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Durability Studies on Polyvinyl Alcohol Fiber Reinforced Concrete

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***Abstract* – The usefulness of fiber reinforced concrete (FRC) in various civil engineering applications is indisputable. Fiber reinforced concrete has so far been successfully used in slabs on grade, shortcrete, architectural panels, precast products, offshore structures, structures in seismic regions, thin and thick repairs, crash barriers, footings, hydraulic structures and many other applications. This report presents a brief state-of-the-art report on durability studies of polyvinyl alcohol fiber reinforced concrete. Civil infrastructure around the world the problem is at the apparent lack of durability in our construction materials, inability on part of the owners to provide timely maintenance, absence of advanced condition assessment tools and lack of long-lasting, cost effective repair materials and technologies. This report will present data to support the argument that polyvinyl alcohol fiber reinforced concrete is an ideal material for achieving these goals. The report also discusses poly vinyl alcohol fiber reinforced concrete materials properties and mix design. The PVA fiber will be added to the conventional concrete 0%, 0.1%, 0.2%, 0.3% and 0.4% by its cement weight. The Compressive strength, Split tensile strength and Modulus of rupture of concrete was found and with comparison of concrete strengths the optimum level of PVA fiber was found. The durability performance of PVA fiber concrete found by immersion the concrete cubes in Sodium Chloride (NaCl), Sodium Sulphate (Na_2SO_4), and Magnesium Sulphate ($MgSO_4$) for 90 days.**

Keywords* – *Polyvinyl Alcohol Fiber, Durability, Sodium Chloride, Sodium Sulphate, Magnesium Sulphate

I. INTRODUCTION

Concrete is a mixture of Cement, Fine aggregate, Coarse aggregate and Water. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete.

In the past, attempts have been made to impart improvement in tensile properties of concrete members by way of using conventional reinforced steel bars and also by applying restraining techniques. Although both these methods provide tensile strength to the concrete members, they however, do not increase the inherent tensile strength of concrete itself.

In plain concrete and similar brittle materials, structural cracks [micro – cracks] developed even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these initial cracks seldom exceeds a few microns, but their other two dimensions may be higher magnitude.

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as a crack arrest and would substantially improve its static and dynamic properties. This type of concrete is known as Fiber Reinforced Concrete.

Fiber reinforced concrete can be defined as a "***composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed fibers"***.

Continuous meshes, woven fabric and long wires or rods are not considered to be discrete fibers. The following fibers are could be used as in concrete,

- Steel fibers.
- Polypropylene fibers,
- Nylon fibers.
- Asbestos fibers.
- Coir fibers.
- Glass fibers.
- Carbon fibers.

Fiber is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber

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is the ratio of its length to its diameter. Typical aspect ratio value ranges from 30 to 150.

II. EXPERIMETNAL PROGRAME

A. *Materials*

For this research work Ordinary Portland Cement 53 grade was used. Locally available fine and coarse aggregate was used with specific gravity of 2.75 and 2.8. The maximum size of coarse aggregate was 12.5mm. The Poly vinyl Alcohol fiber was obtained from Spinning King (India) Limited, Gujarat, India. With following Properties.

TABLE I PROPERTIES OF POLY VINYL ALCOHOL FIBER

Test Item	Tested Value
Material	Poly Vinyl Alcohol
Density	1300 kg/m^3
Diameter	18 µm
Length	6 mm
Modulus of Elasticity	36000 N/mm^2
Tensile Strength	1280 N/mm^2

Fig. 1 Poly Vinyl Alcohol fiber

B. Mix *Design*

The Mix design was performed as per IS 10262: 2009. The following mix proportion was obtained from the mix design. The water cement ration for mix is 0.45.

TABLE II MIX PROPORTION

Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio
1	1.85	2.05	0.45

C. *Casting & Curing*

The concrete was prepared and the fiber was added based on their percentage then the concrete will be placed on moulds. The following moulds are used to caste the specimens.

1. Cube mould of size 150X150X150mm.
2. Cylinder mould of size 150X300 mm.
3. Prism mould of size 100X100X500 mm.

After casting the specimens left for 24 hours thereafter the mould was removed and specimens were put for water curing till the day of testing.

