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Research paper

Experimental Study on Functionally Graded Steel Fibre Reinforced Preplaced Aggregate Concrete

Ram Prasad. K[1], Murali. G[2], Parthiban Kathirvel[3], Haridharan M K[4], Karthikeyan. K[5]

[1, 2, 3]School of Civil Engineering, SASTRA Deemed University, Thanjavur, Tamil Nadu, India
[4]Department of Civil Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India
[5]Assistant Professor (senior), SMBS, VIT Deemed University, Chennai, Tamil Nadu, India
Corresponding Author E-mail: [2]murali_220984@yahoo.co.in

Abstract

This study examines compressive strength of this functionally graded steel fibre reinforced concrete (FGFRPAC). A five mixes were prepared and tested in the present study. The first series of FGFRPAC were prepared and reinforced in three layers of 3%, 1.5% and 3% with crimped, hooked end. The second series were reinforced with 2.5% steel fibre equally in all the three layers. The average amount of fibre used in FGFRPAC specimen was 2.5% which is similar to the fibre dosage used in the second series were the fibres are equally spread in all the three layers. The gathered results revealed that employing FGFRPAC leads to more enhancement in compressive strength than conventional steel fibre reinforced concrete.

1. Introduction

Functionally graded preplaced aggregate is a unique kind of concrete casted by different method compared to that of normal concrete. In preplaced aggregate concrete the coarse aggregate volume is laid in the mould and grout injects to fill the voids. In recent years preplaced aggregate concrete has been used in many applications like underwater construction works, and concrete repair [1,2].Steel fibers have been used for several years for various application like tunnel linings, pavement bridge decks etc [3,4]. The use of steel fiber in concrete have minimized the crack forming mechanism and reducing the crack width and limiting its propagation. Moreover the addition of steel fibre have amended the fracture toughness of concrete [5, 6]. It was reported that by using 1% fibre dosage had minimum effect on the compressive strength of SRFC, while the splitting and flexural strengths have significantly increased [7]. Thus, the ACI 544.1 has restricted the maximum practical usage of fibre dosage in concrete produced by general procedures as 1.5-2% [8].

2. Experimental Program

2.1 Materials and Grout Mixture Proportion

Ordinary Portland cement (OPC) of specific gravity 3.14 is used in this experiment. River sand of 1.47 modulus of fineness and specific gravity of 2.65 is used as fine aggregate. It is observed that fine sand is suitable for preplaced aggregate concrete since the grout mixture has to flow through the course aggregate and fill the voids between them. Grout mixtures with sand-to-binder ratio of 1.0 and water-to-binder ratio of 0.50 were used in the casting of Preplaced aggregate Steel Fibre Reinforced Concrete (TSSFRC). After preparing the grout mixture, the grouts efflux time was calculated based on ASTM C939 [9].

Numerous trial grout mixture were employed to meet the efflux time of 35- 40 seconds as per the guidelines of ACI 304.1[10]. Flow cone with capacity shown in Fig. 1. Two types of steel fibres and their properties were listed in Table [1] and geometry is shown in Fig 2. Steel fibre dosage used in TSC is 2.5% and was filled in two different types of orientations, one is the 3D TSSFRC and another one is the fuctionally graded TSSFRC.



Fig. 1A: Hooked end steel fibre



Fig. 1B: Crimped steel fibre

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Fig. 2: calculation of efflux time

Table 1: Properties of Steel Fiber

STEEL FIBRE	LENGTH	DIAMETER	ASPECT RATIO
HOOKED END	30	0.5	60
CRIMPED	12.5	0.45	27.77

2.2 Experimental Procedures

For flow cone test, before filling the grout sample in the cone the inner part of the cone is wetted by filling the cone with water till the top layer and allow the water to discharge through its outlet pipe. The cones discharge pipe is closed using rubber stopper or finger. The grout mixture is poured in the cone till it rises to the contact level. Watch is started when the stopper or finger is removed from the discharge pipe and stop it when there is a break in the ceaseless pouring of grout. Check whether grout has completely passed through the discharge tube and the efflux time is the time indicated in stop watch. If the grout is not completely poured from the cone then the flow cone test is not applicable to the mixture.

