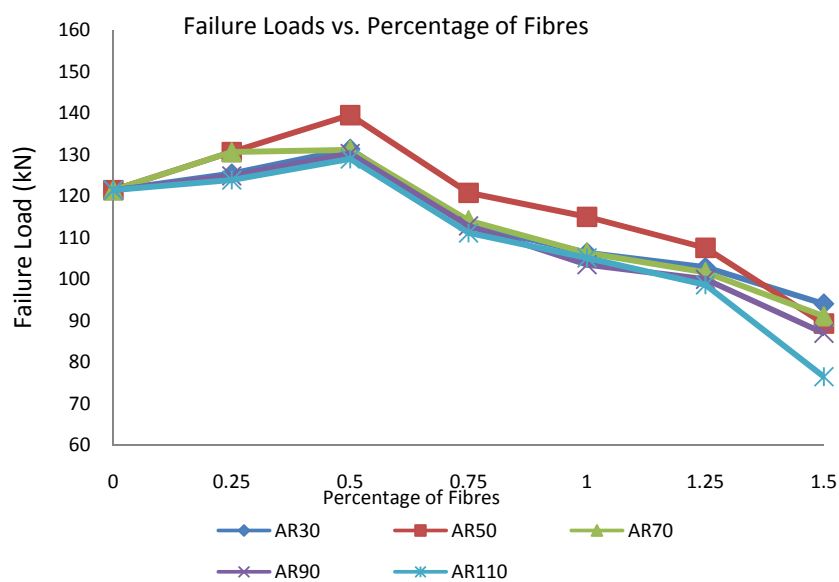


Fig. 5. Failure Load (kN) for various percentages of fibres and aspect ratios

As can be seen from Fig. 4, the breaking load is maximum when the percentage of fibre was 0.5 for all aspect ratios and aspect ratio 50 showed highest failure load. There was an increase of 18% in load taking capacity with aspect ratios 50 after allowing water to penetrate under pressure. The depth of penetration was least at 0.5% fibre when measured using slide caliper. The depth of penetration had reduced by 70.7% at aspect ratio 50 for 0.5% of waste plastic fibres in concrete.

Prepared specimens are subjected to Rapid Chloride Penetration Test and the results are shown in table V and Fig.6. It can be seen from the figure that at 0.5% waste plastic fibre total charges passed is less than 2000 coulombs indicating that the quality of concrete is excellent as per specifications. The concrete can be classified as low permeable concrete. The chloride ions passed was least at 0.5% fibres for all aspect ratios. It can also be observed that at aspect ratio 50 total penetrations of chloride ions was least for all percentages of fibre indicating that the waste plastic fibre concrete becomes more impermeable and 50 is the optimum aspect ratio.

TABLE V TOTAL COULOMBS PASSED FOR ALL ASPECT RATIOS AND PERCENTAGE OF FIBRES

% of Fibre	Aspect Ratio				
	AR30	AR50	AR70	AR90	AR110
0	2927	2927	2927	2927	2927
0.25	2350	1920	2543	2735	2907
0.5	1919	1394	2155	2310	2618
0.75	2609	2161	2906	3129	3352
1	3306	2610	3495	3666	3986
1.25	3750	3522	3970	4185	4483
1.5	4130	3971	4231	4446	4698

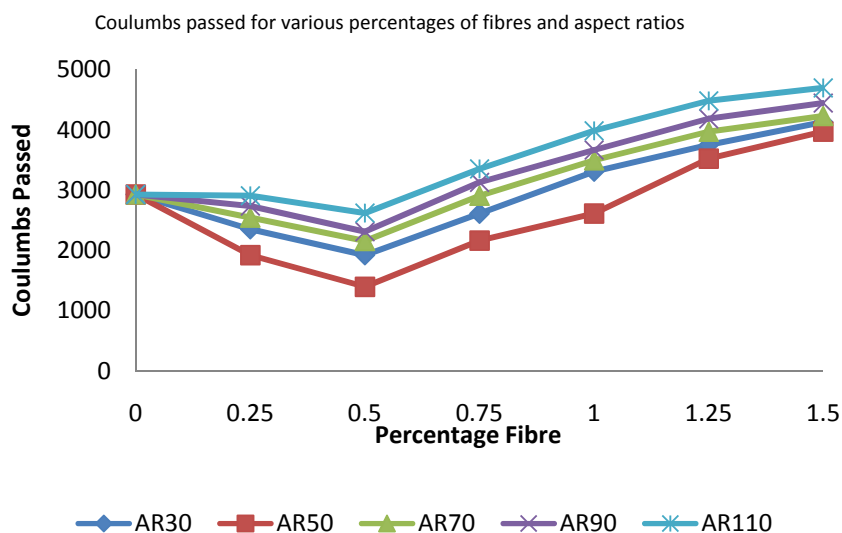


Fig.6.. Average coulombs passed for various percentages of fibres and aspect ratios