III. STRENGTH TESTS ON CONCRETE

A. *Compressive Strength*

Compression test is the most common test conducted on harden concrete, partly because it is an easy test perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. To find the compressive strength 150 X 150 X 150mm cube specimens were prepared. The compressive strength of concrete was found by compression testing machine of 2000 kN capacity.

$$\text{Compressive Strength} = \frac{P}{A}$$

Where

P is the Compressive load.

A is the Area of cube.

B. *Split tensile Strength.*

The test is carried out by placing cylindrical specimen horizontally between the loading surface of a universal testing machine and the load is applied until failure of the cylinder along the vertical diameter. To find split tensile strength of concrete cylinder specimen of 150 X 300mm prepared. The split tensile strength of concrete was found by Universal Testing Machine of 400 kN capacity.

$$\text{Split Tension} = \frac{2P}{\pi LD}$$

Where

P is the compressive load on the cylinder.

L is the length of the cylinder.

D is the diameter of the cylinder.

C. *Modulus of Rupture*

Concrete as we know is relatively strong in compression and weak in tension. To find Modulus of rupture of concrete 100X100X500 mm size prism specimens were prepared. The Modulus of rupture was found by Universal Testing Machine of 400 kN capacity.

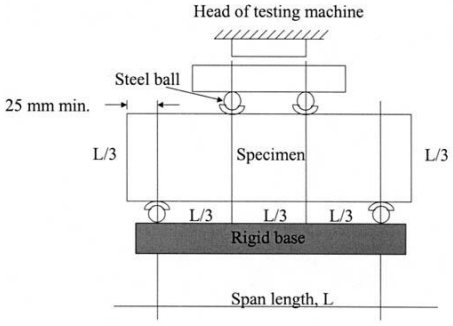

Fig. 2 Third Point Loading Method.

The Modulus of rupture of the specimen is expressed as the moulds of rupture fb which if 'a' equals the distance between the line of fracture and the nearer support, measured on the center line of tensile side of the specimen in cm, is calculated to the nearest 0.05MPa as follows

$$f_b = \frac{Pl}{bd^2}$$

When 'a' is greater than 13.3 cm, or

$$f_b = \frac{3Pa}{bd^2}$$

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When ‘a’ is less than 13.3 cm but greater than 11.0 cm.

If ‘a’ is less than 11.0 cm for 10cm specimen, the result of the test be discarded.

IV. DURABILITY TESTS ON CONCRETE.

The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment.

A. Sulphate Attack

Sodium Sulphate (Na2SO4) resistance of conventional concrete and poly vinyl alcohol fiber reinforced concrete:

Sodium Sulphate resistance of conventional concrete determined by immersing Cube specimens of size 150x150x150 mm in 8% sodium sulphate (Na2SO4) solution. The effect on conventional concrete and poly vinyl alcohol fiber reinforced concrete specimens measured as percentage reduction in weight and compressive strength at 90 days.

Magnesium Sulphate resistance of conventional concrete and poly vinyl alcohol fiber reinforced concrete:

Magnesium Sulphate (MgSO4) resistance of conventional concrete determined by immersing Cube specimens of size 150x150x150 mm in 10% Magnesium sulphate (MgSO4) solution. The effect on conventional concrete and poly vinyl alcohol fiber reinforced concrete specimens measured as percentage reduction in weight and compressive strength at 90 days.

Fig. 3 Specimens Immersed In Na_2so_4 And $Mgso_4$ Solutions.

B. Acid Attack

Acid Attack on conventional concrete and poly vinyl alcohol fiber reinforced concrete:

Marine environment attack determined by immersing Cube specimens of size 150x150x150 mm individually in7% sodium chloride (NaCl) solutions. The deterioration of conventional concrete and poly vinyl alcohol fiberreinforced concrete specimens measured as percentage reduction in weight and compressive strength at 90 days.

