International Journal of Engineering & Technology, 7 (3) (2018) 1544-1547

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i3.13906
Research paper

Study on strength and durability characteristics of polypropylene fiber reinforced blended concrete tiles

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Abstract

Concrete is brittle and widely used as an artificial construction material with incorporation of cement, water and aggregate in necessary proportions. To overcome the brittle behavior of composites, fibers and admixture are added to the concrete. In this present investigation Polypropylene Fiber is added in varying percentage (0.2%, 0.4%, 0, 6%, 0.8% and 1%) to the weight of cement and constant percentage of Rice Husk Ash (15%) is replaced with cement. The polypropylene fiber reinforced blended concrete tiles of size 300mm x 300mm x 30mm are cast as per the code and tested at 28 days curing period. Flexural strength, Abrasion test, Dimensional quality and water absorption are studied. Among different proportion of Polypropylene Fiber Reinforced Blended Concrete, the best performance is achieved by the combination of 15% of Rice Husk Ash with 0.6% of Polypropylene Fiber.

Keywords: *Polypropylene Fiber; Rice Husk Ash; Flexural Strength; Abrasion Test; Water Absorption.*

1. Introduction

Concrete is brittle and widely used as an artificial construction material with incorporation of cement, water and aggregate in necessary proportions. However concrete is a brittle material, poor in crack resistance and have low tensile strength. To overcome the brittle behavior of composites, fibers and admixture are added to the concrete. Even though concrete has many advantages in relevance due to its mechanical and durability characteristics; the brittle behavior of the concrete material remains larger. However behavior of concrete depends by its strength and durability characteristics. Fibers are usually used in concrete to control plastic shrinkage and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce the bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete [14]. The use of fibers has increased tremendously in construction of structures because; addition of fibers in concrete improves the flexural strength, tensile strength and impact strength. Pozzalonic materials are used in concrete for reducing the quantity of cement required for concrete which leads to reduction in pollution as well as construction cost.

Polypropylene fiber reinforced concrete 0.05-0.4% with good choice of length and content in fibers improves ductility and impact strength of concrete [1]. The presence of polypropylene fibers delayed the degradation process and slowed crack growth by forming Connection Bridge [11]. The addition of polypropylene fiber to the concrete was not effective in enhancing the cracking load of concrete, but thick polypropylene fiber increased the ultimate load after cracking and the energy absorption capacity of the concrete [12]. Some of the early researches have examined the use of rice husk ash (RHA) as highly pozzolanic material in concrete. The non crystalline silica and large specific surface area of the RHA is responsible for its high pozzolanic activity. Up to 40% replacement of cement with RHA can be made with no significant change in the compressive strength as compared to the controlled mix, if the rice husk is burnt under optimum temperature condition The reactivity of RHA depends on its surface area, thus it depends on the environment and temperature of the combustion chamber [2] [3][5] [6] [13] [15].

The effect of fibers on the behavior of hardened concrete tile vary depending on the concrete material, mix proportions, fiber type, length and quantity of fiber added. Research from various sources though generally agrees that adding synthetic fibers to concrete can improve the Impact resistance, Abrasion resistance, Permeability properties and Toughness. Concrete tile made with Portland cement are strong in compression but weak in tension and tends to be frail. The use of fibers changes the behavior of the fiber-matrix composite after it has cracked. However the growth of polypropylene fiber reinforced concrete with supplementary cementitious material RHA has provided a scientific source for improving the deficiencies. Therefore the aim of this investigation is to accrue the benefits of RHA and Polypropylene Fibers in the manufacturing of tiles.

2. Objective of the study

The main objective of this research is to evaluate Flexural, Abrasion, Water Absorption characteristics for different proportions of polypropylene fiber with 15% of RHA.

3. Experimental program

3.1. Materials

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Cement and RHA are used as cementitious materials. The Ordinary Portland Cement of 53 grade confirming to [8] is used in this investigation. The RHA is used as a partial replacement of cement. The specific gravity of cement and RHA are 3.15 and 2.67 respectively. The fineness of cement and RHA is found to be as 2950cm^2/gm and 2170 cm^2/gm respectively. The chemical composition of cement and RHA are shown in Table 1. A chemical admixture in the form of Sulphonated Naphthalene Polymers (CONPLAST-SP 430) with specific gravity 1.220 – 1.225 complies with (IS: 9103, 1999) and ASTM 494 type F is used to increase the workability of concrete [7] [4]. Locally available River sand is used as fine aggregate with 7.22 fineness modulus and specific gravity as 2.74. Crushed aggregates of size 10mm with specific gravity 2.57 are used as coarse aggregates. Both the aggregate are complied with the requirements of [10]. Market forms of Recron 3s Polypropylene Fibers from Reliance industry are employed in this investigation. Monofilament Polypropylene Fibers of length 6 mm with filament diameter 40 microns, triangular cross section of specific gravity 0.91 are used.

