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Effect of Polypropylene Fibers on Durability Characteristics of No-Aggregate Concrete

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Abstracts

Objective: To study the effect of Polypropylene Fiber (PF) on the durability of No-Aggregate Concrete (NAC), replacing aggregates completely by incorporating fly ash and minimal water for hydration. **Method:** The chemical durability characteristics such as water absorption, sorptivity and resistance to acid attack are tested for NAC with PF in 0.2, 0.4, 0.6 and 0.8 percentage of volume replacement with fly ash and compared with control NAC. The reason for using PF is to improve the tensile strength of NAC. In the previous study conducted on NAC steel fibers were used, which settled down due to high relative density. **Findings:** The test results on water absorption show that PF with 0.4 percentage of volume replacement with fly ash offers better resistance. Even though the water absorption for other volume fractions do not vary significantly at the age of 28 days. This is due to the pores which will get subsequently filled by secondary C-S-H gel at later ages leading to less absorption. The test results for sorptivity and resistance to acid attack reveal that PF with 0.6 percentage of volume replacement with fly ash offers better resistance compared to other volume fractions. As pozzolonic reaction of fly ash is directly related to permeability, considerable imperviousness may develop at later ages. The results on resistance to acid attack for NAC with PF shows considerable loss in strength. This cannot be justified at this stage as only visual inspection is done, but the penetration of acid is not measured. However, the surface of the specimen turned softer but they are structurally intact. **Improvement:** The test results presented in this paper are at early ages and these parameters are under study for later ages up to 180 days.

Keywords: Acid Attack,No-Aggregate Concrete, Polypropylene Fiber, Sorptivity,Water Absorption

1. Introduction

As construction is the 2nd largest sector in India after agriculture, the demand for use of concrete never seems to reduce. Thus, leading to the modification of its ingredients which is inevitable. The scarcity of natural aggregates, the increasing CO_2 emission accompanying the cement manufacturing process, the destruction of ecosystem due to quarrying and non-availability of river sand are the key factors that impose need for the sustainable and durable concrete. On the other hand, research also shows that use of the mineral and chemical admixtures which to some extent reduce the need for water and cement. But as of now, no studies have been carried out where the use of aggregates is completely inhibited. Of the numerous mineral admixtures available, fly ash is one such mineral admixture which has found its extensive use in concrete as a replacement for cement or use in cement manufacturing process to produce blended cement.

Extensive studies were being carried out to study the effect of addition of fly ash in various proportions as replacement for cement on fresh and hardened properties of concrete. Few such examples which have been practically implemented are use of Self-Compacting Concrete, High

Performance Concrete, and High Volume Fly Ash Concrete. But in all types of studies limits the use of fly ash for replacement of cement and in most of the cases the following factors varies: Aggregate consumption, size of aggregates, water to cement or water to powder ratio, replacement of cement with fly ash in varying proportions. Most of the times even though recent advancement in concrete technology has been implemented practically, due to the lack of knowledge or experience structure fail

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even before they reach the end of the service life for which they are designed for.

It is very difficult to produce a concrete that doesn't require natural aggregates; requires minimal amount of water to trigger the hydration reaction and incorporates large quantity of fly ash[1]. This type of concrete is given name as No-Aggregate Concrete (NAC). The advantage of such concrete over existing one is sustainable construction.

NAC is a composite construction material which is made of cement, fly ash, gypsum, water and admixture. The usage of aggregates are completely avoided in the making of NAC. It is easily pump able and provides a homogeneous mass with neither vibrators nor compactors. The absence of transition zone avoids frailty of ordinary concrete and high compressive strength (40-80MPa) and low density (1800kg/m³) makes it more favorable for structural design[1].

In the previous study regarding NAC, Reference[2] conducted a study to understand the strength properties of NAC with steel fibers of two different aspect ratio. They observed that NAC gives more strength compared to normal concrete with lower cement content, but it undergoes brittle failure and has low tensile strength. Adding steel fiber in NAC improved both flexural and tensile strength, but at the same time reduction in compressive strength was also observed for both aspect ratios. This provides an argument for the further investigation on physical and durability properties of NAC with other fibers in strength and economic aspect. Polypropylene fiber is widely used as fiber reinforcement because of its economic feature. Studies on different kinds of concrete shows polypropylene fiber in low volume fraction effectively improves the durability properties of concrete and also improves mechanical properties[3-7]. The present paper

aims to study the durability characteristics of the NAC in terms of water absorption, sorptivity and acid attack. It also verifies the effect of incorporating polypropylene fiber of 12 mm length in four volume fractions starting from 0.2, 0.4, 0.6 and 0.8 percentage replacement with fly ash.

2. Experimental Investigation

No-Aggregate Concrete (NAC) used here is made up of Ordinary Portland cement (43grade), fly ash (Class F), Gypsum, Chemical Admixture and Water. Polypropylene fibers are used as fiber reinforcement.