Acid attack determined by immersing Cube specimens of size 150x150x150 mm individually in 0.1N solution of Hydro chloric acid (Hcl). The deterioration of conventional concrete and poly vinyl alcohol fiber reinforced concrete specimen measures as percentage reduction in weight and compressive strength at 90 days.

Fig, 4 Specimens Immersed In Nacl And Hcl Solutions.

V. RESULTS & DISCUSSION

A. Compressive Strength

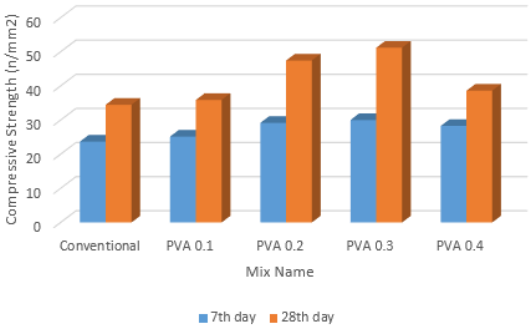

Fig. 5 Compressive Strength Result.

B. Split Tensile Strength

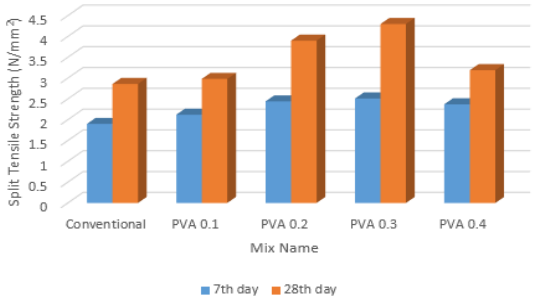

Fig. 6 Split Tensile Strength Result.

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C. *Modulus of rupture*

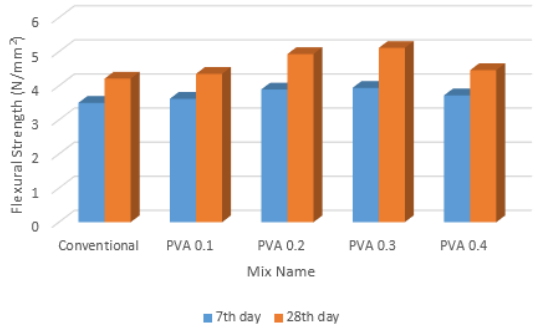

Fig. 7 Modulus Of Rupture Result.

D. *Sulphate attack*

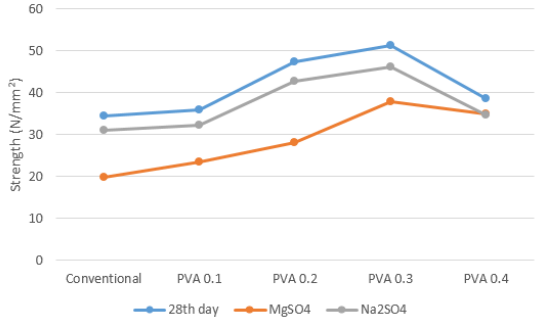

Fig. 8 Compressive Strength After Immersed In Sulphate Solution For 90 Days.

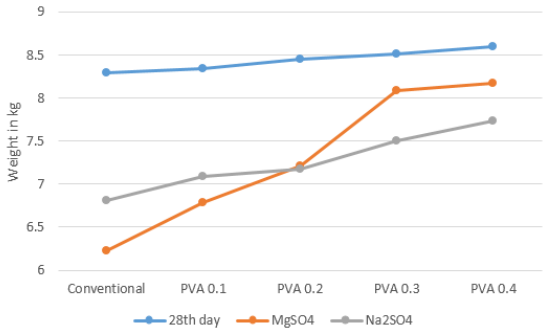

Fig. 9 Weight Loss After Immersed In Sulphate Solution For 90 Days.

