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Article

Study on Flexural Behavior of Carbon Fibre Reinforced Precast Roof Slab Panels

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A B S T R A C T

The paper presents the results of an experimental investigation and analysis is carried out to assess the strength of pre-cast roof slab system for different sizes and composites. The size of pre-cast slab panels considered in the experimental investigation is 2400 x 300 mm, 2700 x 300 mm and 3000 x 300 mm. The thickness of the specimen is kept constant as 50mm.The flexural behavior of pre-cast slab panel reinforced with internal wrapping of carbon fibre sheet and RCC slab panel is compared with plain concrete slab panels. In the design of panels, the cement was replaced by 30 % fly ash. This pre-cast roof slab system proves out to be a cost effective, reduces dead weight, eliminates complicated formwork, and structurally safe and viable alternative for low cost housing. The experimental result shows that there is 56.6% increase in flexural strength of carbon fibre sheet reinforced slab panel compared to plain concrete slab panel. Analysis of the slab panel is carried out using ANSYS software also but in this paper included only experimental investigation details.

Keywords: Precast Slab Panel, Random Distribution and Internal Wrapping of Carbon Fibre, Three-Point Bending Test, Flexural Strength

Introduction

Due to acute housing shortage there is a need for the development of an appropriate cheap construction technology. Thus any effort in the direction of reduction in time consumption for casting and cost of housing elements will be a valuable contribution and service to the society. To optimize the cost the cement is replaced by fly ash.[4] Corrosion of reinforcement in RCC structure is major problem affecting infrastructure hence the steel is replaced by carbon fibres.[2]

Carbon fibers are inert, medically safe, chemically stable, low in density, and their strength-to-density ratio is one of the highest among all fiber types. Addition of discontinuous fibers to concrete makes it a homogeneous and isotropic materials and converts brittleness into a ductile behavior.

Materials

Cement

Ordinary Portland cement of 43 grade confirming to IS: 8112-1987(9) with a specific gravity of 2.98 was used in the present study.

Fine Aggregates

Natural sand as per IS 383-1970 is used in the work. The fine aggregate passing through 4.75mm sieve and had a specific gravity of 2.65 is used for the present work.

Coarse Aggregate

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 10 mm down of specific gravity 2.78 and fineness modulus 7.20 are used.

Carbon Fiber Sheet

The carbon fiber sheet used in this study is supplied from FOSROC chemicals Bangalore. The fibers sheet is used to replace the steel reinforcement. The engineering properties of the fibers are shown in table 1.

Table 1.Properties of Carbon Fiber sheet

Properties of carbon fibre	
Fiber orientation	**Unidirectional**
Weight of Fiber	200 g/m^2
Density	1.80 g/cm^3
Fiber thickness	0.3mm
Tensile modulus	28500 N/mm^2
Tensile strength	3500 N/mm^2
Ultimate elongation	1.50%
Modulus of elasticity	1.65×10^5 N/mm^2
Poisson's ratio	0.25

Fly Ash

The fly ash used in the experimentation is obtained from Raichur Power Thermal Station, Raichur. The chemical composition of fly ash is shown in table 2 below.

Table 2.Properties of Fly Ash

Chemical	Percentage
Silica (SiO_2)	56.88
Alumina (Al_2SO_4)	27.65
Iron oxide (Fe_2O_3)	6.28
Alkali's ($Na_2O + K_2O$)	0.46

Literature Review

E. Mohamedelhassan et al. (2014) studied experimentally and investigated the change in concrete properties with addition of cellulose, carbon, steel and PET fibers. Carbon fibers increase the flexural and tensile strengths by up to 11% and 45%, respectively.

J.M.L. Reis et al. (2014) studied the fracture properties of epoxy polymer concrete reinforced with short carbon and glass fibers. The fibers were blended in the polymer concrete mix by 1% and 2% of the total weight, and the fiber lengths considered was in average, 6 mm long. Their result shows that fracture toughness is increased by 29 % and 12% for carbon and glass fibres.

Chen and Chung et al. (1993) conducted an experimental investigation on the improvement of the flexural properties of concrete specimen using carbon fibres. They utilized carbon fibres of 0.5% by weight of volume, together with chemical agents and silica fume, in concrete. The results showed that flexural strength increase by 85%, a compressive strength increment by 22%. They conclude that base carbon fiber content or minimum carbon fibre content for flexural strength increment was 0.1vol%.

Jagadesh. Sunku et al. (2006) In this study 30 to 35% of fly ash is used as a cement replacement in the production of fibre cement sheets. Results show that fibre cement sheets made with up to 40% of fly ash replacing the cement content are meeting the minimum load bearing strength of 5000 N/m after 10 days.