2.1 Materials Used

- Cement: ordinary Portland Cement 43 grade with a specific gravity of 3.15 and initial and final setting time of 50 min and 145 min respectively.
- Fly Ash: fly ash obtained from Raichur Power station (RTPS) located in Karnataka (India), is tested for its type, specific gravity and strength activity index with Portland cement according to standards mentioned in reference[8-10].The test results show that the type of fly ash is class F and correspondingvalues of specific gravity and strength activity index with Portland cement is 2.06 and 75.94.
- Gypsum: first grade gypsum, white colour and in powder form with a specific gravity of 2.32 is used. It plays a dual role in NAC, it acts as a retarder as well as strength accelerator.
- Water: portable water without any presence of salts or other impurities is used for all mixes.
- Chemical Admixture: a wine red colour solution which disperses in water is used as chemical admixture. Since it is a newly developing material, the name or chemical composition is still private. It is supplied by Eco Carbon Private Limited, Visakhapatnam and the dosage is specified as 0.4% by weight of cementitious material.
- Polypropylene fibers: fibers of length 12 mm and 0.91 relative density is used for all the mixtures. Mixtures are made with four volume fraction starting from 0.2, 0.4, 0.6 and 0.8 percentage with fly ash. As dry mixing procedure is followed no additional dispersion agents are used. A sample polypropylene fibers is shown inFigure 1.

2.2 Mixture Composition of NAC

In total five mixtures of No-Aggregate concrete are prepared. Table 1 shows the composition of each mixture. Control concrete (NAC) without fibers is prepared to study the durability properties with reference to the

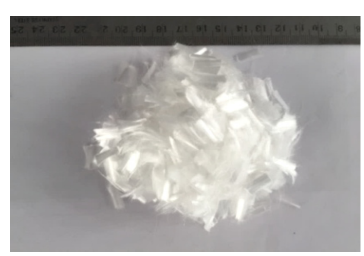

Figure 1. Polypropylene fiber.

NAC with polypropylene fibers of four different volume fractions increasing from 0.2, 0.4, 0.6 and 0.8 percentage with fly ashin a pan mixer.

Typical mix composition for NAC is as below:

Cement: Fly ash	-	1:4
Gypsum	-	2% of Fly ash
Chemical Admixture	-	0.4% of cementitious material
Water	-	15-18% cementitious materialss

2.3 Preparation of Specimens

After fixing the mix proportions for all the mixtures, required quantities of materials for one NAC mix is batched by weigh batch method. Feeding of materials into pan mixer is carried out in the following sequence: First half quantitiesof cement, fly ash and gypsum are mixed in dry state. After getting a homogeneous mix, remaining quantity of materials is also added and mixed in dry state. This process is continued with adding water and admixture until a consistency of thick slurry is reached without any lumps or nodules. Immediately after mixing, slurry is poured in to the moulds and the surface of the specimen is finished by removing the excess slurry from the mould. In case of mixtures with fiber, fibers are added after getting the consistency of thick slurry. Then the mixing is continued for 5-10 minutes to get a uniform mix. Fibers are made wet before adding to the mix using the quantity of water to be added to prepare NAC to avoid the loss of thin fiber particles from flying. Quantity of each mix is used to prepare nine cubes of 100mm and three cylindrical specimens of 100mm diameter and 50mm height.

3. Test Procedure and Results

3.1 Water Absorption

For determining water absorption three numbers of 100mm cubes are prepared in each mix and cured for 28 days. The test specimens are taken out from the curing tank and are dried in oven at a specified temperature to get a constant mass (W_1). Then the specimens are immersed in water and the mass is measured after 30 minutes (W_2) as initial absorption. For getting ultimate absorption, specimens are immersed in water until they reach a nearly constant mass (W_3) and this is achieved if the specimens have difference in mass within 0.5% compared to previous 24 hour observation. Absorption is calculated by taking ratio of mass of absorbed water todry mass of concrete. The initial and ultimate absorption of NAC and NAC with fibers are shown in Figure 2 and Figure 3 respectively.It is observed that the addition of polypropylene fiber leads to a slight increase in initial as well as ultimate water absorption except for NAC with 0.4 volume fraction represented as PFNAC2. It is also observed that for volume fractions above 0.4there is a gradual increase in water absorption.

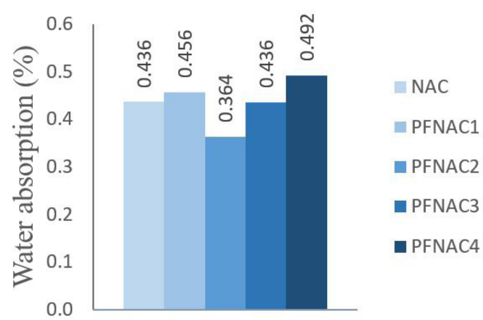

Figure2. Initialwater absorption.