E. *Acid Attack*

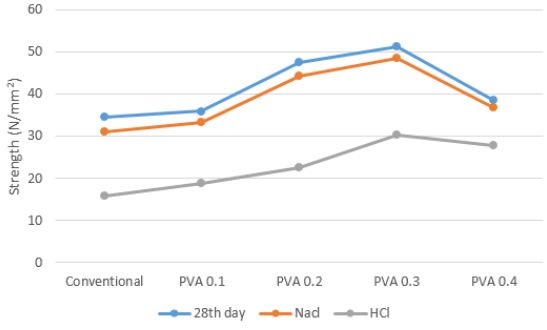

Fig.10 Compressive Strength After Immersed In Acid Solution For 90 Days

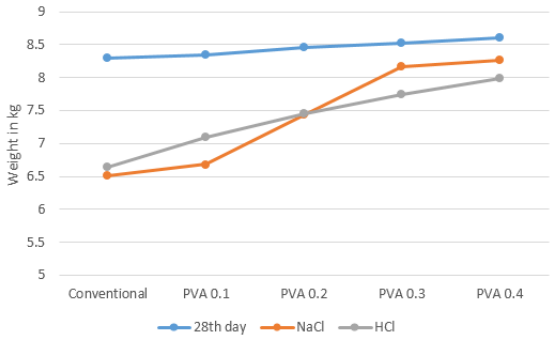

Fig. 11 Weight Loss After Immersed In Acid Solution For 90 Days.

VI. CONCLUSION

From the results of this experimental investigation, the following conclusions are drawn on concrete without and with poly vinyl alcohol fiber.

1. With the addition of poly vinyl alcohol fibers leads to increase in compressive strength, split tensile strength and modulus of rupture with age and with the increase of poly vinyl alcohol fiber content up to 0.3% compared to control concrete at 28 day.
2. Compared to conventional concrete poly vinyl alcohol fiber reinforced concrete specimens attains 48.5% higher compressive strength, 50.4% higher split tensile strength, 21.4% higher modulus of rupture.
3. Based on the compressive strength, split tensile strength and modulus of rupture, the optimum level of poly vinyl alcohol fiber content was 0.3%.
4. When immersed in Magnesium Sulphate solution (MgSo4) for 90days, the poly vinyl alcohol fiber reinforced concrete compressive strength was 37% less compared to 28th day poly vinyl alcohol fiber reinforced concrete 89.8% higher than the conventional concrete.
5. When immersed in Magnesium Sulphate solution (MgSo4) for 90days, the poly vinyl alcohol fiber reinforced concrete weight was 17.2% less compared to 28th day poly vinyl alcohol fiber reinforced concrete and 29.8% higher than the conventional concrete.
6. When immersed in Sodium Sulphate solution (Na2So4) for 90days, the poly vinyl alcohol fiber reinforced concrete compressive strength was 11% less compared to 28th day poly vinyl alcohol fiber reinforced concrete 48.5% higher than the conventional concrete.
7. When immersed in Sodium Sulphate solution (Na2So4) for 90days, the poly vinyl alcohol fiber reinforced concrete weight was 13.6% less compared to 28th day poly vinyl alcohol fiber reinforced concrete and 10.1% higher than the conventional concrete.
8. When immersed in Sodium Chloride solution (Nacl) for 90days, the poly vinyl alcohol fiber reinforced concrete compressive strength was 5.45% less compared to 28th day poly vinyl alcohol fiber reinforced concrete 56.7 % higher than the conventional concrete.
9. When immersed in Sodium Chloride solution (Nacl) for 90days, the poly vinyl alcohol fiber reinforced concrete weight was 4.3% less compared to 28th day poly vinyl alcohol fiber reinforced concrete and 25.5% higher than the conventional concrete.

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10. When immersed in Hydro Chloric Acid solution (Hcl) for 90days, the poly vinyl alcohol fiber reinforced concrete compressive strength was 69.3% less compared to 28th day poly vinyl alcohol fiber reinforced concrete 90% higher than the conventional concrete.
11. When immersed in Hydro Chloric Acid solution (Hcl) for 90days, the poly vinyl alcohol fiber reinforced concrete weight was 10% less compared to 28th day poly vinyl alcohol fiber reinforced concrete and 16.7% higher than the conventional concrete.
12. Compared to conventional concrete the poly vinyl alcohol fiber reinforced concrete with 0.3% of fiber content has good durability characteristic.

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