Methodology

Total eighteen numbers of slab panels were casted for the present work. Out of which six slab panels for each PCC and RCC controlled slab panels and remaining slab specimens were casted with randomly distributed carbon fibers. Size of the slab panels are 2.4 x 0.3x 0.05m, 2.7x 0.3x 0.05m, 3x 0.3x0.05m. 0All the slab panels were casted using 30% of replacement of cement by fly ash. The constituents were weighed and the materials were mixed by hand mixing for M20 grade of concrete with the designed mix proportion of 1: 1.78: 1.55: 0.45(C: FA: CA: W).All tests are conducted at the age of 28 days.

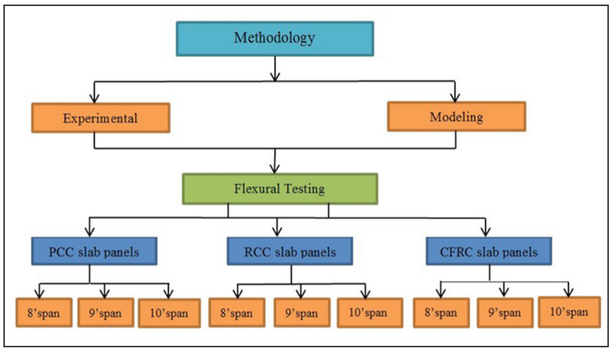

Figure 1.Tree Diagram Showing Methedology

Experimental Work

Mix Design

The mix deign of M20 grade concrete is carried out according the Indian standard recommended method IS 10262-2009.

Table 3.Properties of Fly Ash

Description	Cement	FA	CA	W/C
Proportion	1	1.78	1.55	0.5

Design of Slab Panel

Design of simply supported one-way slab over a clear span of 2.4m, 2.7m and 3.0 m is as follows. It carries a live load of 1.5kN/m^2. The width of supporting wall is 230 mm. Adopt M-20 concrete & Fe415 steel. Main bars of 3 no's of 8mm diameter and distribution bars of 6mm diameter with spacing of 300mm c/c is provided.

Casting of Specimens

For conducting experiment, 6 number of each Plain concrete slab panels, RCC slab panels and Carbon fiber reinforced (Random distribution, internally wrapped and Random with internally wrapping) precast slab panels of three different spans are casted.

The size of the panel is 2.4m, 2.7m and 3m in length with fixed width and thickness of 0.3m and 50mm respectively. The calculated mix proportion is 0.5: 1:1.78:1.55 as water, cement, fine aggregate and course aggregate. The moulds of required size are prepared using water proof plywood.

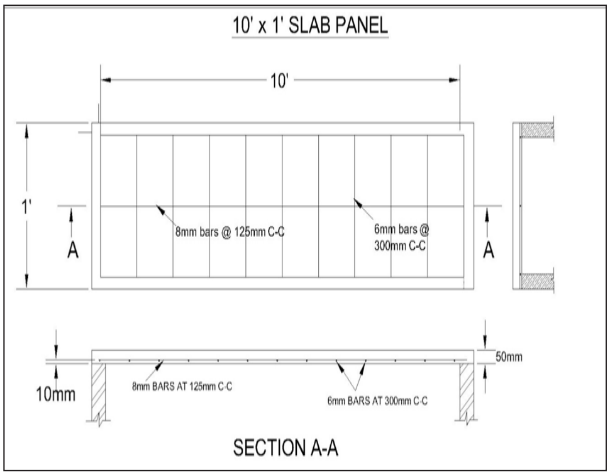

Figure 2.Reinforcement Details for slab panel

Carbon Fibre Reinforced Slab Panel

For internal wrapping slab panels, uniformly mixed concrete is poured in to the mould and uniform tamping is carried out for the first layer of depth 12.5mm. The carbon fibre sheet of desired dimension is cut and laid on the first layer. The concrete is poured in to the slab in two layers with uniform compaction. For random distributed slab panels, the technique of dispersing the carbon fibres randomly in the concrete mix is critical to the success of carbon fibre reinforced concrete technology. In the present work dry mix method is used for mixing of carbon fibres. In this procedure first we have to mix the fibres of 0.5% by weight of concrete with cement and fine aggregates in the dry state and mix it with coarse aggregate.

