A Study on Shrinkage, Cracking and Strength of Concrete Using Synthetic Fibers

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Abstract - *Cracking failure of concrete due to shrinkage is a common problem in concrete structures. This is of particular in the case of slabs type structures such as pavements, industrial floors, bridge decks, tunnel lining and precast elements, etc that show much larger surface areas compared with other kinds of structural components, such as beams and columns. There are much more solutions to control or reduce early age shrinkage cracking.*

The present study is proposed to introducing some synthetic fibers in addition to a simple concrete mix. In this we are using different types of synthetic fiber such as polypropylene, AR glass fiber etc. By performing different tests (image analysis and compressive strength) on synthetic fiber reinforced concrete, we will compare their results with regular concrete and we will find out the best synthetic fiber to be used for slab type structures.

***Key Words*: Shrinkage, Cracking, Synthetic Fiber, Image Analysis, Compressive Testing**

1. INTRODUCTION

Concrete is a composite material, comprising a matrix of aggregate and a binder, which holds the matrix together. Many types of concrete are available, determined by the formulations of binders and the types of aggregate used to suit the application for the material. Due to the early age shrinkage, the concrete is subjected to cracking, which may directly affect the durability, strength etc of the structure.

Nowadays there are many solutions for avoiding early age shrinkage in concrete, but many of solutions are not economical. To increase the strength and performance of concrete, reinforcement is a most commonly used solution. The reinforcements like steel, AR glass fiber, Polypropylene etc are used in concrete structures, but users don't have idea about best and economical fibers which needs to be used.

So in this research we will find out the best fiber to be used. By casting the slab specimens, and by performing some tests and analysis on it, it is easy to find out best and economical synthetic fiber.

2. OBJECTIVES

The main objective of this research is to find out best synthetic fiber to be used i.e. AR glass fiber or Polypropylene fiber. By observing and analyzing the cracks formed on the surface will allow to decide best synthetic fiber.

3. LITERATURRE REVIEW

N. Banthia (2007) performed a test method on a rectangular box specimen. A novel test technique for characterization of restrained plastic shrinkage cracking in cementitious materials is described. Results also indicate that fibre reinforcement is considerably effective in reducing shrinkage induced cracking in cementitious materials.

A. Mazzoli (2015) focused on early age shrinkage cracking to reduce shrinkage phenomena through the addition of synthetic fibres within cement matrix. An easy methodology based on image analysis has been developed. And the outcome use of fibres confirmed to be very effective in the width reduction of the cracks and, even if not so significantly, in the length reduction. The most important parameter is confirmed to be the aspect ratio, assuming that the number of fibres is about of the same order of magnitude.

A. Sivakumar (2006) stated that the volume change occurs due to rapid loss of surface bleed water. This leads to shrinking of concrete. Shrinkage typically occurs in a thin concrete element with high surface area. When evaporation rate higher than bleeding rate, it can cause high tensile stresses. This paper reported experimental results of plastic shrinkage studies conducted on high strength silica fume concrete incorporating hybrid combinations of fibres. The conclusions is Plastic shrinkage cracks were reduced significantly by fiber addition by 50–99% compared to plain concrete without fibres .

R. Mishra (2015) carried an investigation on early age shrinkage pattern of concrete, prepared, on 50% replacement of industrial by-product (like pond ash and granulated blast furnace slag) as fine aggregate using OPC, PPC and PSC as a binder. And the conclusion is 1) When PPC cement used as a binder evaporation of water from mix should be avoided or zero moisture movement condition should be maintained to have maximum hydration and strength gain. 2) From shrinkage point of view PSC cement acts like OPC cement.

O. Fenyvesi (2014) carried out experimental work to evaluate early age shrinkage cracking tendency of every mixture. He summarized the length of every crack for each specimen. The average of the summarized crack length of the four ring specimens indicates the crack tendency of mixtures. To evaluate the effectiveness of the different dosages of different fibres, before every sequence, they prepared a reference Fibres were added to the mixture before the water for better mixing of fibres. Outer diameter of the ring is 60 cm, the inner is 30 cm. The height of the ring is 4 cm. To the inner side of the outer formwork steel plates are welded, to increase crack tendency of the specimen. And the conclusion is, the relationship between fibre dosage and early age shrinkage crack tendency was found to be linear in case of every tested type of fibres.