Table 1: Chemical Properties of Cement and RHA

Material	Chemical composition (%)		
	$SiO_2+Al_2O_3+Fe_2O_3$	CaO	LoI
Cement	26.18	61.60	1.7
RHA	82.64	0.99	3.49

3.2. Casting and curing of tiles

As per the guidelines of [9] the tiles of size 300mm x 300mm × 20mm are cast. The constituent of tiles are the mixture of ordinary Portland cement, natural aggregates, RHA and Polypropylene Fibers. RHA is partially replaced to cement by 15% for all mixes and Polypropylene Fiber is added to concrete in various percentages of 0.2%, 0.4%, 0.6%, 0.8% and 1% to the weight of cement. The concrete is prepared, poured in the moulds and vibrated using vibrator table. The tiles are layered and care is taken to prepare and noted that the tile does not exceed + or - 10% of the minimum thickness. The moulds are placed upside down on the surface and allowed to set for 24hrs. After 24hrs it is demoulded and placed in water for curing.

3.3. Test procedure

3.3.1. Flexural strength

Tiles of each 10 numbers of same type, class, shape and size for varying proportions of fiber (0.2%, 0.4%, 0.6% ,0.8% and 1% with RHA 15% are cast. Before testing the tiles are soaked in water for 24 hrs. The specimens are placed horizontally on two parallel steel supports, with wearing surface upwards and its sides parallel to the supports. One of the supports shall be self-adjusting. The load is applied by means of a steel rod parallel to the supports and midway between them. The length of the supports and the loading rod should be longer than the tile. The span between the supports is 250mm. Plywood padding about 3mm thick and 20 mm wide is placed between the tile at each supports and between the tile and the steel rod. The length of the padding shall be at least as long as the tile. The load is applied gradually and at a uniform rate not exceeding 2000 N per minute, until the tile breaks. The load P is recorded. The thickness t shall be determined as the average of two measurements at the location of the fracture, 50 mm from each edge. The flexural strength f shall be calculated as per IS 1237:2012

$$f = \frac{3pl}{2bt^2}\ N/mm^2$$

Where, P = breaking load in N,
l = span between supports in mm,
b = tile width in mm,
t = tile thickness in mm.

3.3.2. Abrasion test

Ten full size tiles of same type, shape and size with varying fiber proportions are cast. Test specimen is 50cm^2 in area. 50cm^2 are sawn only from each tile, preferably from the central part of the tile. The deviation in the length of the specimen shall be within ± 2%. The surface to be tested is ground smooth. Specimens are dried at 110º ± 5ºC for 24 hrs, after initial drying weight is taken. Grinding path of the disc of abrasion machine shall be evenly strewn with 20gm of abrasive powder. A load of 300 N is placed at the centre and subjected to 220 revolutions. At every 20 revolutions 20gm of abrasive powder should be strewn off. The disc, specimen, and abrasive powder shall be kept dry throughout the duration of the test. After 220 revolutions, the specimens are reweighed. Wear of the specimen is determined from the difference in reading obtained by measuring instrument before and after the abrasion of the specimen. The average loss in thickness for varying proportions of tiles are calculated using the formula as per IS 1237:2012.

$$t = \frac{(W1 - W2)V1}{W1 \times A}$$

Where, t = average loss in thickness, mm
W_1 = initial mass of specimen in gm
W_2 = final mass of the abraded specimen in gm
V_1 = initial volume of the specimen in mm^3
A = surface area of the specimen in mm^2

3.3.3. Dimensional quality test procedure

Tiles of each 10 numbers of same type, class, shape and size for varying proportions of fiber (0.2%, 0.6%, 0.6%, 0.8% and 1%) with RHA 15% are cast. The same count of tiles is tried for each type of test. For confirming the dimensional quality following tests are performed according to (IS 1237, 2012).

1) Flatness of Tile Surface: The flatness is checked by using the ruler which should be greater than the diagonal of the specimen.
2) Perpendicularity: The gap between the arm of the square and the edge of the tile should be 4mm
3) Straightness test: The tiles should be straight in all four edges

3.3.4. Determination of water absorption

Tiles of each 10 numbers of same type, class, shape and size for varying proportions of fiber (0.2%, 0.6%, 0.6% ,0.8% and 1% with RHA 15% are cast. The tiles are immersed in water for 24 hrs. The tiles are taken out and wiped dry. Each tile weighed immediately after saturation and wiped off. The tile is then oven-dried at a temperature of 65 ± 1ºC for a period of 24hrs, cooled to a room temperature and reweighed. The water absorption for varying proportions of tiles are determined as per IS 1237:2012.
Percentage of water absorption by mass

$$= \frac{M1 - M2}{M2} \times 100$$

Where, M1 = mass in gm of the saturated specimen.
M2 = mass in gm of the oven-dried specimen.

4. Results and discussion

The polypropylene fiber reinforced blended concrete are subjected to mechanical and durability characterization. Its mechanical and durability properties studied are analyzed and compared. The results revealed that the CPPR6 mix exhibits better mechanical and durability properties. The polypropylene fiber has good impact and fairly high proportion of stiff, amongst the other fibers. Finer RHA incorporated in the concrete results in denser concrete matrix.