Add the water to dry mix and mixed uniformly. The mixing of total mass will be continued until the binding paste covered all the aggregates and mixture become homogeneous and uniform in colour. After casting, the specimens are stored in the laboratory for 48 hours from the time of addition of water to the ingredients. After this period, the specimens are removed from the moulds and kept for curing. The curing of the specimens is carried out using gunny bags. The flexural test is conducted at the age of 28 days.

Figure 3.Internal wrapping

Figure 4.Randomly Distributed Carbon Fibres

Three-point flexural test

The testing procedure for the all the specimen is same. The slab panels are cured for a period of 28 days then it is kept for drying for an hour before testing. All specimens were loaded in Three-point loading. Specimens are loaded symmetrically about its centreline with keeping the support length of 115mm from the edge at both sides. Load setup is done as shown in fig 5 below.

Figure 5.Load setup for single point loading

Result and Discussion

The test results and load-deflection curve for both RCC slab panel and carbon fibre reinforced slab panel are shown in the following tables and figures below. The test results of plain concrete show an ultimate load of 1.93kN, 1.9kN and 1.84kN is recorded for slab panel of length 2.4m, 2.7m and 3m respectively.

Load-Deflection curve of RCC slab panel

It is experiential that as the applied load increased, the initial cracks were formed and the slab experienced a slight gradual loss in stiffness. It is experiential from the tables that the maximum load of 4350N is carried by the RCC slab panel L_1 and the maximum deflection at ultimate load is observed in RCC slab panel L_3.

Load-Deflection curve of Carbon fibre reinforced slab panel (Random Distribution, Internal Wrapping and Random with internal wrapping)

For randomly distributed carbon fibre reinforced slab panel the ultimate load is observed as 4500N. The maximum increase in the ultimate load is 47% greater than plain concrete slab panel. Load deflection curve for randomly distributed carbon reinforced slab panels is shown in table 5.

For internally wrapped carbon fibre reinforced slab panel the ultimate load is observed to be 4400N. The maximum increase in the ultimate load is 56% greater than plain concrete slab panel. Load deflection curve for internally carbon sheet reinforced slab panels is shown in table 5.

For randomly distributed with internally wrapped carbon fibre reinforced slab panel the ultimate load is observed to be 4250N. The extreme increase in the ultimate load is 54% greater than plain concrete slab panel. Load deflection curve for randomly distributed with inside wrapped carbon reinforced slab panels is shown in table 5.

Flexural Properties

In this all the flexural properties obtained from test results are tabulated for all slab panels with different compositions. All the hardened properties of control slab panel's panels. The test results of plain concrete slab panel show a Flexural strength of 8.95, 9.54 and 10.34N/mm2 is recorded for slab panel of length 2.4m, 2.7m and 3m respectively. Flexural properties of RCC and Carbon reinforced slab panels are tabulated in table 5.

The experimental results pointed out important differences between composites both for the ultimate load, maximum deflection, flexural strength and the modulus of elasticity as shown in table 5.

Cost Analysis

The cost of conventional RCC slab panel of depth 150mm for slab panel is analyzed based on the quantity of materials required. The cost of RCC and carbon fibre reinforced slab panel based on the quantity of materials is presented in the following figures.

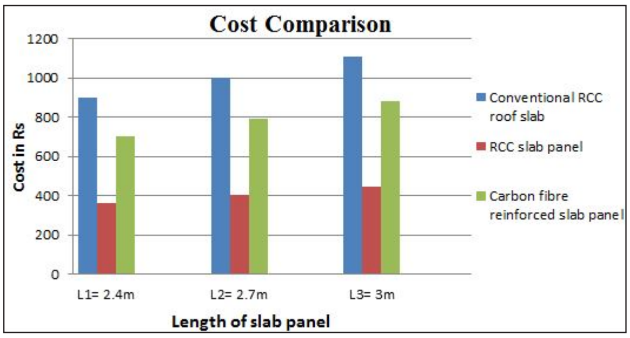

Figure 8.Cost comparison

It is observed that the RCC slab panel of depth 50mm is 60% cost effective compared to conventional slab. The carbon fibre sheet reinforced slab panel of depth 50mm is seen to be 22% cost effective compared to conventional RCC slab. The carbon fibre reinforced slab panel of depth 50mm is seen to be 30% costlier than the conventional RCC slab because prices found in this research were for laboratory amounts. Cost will be reduced when buying the all the materials in bulk. It also observed that dead weight of the slab was reduced as compared to the conventional RCC slab panels because of reduced thickness of slab panels.

Conclusion

- The ultimate load carrying capacity of all the slabs reinforced with carbon fibres were enhanced as compared to the Control slabs.