Four FGFRPACcubical specimens (150mm) and one TSC cubical specimen (150mm) were prepared. In 3D FGFRPACthe coarse aggregates and the steel fibres are preplaced randomly in the mould. The grout mixture was injected using gravity method where the grout is poured directly atop of the aggregate and allowed to penetrate to the bottom layer under its own weight [11]Fig 3. For the FGFRPACthe steel fibres are filled in such a way that the top and bottom layer have more amount of fibre dosage as compared to that of middle layer. The main reason is to increase the fibre dosage on the impact surface of the specimen. The specimens were removed from their mould after 24 hrs and placed for moisture curing for 28 days. The compressive strength were evaluated as per ASTM C943 and for the compressive strength test, the FGFRPACspecimen were centered in the compression testing machine and the load was applied at a steady rate of 0.25 MPa/s until failure.

3. Results and Discussions

3.1 Flow Cone Test

Table 2 presents the efflux time results obtained for the different grout mixtures using flow cone test. It is clear that the efflux time is directly based on the water cement ratio, as the water cement ratio increases the efflux time value gets decreased. The optimum value is obtained for 0.50 water cement ratio and this consistency is used for the grout mixture in this experiment.

Table 2: Calculation of efflux time

S.NO	W/C	EFFLUX TIME (SEC)
1	0.45	15
2	0.50	29
3	0.55	21
4	0.60	18
5	1.00	7.3

3.2 Compressive Strength Test

Table 3 represents the compressive strength values obtained for different FGFRPACassimilating various different steel fibre volumes. From the results in Table 3 it is seen that specimen assimilating steel fibre acquired higher value of compressive strength than the plain preplaced aggregate concrete mix. The steel fibred specimen achieved 17.85% higher compressive strength than the plain preplaced aggregate concrete mix[12,13]. The volume of steel fibre used in normal concrete mix is confined to 2% due to factors like workability and uniform proportioning of steel fibre[14,15]. The mix assimilating more than 2% of steel fibre may lead to honeycombing, balling of fibre and creating more amounts of voids in the mixture[16]. Contrarily in the preplaced aggregate concreting method higher steel fibre can be used eliminating such problems[17]. The mix associating hooked end steel fibre had a higher compressive strength than the crimped steel fibre, it is seen that Hooked end Fibre Reinforced Concrete (HFRC) attained 3% increase in compressive strength than that of Crimped Fibre Reinforced Concrete (CFRC). The FGFRPACattained higher compressive strength than the normal 3D FGFRPAC. Using crimped steel fibre the functionally graded system attained 2.34% higher compressive strength than CFRC. Using hooked end steel fibre this functionally graded system FGHFRC attained 3.45% increase in compressive strength than HFRC.

Table 3: Compressive strength of TSSFRC

S.no	Mix id	W/c	S/b	Type of Steel Fibre	Steel Fibre Layer			Compressive Strength
					1	2	3	
1	PC	0.50	1	-	-	-	-	32.61
2	HFRC			Hooked end	2.5	2.5	2.5	48.15
3	FGHFRC				3	1.5	3	50.49
4	CFRC			Crimped	2.5	2.5	2.5	48.99
5	FGCFRC				3	1.5	3	53.33

4. Conclusions

This study reveals the conception of FGFRPAC where the steel fibres are gradually divided in layers where the top and bottom layer of the specimen consist of more amount of fibres than the middle. Conclusion revealed from this experimental procedure is drawn below:

In spite of additional cost of steel fibre, the preplaced aggregate concrete has strength benefits since the coarse aggregates are directly laid in the mould and it requires a very less compaction. It is eco-friendly since the amount of cement is reduced as compared to the normal conventional concrete.

In conventional concrete the steel fibre volume is fixed upto 2% whereas in preplaced aggregate concrete we can increase the fibre dosage and thereby increasing the efficiency of concrete.

Preplaced aggregate concrete provides cost benefits since more amount of coarse aggregates are directly laid in the moulds and mixing and pumping works gets reduced.

Compressive strength increases with increase in steel fibre volume and steel fibre length had minimal effect on compressive strength.

While comparing the results of hooked end and crimped steel fibre the compressive strength of hooked end steel fibre was found to be much higher.

The compressive strength value of Functionally graded steel fibre reinforced concrete were found to be higher than that of normal steel fire reinforced concrete, this is due to the fact that more

amount of fibre were placed in top and bottom layer and reducing their amount in middle portion of the specimen.

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