4.1. Flexural strength

The flexural strength results of varying proportions of polypropylene fiber reinforced blended concrete tiles after 28 days curing are shown in Fig.1. The results indicate that the flexural strength decreases beyond 0.6% of polypropylene fiber content in the mix. From Fig.1 it is evident that 0.6% of polypropylene fiber with 15% of RHA shows the maximum flexural strength of 3.98 N/mm^2 at 28 days curing. However when percentage of fiber is increased the balling effect of fiber reduce the bridging of fibers finally flexural strength decreases.

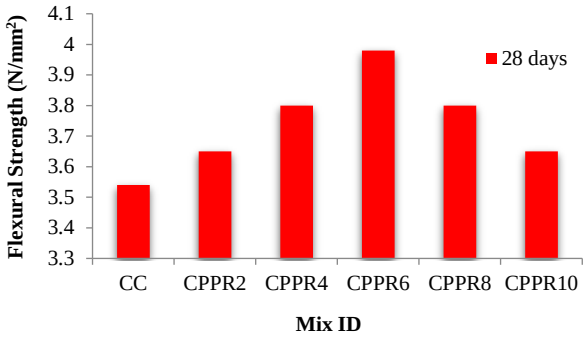


Fig. 1: Variation of Flexural Strength Test Result.

4.2. Abrasion test

Abrasion indicates the toughness as well as the extent of wear of a material when it is subjected to the revolution and gives a measure of loss in thickness of the material. On observation from Fig.2 CPPR6 mix shows better results than other mixes.

4.3. Dimensional quality test procedure

Tiles of each 10 numbers of same type, class, shape and size for varying proportions of fiber (0.2%, 0.6%, 0.6% 0.8% and 1%) with RHA 15% are cast.

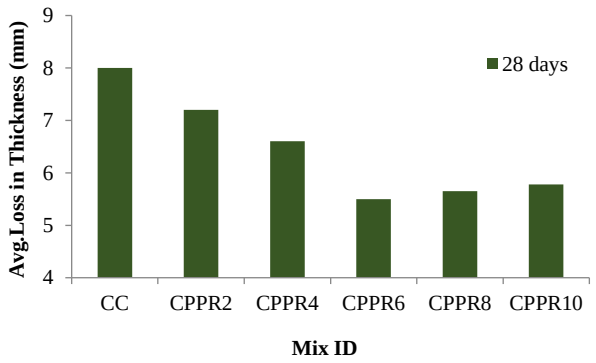


Fig. 2: Variation of Abrasion Test Result.

The same counts of tile are tried for each type of test. The dimensional quality are confirmed as per (IS 1237:2012).

1) Flatness of tile surface: The flatness has been checked by using the ruler which is greater than the diagonal of the specimen.
2) Perpendicularity: The gap between the arm of the square and the edge of the tile are 4mm
3) Straightness: The tiles are straight in all four edges.

4.4. Water absorption test

Specimens are tested for each mix and the average water absorption percentage for 28 days cured specimens are shown in Fig.3. It is observed that the higher value of 2.71 % of water absorption is found in control concrete mix when compared to other mixes. Whereas, CPER6 mix shows the lowest water absorption percentage as 1.06 %. The percentage reduction in water absorption is observed in all blended concrete mixes when compared to control concrete. This may be due to the formation of secondary C-S-H gel present in concrete resulting in nonporous structure.

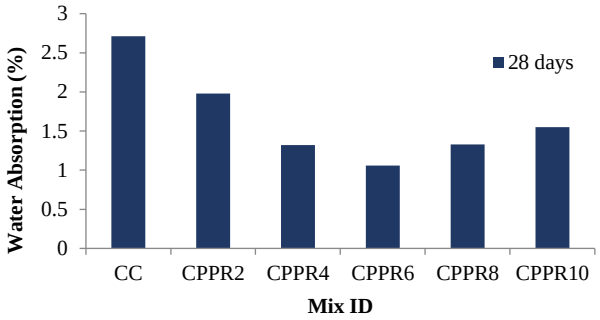


Fig. 3: Variation of Water Absorption Test Result.

5. Conclusion

Based on the experimental investigation of polypropylene fiber reinforced blended concrete tile the following conclusions are made. The concrete mix gets harsher and less workable with increase of fiber content. It is noticed that beyond 0.6% of fiber and 15% of RHA the strength and durability properties get reduced. At the age of 28 days, there is a significant improvement in the flexural strength and abrasion value with the addition of fibers. The increment in the flexural strength is from 3.65% to 3.98% and that of loss in thickness is from 7.2mm to 5.5mm when percentage of fiber varied from 0.2% to 0.6% respectively. In the case of dimensional quality the visual examination results are well compared to the actual specifications of the code (IS: 1237-1980) and found good. As the fiber content is increased from 0.2% to 0.6% there is a decrease in the water absorption from 1.98 % to 1.08 % beyond that water absorption increases. Though the combinations of polypropylene fiber and RHA have some merits and demerits, the mixture of the useful properties of two different materials, make them as a versatile material in the construction industries.

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