Table 1. Mixture proportions of concrete per cubic meter

Mixture	Cement (kg/m³)	Fly Ash (kg/m³)	Gypsum (kg/m³)	Polypropy-lene Fiber (kg/m³)	Water-Powder Ratio	Admixture (kg/m³)
NAC	315.5	1262	25.24	-	0.16	6.31
PFNAC1	315.5	1259	25.24	1.81(0.2%)	0.16	6.31
PFNAC2	315.5	1256	25.24	3.64(0.4%)	0.16	6.31
PFNAC3	315.5	1253	25.24	5.46(0.6%)	0.16	6.31
PFNAC4	315.5	1250	25.24	7.28(0.8%)	0.16	6.31

3.2 Sorptivity

The sorptivity is determined by the measurement of the capillary absorption. Three cylindrical specimens of 100mm diameter and 50mm height from each mix are cured for 28 days and used. The test is carried out as per ASTM C1585-13 guidelines[11]. The specimens are driedin oven at a temperature of 50°C until we get a constantmass and cooled at room temperature. After measuring the diameter (at least average of four values), sides are sealed using insulation tape and top surface of the specimen is covered with polythene cover to avoid loss of water due to evaporation. After taking initial mass, a depth of 1-3 mm of the specimens isimmersed in water. Mass of these specimensis recorded at 60 sec, 5min, 10min, 20min, 30 min, 60min, 2hour, 3hour, 4hour, 5hour and 6hour. Then absorption (I) is calculated by ratio of mass of absorbed water to product of cross sectional area and density of water.Rate of water absorption (mm/$s^{1/2}$) is defined as the slope of the line that is the best fit to I plotted against the square root of time in seconds ($s^{1/2}$). The test results for sorptivity are shown in Figure 4.It was observed that addition of polypropylene fibers show reduction in sorptivity. The reduction is gradual till volume fraction of 0.6 represented as PFNAC3 and then a trivial increase for volume fraction of 0.8 represented as PFNAC4.

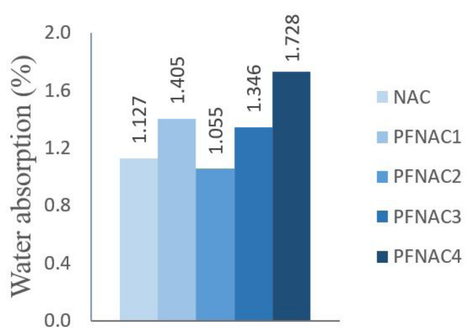

Figure3. Ultimatewater absorption.

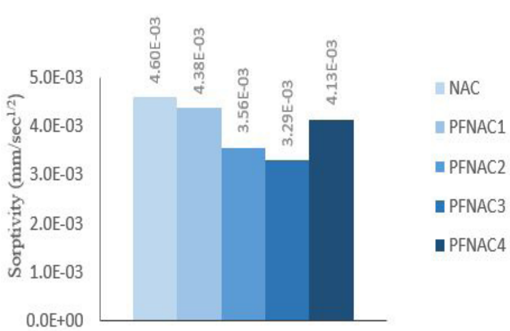

Figure 4. Test results for Sorptivity.

3.3 Resistance to Acid Attack

Six 100mm cubes from each mix are used for testing resistance to acid attack. After 28 days of curing, three

out of six cubes are weighed and immersed in 3% sulfuric acid for 28 days and then tested for loss of weight and compressive strength. Remaining three cubes are used as control cubes to determine the loss of strength. Test results of acid resistance is shown in Table 2. It is observed that NAC with fiber of 0.6 volume fraction gives better resistance as compared to other volume fractions and control NAC is better in acid resistance as compared to NAC with fibers.

4. Discussion

The test results for water absorption shows that NAC with 0.4 volume fraction absorbs less water compared to NAC with other volume fractions and control NAC. Studies show that concrete containing fly ash in high percentage are more prone to water absorption at the early age. Studies have also revealed that at this stage the amount of pozzolanic reaction due to fly ash is very less. Hence the test should be continued for more duration to understand the significance of different volume fractions.

- The test results for sorptivity shows that NAC with fiber of 0.6 volume fraction is less permeable compared to NAC with other volume fractions and control NAC. For concrete containing higher volumes of fly ash the permeability is directly related to the quan-

Table 2. Test Results of Acid Resistance

	Loss of Strength (%)	Increase in Weight (%)
NAC	20.83	0.63
PFNAC1	34.03	1.05
PFNAC2	32.50	0.85
PFNAC3	23.59	0.43
PFNAC4	23.86	0.85

tity of hydrated cementitious material at any given time. If the tests are conducted for longer duration considerable imperviousness may be developed due to pozzolanic reaction of fly ash.

- The test results for acid attack show that control NAC offers better resistance. However in the mixture containing different volume fraction of polypropylene fiber with 0.6 volume fraction offers better resistance. An increase in weight due to surface absorption of liquid was noticed along with sudden loss of strength for 28 days of immersion in 3 percentage H_2SO_4 solution. Visual inspection shows that the surface turned softer. Hence, the deterioration of the surface for all the volume fractions are similar.

5. Conclusion

On the basis of findings at early age of 28 days for the present study following conclusions are drawn;

- At early ages concrete containing higher percentages of fly ash absorbs more water due to the pores which will subsequently get filled with secondary C-S-H gel due to pozzolanic reaction of fly ash
- Pozzolanic reaction of fly ash is directly related to permeability. Considerable imperviousness may develop for the specimens if tested for longer curing periods.
- The surface of the specimens immersed in 3 percent sulphuric acid concentration turned softer and led to sudden loss in strength. However, they are structurally intact.

6. Acknowledgement

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