Sorptivity is a measure of capillary rise of water which is obtained by taking out the difference in weight of the specimen before and after immersion in water. Though the weight is checked at regular intervals, absorption at the end of 6th hour and 8th day is considered as standards. Fig. 6 shows the absorption for various percentages of fibres and aspect ratios at the end of 6th hour and 8th day. The figure clearly indicates that 50 is the optimum aspect ratio and 0.5% is the optimum fibre percent which shows the least change in mass indicating dense concrete. Rate of absorption is appearing to be more above 0.75% of waste plastic fibre and not recommended.

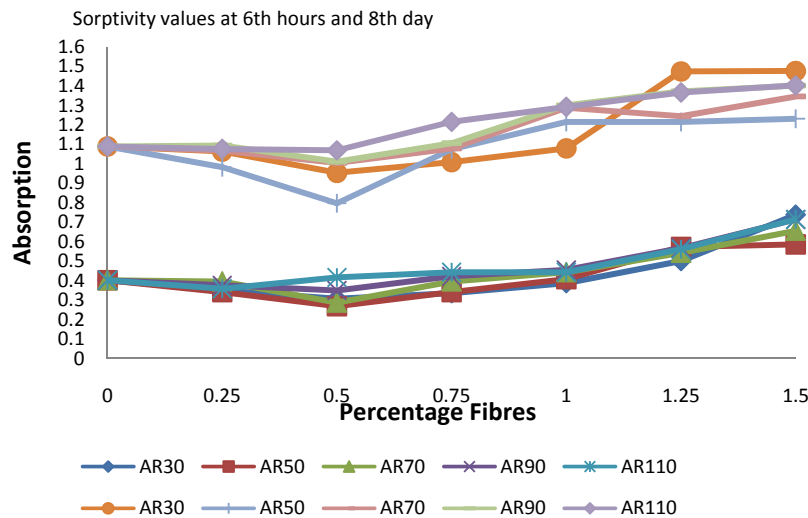


Fig 7. Comparison of absorption at 6th hour and 8th day for various percentages of fibres and aspect ratios

The permeability of waste plastic fibre reinforced concrete is found to decrease initially up to an addition of 0.5% of fibres by all three methods of tests. The reason could be the homogeneous dispersion of plastics in the concrete with limited and optimum percentages and aspect ratios. Beyond this, concrete tends to become heterogeneous altering the pore structure of concrete, making the waste plastic fibre reinforced concrete more permeable and allow more fluid inside. This is found to be the same for all aspect ratios. The concrete with aspect ratio 50 and % of fibre 0.5 is found to be most impermeable. Hence, it can be considered from the results that 0.5% and aspect ratio 50 are optimum values.

Increase in percentage of fibres decreases chloride ion penetrability initially up to 0.5% beyond which pass ability increases. The trend is same in all aspect ratios. It is observed that aspect ratio 50 is more efficient in resisting the permeability. As per the ASTM standards, the quality of concrete becomes better as the pass ability is changed from moderate to low as observed in charts and graphs. The concrete becomes more permeable as the percentage of fibres increased beyond 0.5.

Hence, from all permeability tests, it can be concluded that the 0.5 % of fibres at aspect ratio of 50 will efficiently resist the permeability of waste plastic fibre reinforced concrete and make it more impermeable.

V. CONCLUSIONS

The following conclusions are drawn from the investigation.

1. Water permeability, sorptivity and rapid chloride penetration values decrease when waste plastic fibres are added up to 0.5% by volume of concrete. Hence 0.5% of waste plastic fibres can be safely added to concrete which would enhance the performance of the concrete.
2. Aspect ratio 50 showed better resistance to permeability in all three tests. Hence 50 can be accepted as optimum aspect ratio.
3. The depth of water penetration was reduced by 70% and chloride ions passed by 52% with 0.5% of waste plastic fibres.
4. Sorptivity values also showed that the absorption by capillary rise of water is least in the concrete with 0.5% waste plastic fibres of aspect ratio 50.

Hence, the study reveals that the waste plastic fibres obtained from plastic flush doors can be used for making durable and impermeable concrete. However, the percentage of fibres should be restricted to 0.5 by volume of concrete and preferred aspect ratio is 50.

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