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Precast Carbon Fibre Reinforced Footing

Sharanabasava Patil

PG Scholar, Department of Civil Engineering, BVBCET, Hubballi, Karnataka, India - 560019

Abstract - *Prefabrication has been used widely and extensively for many years around world. The concept of precast or prefabricated construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. This paper describes and implements the main features of different low-cost construction processes.*

Key Words*: *Prefabrication, Precasting, Reinforcement, RCC Footing, Fibre Reinforced Polymers

1. INTRODUCTION

Prefabrication has been used widely and extensively for many years around world. However, the first prefabricated building is known to be constructed in the year 1905. In the early years, stone and logs materials were used extensively, and such a construction was called as ultra-light construction. However, after the end of World War I the boom in the prefabrication market was occurred. And since then, massive prefabricated buildings have been constructed, owing to the fluctuating trends in construction industries and demand for homes at cheaper rate, due to tremendous losses suffered in World War 1.

The concept of precast or prefabricated construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly[1][2]. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost.

The main features of this construction process are as follows.

- Quality of the product can be controlled i.e. durability increase.
- Rapid construction can be achieved i.e. speed of construction increased.
- The division and specialization of the human workforce.
- The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products.

1.1 Study of Carbon Fibre Sheets

Carbon fiber is a material consisting of fibers about 5-10 μm in diameter and composed of mainly carbon atoms [4][7]. The carbon atoms are bonded together in crystals that are aligned parallel to the long axis of the fiber. The crystal alignment gives the fiber high strength to volume ratio (makes it strong for its size).

Carbon fibres were developed primarily for their high strength and stiffness properties for applications within the aerospace industry. Compared with most other synthetic fibre carbon fibres are expensive. Carbon fibres have high tensile strength and elastic modulus. They are also inert to most chemicals. Polyacrylonitrile (PAN) based CFs are manufactured by carbonizing PolyAcryloNitrile yarn at high temperatures while aligning the resultant graphite crystallites by a process called "hot stretching". They are manufactured as either High Modulus (HM) fibres or High Tensile strength (HT) fibres and are dependent upon material source and extent of hot stretching for their physical properties [5][6]. They are available in a variety of forms.

It has been shown that carbon fibres can be made from coal or petroleum pitch, which are less expensive than the PAN based carbon fibre. Pitch based carbon fibres [9] are also manufactured in two types. General Purpose (GP) fibres are made from isotropic (non-oriented fibre structure) pitch and are low in tensile strength and elastic modulus [12]. High Performance (HP) fibres are made from mesophase (highly oriented fibres) pitch which produces fibres with high tensile strength and high elastic modulus. Carbon fibre is typically produced in tows (strands) that may contain up to 12000 individual filaments. Tows are commonly pre-spread prior to incorporation in CFRP to facilitate cement matrix penetration and to maximize fibre effectiveness

Fig.1.1 Carbon fibre sheet

Fig.1.2 Carbon fibre sheet

1.2 Advantages of Carbon Sheets

- Very high strength to thickness or weight ratio. Appreciable increase in strength and load carrying capacity without significant increase in dead load.
- Enhanced Stiffness, shear and tensile capacity; increased load carrying capacity and better resistance to seismic forces and deflection.
- Chemical resistant; Excellent resistance to acids and alkalis.
- Flexible; can be applied to any shape.
- Thin sections; can be effectively used in space constrained areas.
- Creep and fatigue resistance; ideal for conditions of sustained loading and repeated loading.

2. LITERATURE REVIEW

Externally bonded, FRP sheets are right now being considered and connected far and wide for the repair and strengthening of structural concrete members. Strengthening with Fiber Reinforced Polymers (FRP) [1][2] composite materials as external support is of great interest to the structural designing group. FRP composite materials are of awesome enthusiasm to the structural designing group on account of their unrivalled properties, for example, high strength and quality and in addition simplicity of establishment when compared with other repair materials.

Additionally, the non- corrosive and nonmagnetic nature of the materials alongside its imperviousness to chemicals made FRP a brilliant alternative for external reinforcement.

Research on FRP material for utilization in concrete structures started in Europe in the mid 1950's by Rubinsky and Rubinsky[8][11].