T. Rehman (2015) carried some experimental programs to investigate the influence of application of polyolefin fibers on plastic shrinkage cracks, drying shrinkage, and restrained shrinkage of mortar under laboratory. A mortar mix is evaluated at two different polyolefin fiber contents and without fibers. The test results show that adding polyolefin fibers to the mortar mix can arrest plastic shrinkage cracks and cause a decrease in drying shrinkage whereas they affect the flexural strength slightly. The flexural strength of polyolefin fiber reinforced mortar with 3 kg/m3 increased by 14% compared with plain mortar, however no improvement observed by increasing the amount of fiber to 6 kg/m3.

Application of polyolefin fibers at dosage of 3 kg/m3 reduced the maximum crack width and total crack area by 44% and 51%, respectively. In the case of 6 kg/m3, no cracks were detected. At the age of 56 days, there was a reduction of 11% and 14% for fiber reinforced mortars with dosages of 3 and 6 kg/m3, respectively.

4. METHODOLOGY

- Materials used and mix proportion
- Specimen dimension and casting
- Environmental Chamber
- Image analysis and Crack Measurement
- Compression strength test
- Results and Conclusion.

Materials used and Mix Proportion

Ordinary Portland cement was used for the concrete mixtures. Natural sand with a specific gravity of 2.55 was used as the fine aggregate, while crushed granite of specific gravity 2.65 was used as coarse aggregate. The fibers used in the study were Polypropylene and AR-glass, obtained from manufacturers. Two trial mixtures were prepared to obtain target strength of 40MPa at 28 days. Concrete was mixed by Hand mixing. The coarse aggregate, fine aggregate and cement were first mixed dry for a period of 2-3 min. and then mixed thoroughly by the addition of water in a specified mixing proportion.

Water	Cement	Fine Aggregate Fa	Coarse Aggregate Ca
189	472	583	1136
0.40	1	1.24	2.41

Table 1. Quantity of materials

AR-Glass Fiber	Weight (gm)	Polypro-pylene	Weight (gm)
0 %	0	0 %	0
0.5 %	13.14	0.5 %	13.14
1%	26.29	1%	26.29

Table 2. Fiber content

Specimen dimension and casting

The slab mould of dimension 60x100x200 mm was made of Laminated board. A thin polyethylene sheet was placed over the base to eliminate base friction between the concrete and laminated board. Bolt and nut arrangement were provided at the ends to restrict the longitudinal movement of the concrete slab from the edges and to provide additional restraint. The overlay layer was prepared to obtain target strength of 40MPa at 28days.

The entire operation of placement of overlay layer, external vibration and finishing is completed in less than 10 minutes. The entire assembly is then transferred to the environmental chamber. After 2±1 hr. the chamber is open, and sides of the moulds are removed to expose the specimen to a uniform state of drying. The chamber is then closed and the environmental parameters like temperature, relative humidity and air velocity are maintained for a next 22hrs.

Fig 1. Slab Mould

Environmental Chamber

The test has been performed in a short period of time (24h) in order to focus on cracking related solely to the early age shrinkage. The concrete slabs were stored in an environmental chamber with dimension 175 x 350 x 550 mm as shown in fig. Apart from controlling temperature and humidity this chamber is equipped with a high-speed fan is fixed on the walls of the chamber to accelerate drying on concrete. Also, it is equipped with a digital anemometer which is capable of recording and maintaining the environmental parameters such as air velocity, temperature and relative humidity.

The upper surface of each slab, after casting and finishing, has been exposed to adverse environmental conditions such as: low relative humidity (50 ± 2%), high wind speed (3.9 m/s) and a temperature between33 ± 1 °C in order to assure shrinkage and consequent cracking phenomena

Fig 2. Environmental Chamber

Fig 3. Digital Anemometer

Image analysis and Crack Measurement

The crack measurements comprise of the crack length, crack width (maximum and average) and total crack area. Images of the crack were captured using an optimal zoom camera based on crack visibility; the captured images were processed and edited with image analysis software to get a clear crack profile using various mathematical operations such as binarization, thresholding, cleaning and filtering.

Compressive strength testing

Compressive testing of each specimen has been performed after 28 days. This test has been performed on Compression testing machine (CTM). The results of plain cement concrete and synthetic fiber reinforced concrete are noted in proper manner.