Table 4.Calculation of flexural parameters

	Size of panel (m)	Ultimate Load (N)	Maximum Deflection (mm)	Flexural stress (N/mm^2)	Flexural strain	Flexural Modulus (GPa)
RCC	2.4	4350	5.15	19.14	0.00032	60.01
	2.7	4230	4.84	21.21	0.00023	92.02
	3	3800	5.8	21.36	0.00022	96.99
Random Distribution	2.4	4500	2.91	19.56	0.00017	10.92
	2.7	4250	3.11	21.03	0.00014	14.25
	3	3900	3.09	21.63	0.00011	185.6
Internal wrapped	2.4	4400	4.45	19.36	0.00028	70.18
	2.7	4350	5.22	21.84	0.00024	89.47
	3	3850	3.89	21.64	0.00015	116.58
Random Distribution with internal wrapping	2.4	4250	4.45	18.44	0.00028	65.05
	2.7	3800	4.8	19.51	0.00023	83.98
	3	4000	5.175	20.77	0.0002	102.67

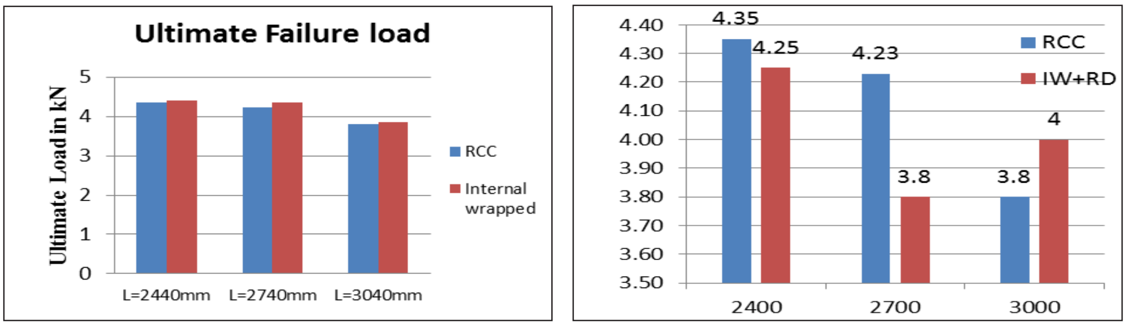

Figure 6.Variation of Ultimate load comparing RCC and carbon fibre reinforced slab panel

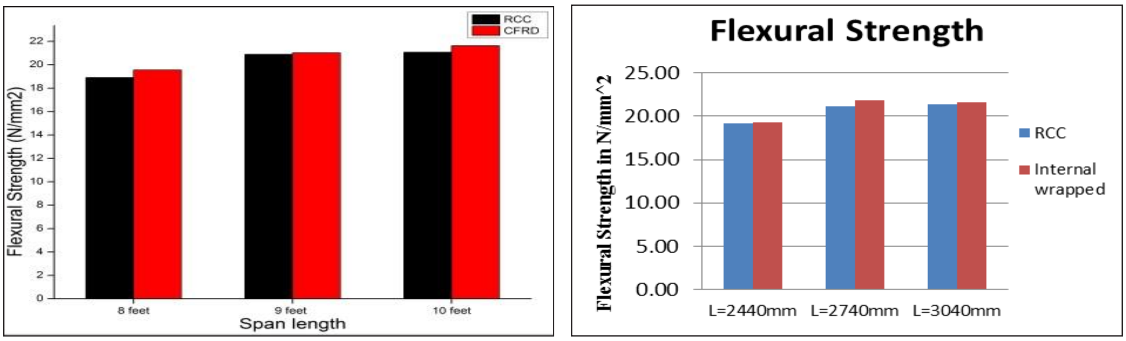

Figure 7.Variation of Ultimate load comparing RCC and carbon fibre reinforced slab panel

- Ultimate load carrying capacity of 2.4m feet slabs is more as compared to the other span length slabs in random.
- distributed slab panels. And the maximum increase flexural strength by 56.6% is observed in the carbon fibre sheet reinforced slab panel of length 2.7m.
- The cost of RCC slab panel is observed to be 60% cost effective compared to conventional RCC slab of depth 150mm.
- The cost of Carbon fibre sheet reinforced slab panel is observed to be 22% cost effective compared to conventional RCC slab of depth 150mm.
- The cost of Carbon fibre sheet reinforced slab panel is observed to be about 25% costlier for internally wrapped and 30% costlier for random distributed as compared to the conventional RCC slab of depth 150mm.
- When analyzing the impact on concrete price, the use of carbon fibers made concrete judiciously more exclusive, but the price increase was compensated by the enhanced presentation.

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