The pioneering work of bonded FRP system can be credited to Meier (Meier 1987) [6][9]; this work led to the first on-site repair by bonded FRP in Switzerland (Meier and Kaiser 1991). Japan developed its first FRP applications for repair of concrete chimneys in the early 1980s (ACI 440 1996).

By 1997 more than 1500 concrete structures worldwide had been strengthened with externally bonded FRP materials. Thereafter, many FRP [11][7][13] materials with different types of fibres have been developed. FRP products can take the form of bars, cables, 2-D and 3-D grids, sheet materials and laminates. With the increasing usage of new materials of FRP composites, many research works, on FRPs improvements of processing technology and other different aspects have been performed.

Several researchers have been engaged in the investigation of the strengthened concrete structures with externally bonded FRP sheets/laminates/fabrics.

2.1 Summary of Literature Review

- Addition of Carbon fibers increased flexural and tensile strengths by up to 11% and 45%, respectively. Addition of cellulose causes reduction in compressive strength around 9.8% and 16.4%. Improvement in flexural and tensile strength is also observed in addition of steel fibers.
- Addition of fibers in pre-cast concrete improves the shrinkage resistance as well as crack resistance. Permeability of concrete is significantly reduced due to fiber addition, which leads to preventing the degradation of reinforcement by sulphate attack etc. finally durability of concrete is increased.
- Increasing the width of the carbon sheets above 150 mm for the investigated type of samples is not producing significantly better results.
- Slabs with higher internal reinforcement ratio are having similar results for 100, 150 and 300 mm up to 130 KN of load and more significant difference above this level.
- The test results showed that the use of carbon fiber reinforced polymer (CFRP) sheet, in addition to steel reinforcing bars, as flexural reinforcement improves the punching shear strength of slabs.

3. PROBLEM STATEMENT

Small scale industries play an important role in the country's economy. Currently there is increasing scope for the setting up of the small-scale industries, which leads to the large construction of small-scale industrial sheds or buildings. Footing is the basic structural component, which is important part of the industrial shed. Footing transfers the super structure load to the soil safely without any settlement. But the construction of conventional footings i.e. RCC footings increases construction period and footings are more susceptible to flexural and shear failure. The idea of pre-cast carbon fibre reinforced footings reduces the construction period, quality and durability of the product increases and sustain high loads.

The pre-cast elements made using conventional concrete generally have to be reinforced with steel bars which are susceptible to corrosion. Handling and bending of steel bars are difficult. Furthermore, the placement of the steel reinforcement is time consuming and leads to rather thick and heavy structural elements. Fibre reinforced polymer is one of the solutions to that problem. In present experimental study an attempt has been made to replace the steel by carbon fibre. Ultimate load carrying capacity of carbon fibre reinforced pre-cast footing is compared with conventional steel reinforced precast footings.

3.2 Objectives of the Present Study

In this project our main objective is to study the suitability of Pre-cast carbon fibre reinforced concrete footings for small scale industrial sheds or buildings.

- To study the ultimate load carrying capacity of the Carbon fiber reinforced footings and conventional RCC footings.
- To study the load deflection curves of Carbon fiber reinforced footings and conventional RCC footings.
- To study the influence of replacement of steel by carbon fibres in the footing.
- To study the cost effectiveness of pre-cast carbon fibre reinforced footing over conventional steel reinforced footing.

3.2 Scope of the present Work

- Length and breadth of footing is 600 mm (2')
- Thickness of footing is 127 mm (5").
- Grade of concrete used for the work is M20.
- Carbon fiber is used as reinforcement material.

4. METHODOLOGY

- Load calculation for industrial sheds (truss) of span 10m, 15m and 20m.
- Design of reinforced cement concrete (RCC) footings.
- Mix Design for reinforced concrete and plane concrete as per IS: 10262-2009
- Length and breadth of footings are 600 mm (2') and depth or thickness of footing is 127 mm (5").
- Total nine numbers of footings were casted for the present work. Out of which three footings for each plain cement concrete (PCC), reinforced cement concrete (RCC) and Carbon fiber reinforced footings.
- The constituents were weighed (weight batching) and the materials were mixed by hand mixing for M20 grade of concrete.
- The concrete was filled in different layers and each layer was compacted.
- The footing specimens were de moulded after 24 hrs. And then cured for 28 days, by covering the slab surface by using gunny bags and keeping them moist.
- All tests are conducted at the age of 28 days.