Fig 4. Compression testing machine

5. PROCEDURE FOR CASTING

Mixing Procedure-

We have tried two mix procedures for the mixing of fibers i.e. one specimen was casted by mixing fibers by the procedure of layer by layer and one specimen was casted by mixing the fibers into concrete mixing while mixing of the concrete.

Module 1-

In First module coarse aggregate, fine Aggregate and cement were mixed by dry process then water is added to the mix after that at the time of casting of the mould the one layer of fiber is sandwiched in between concrete mix and then specimens were casted.

Module 2-

In Second module coarse aggregate, fine Aggregate and cement were mixed by dry process then water is added to the mix after that fibers were mixed into the slurry and with that addition of fiber mixed concrete specimens were casted.

We have casted 3-cubes of each sample. i.e. one cube for plain cement concrete, one cube for AR-Glass fibres and one cube of regular cement concrete mix. Also, we are added fibres in the concrete in three different proportions as confirmed by Fiber Suppliers as mentioned above.

1) AR-Glass Fiber
2) Polypropylene Fiber

As casting is to be done for 3-cubes for two different fibres i.e. one for regular mix for module 1 and same as above mentioned for module 2. That means we are casted total 6no.s of cubes for observation and result purpose.

The following steps are to be considered for the casting and observation.

a) Casting of the mould specimen.
b) Placing of specimen in environmental chamber and maintaining environmental parameters.
c) Observation of the cracks.

a) Casting of the mould specimen-

Concrete of compressive strength of 40MPA (@28days) is casted in a mould of size 60x100x200These moulds are kept for 1day under curing condition. After 1day of casting and curing process, the specimen is then removed from wooden mould for the next casting procedure.

b) Placing of specimen in environmental chamber and maintaining environmental parameters.

After doing all the casting process, the specimen is then shifted to environmental chamber where environmental parameters such as air velocity, temperature and relative humidity are maintaining over a period of 1day. After the 2±1 hr casting and placing the specimen under the environmental chamber, the specimen is then removed from the moulds and they again undergo the environmental chamber for a period of 1 day for further observation process.

The environmental parameters are maintained and measure by the instrument called Digital Anemometer in front of the chamber. The anemometer can measure the environmental parameters at once.

c) Observation of the cracks.

Observed the cracks in all concrete specimens (with fibre and without fibre specimens). Then compare d this observation with plain cement concrete. Also checked the shrinkage percentage of both types of specimens (fibre reinforced specimen and plain concrete specimen).

d) Compressive strength test

Tested the all specimens for compressive strength by using compression testing machine (CTM) after 28 days and then compared the results.

6. RESULTS AND OBSERVATIONS

After the 28 days of casting the three concrete cubes namely Regular, Polypropylene and AR- Glass Fiber have been tested in Concrete Testing Laboratory and the following results were obtained as shown in the table.

a. Compression Test Results

Module 1

Specimen No.	Mix	Age (Days)	Strength (MPa)
B1	Regular	28	34
B2	Polypropylene	28	38.50
B3	AR-Glass	28	36.90

Module 2

Specimen No.	Mix	Age (Days)	Strength (MPa)
A1	Regular	28	33.50
A2	Polypropylene	28	36
A3	AR-Glass	28	35

b. Crack Observations

Module 1

Sr. No.	Type	Specimen 1	
		Crack Width	Crack Length
1	Plain Concrete	30.20 – 200.70	320.11
2	AR- Glass Fiber Reinforced	-	-
3	Polypropylene Fiber Reinforced-	-	-

Module 2

Sr. No.	Type	Specimen 2	
		Crack Width	Crack Length
1	Plain Concrete	21.40 – 140.80	302
2	AR- Glass Fiber Reinforced	-	-
3	Polypropylene Fiber Reinforced-	-	-

7. CONCLUSIONS

1. The use of fibers confirmed to be very effective in the width reduction of the cracks and, even if not so significantly, in the length reduction.
2. The addition of Polypropylene and AR-Glass fibers exhibits the best performance: a certain delay in cracking formation and a wide decreasing were exhibited.
3. Results also indicate that fibre reinforcement is considerably effective in reducing shrinkage induced cracking in cementitious materials.
4. The addition of fiber at the time of mixing of concrete, cubes becomes porous that means the w/c ratio has been decreased due to this type of mixing.
5. The Compressive strength of fiber reinforced concrete is greater than regular concrete.
6. The Performance of Polypropylene fiber reinforced concrete is observed more effective than AR fiber reinforced concrete.

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