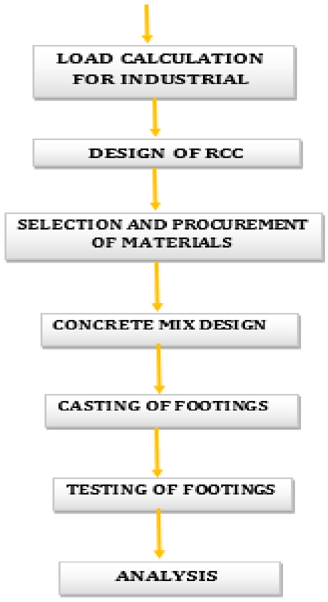

Fig 1: Load Calculation for Industrial Shed

5. EXPERIMENTAL OBSERVATIONS AND RESULT ANALYSIS

The results of punching shear test of footing units are presented in the form of tables and graphs as indicated below.

5.1 Observations

Table – 1: Load vs deflection for plain concrete footings @ 28days test

Load(kN)	0	2	4	6	8	10	12	14	16	18	20	22
Deflection(mm)	0	0.1	0.2	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.6	1.7

Table – 2: Observations for First Specimen

Load(kN)	24	26	28	30#	32	34	36	38*	20	16	10
Deflection(mm)	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1c	2.3	2.4	2.5

Table – 3: Observations for Second Specimen

Load(kN)	0	5	10	15	20	25	30	35#	40	45*	35	30
Deflection(mm)	0	1.0	1.2	1.6	1.8	2.0	2.1	2.2	2.3	2.6c	3.4	3.8

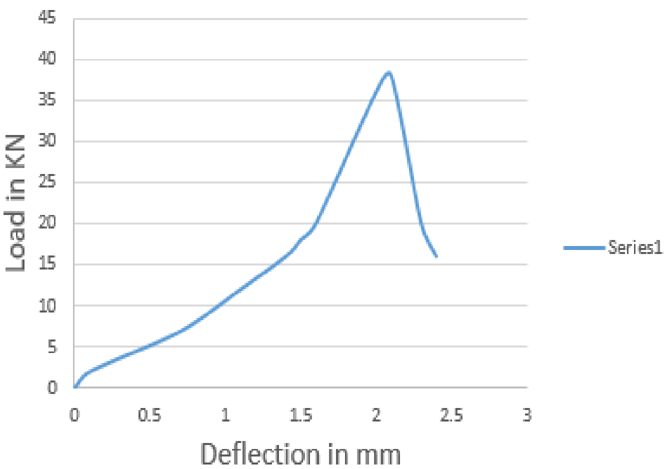

Chart – 1: Plane Concrete Footing

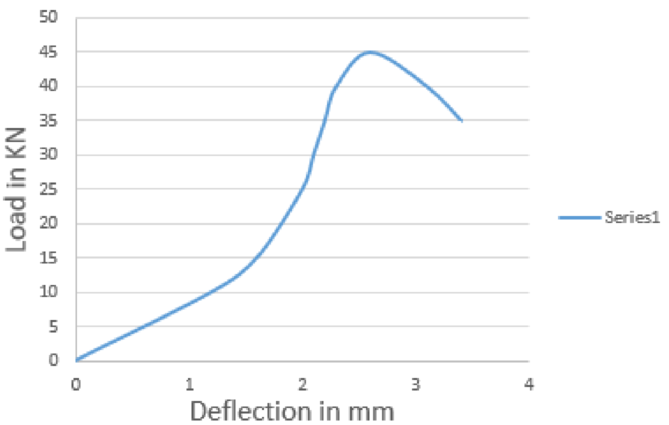

Chart – 2: Plane Concrete Footing - 2

5.2 Result Analysis

Table – 3: Observed Results

Footing	Self-weight (Kg)	Initial crack load(kN)	Ultimate load(kN)	Deflection (mm)	Cost(Rs)
Plain concrete	113.0	33	41.5	2.3	146
R.C.C	115.4	106.5	135.5	6.5	266
CF Reinforced	113.1	61	84.5	11.1	341
CF Reinforced +Externally wrapped	113.2	------	149.5	7.4	426

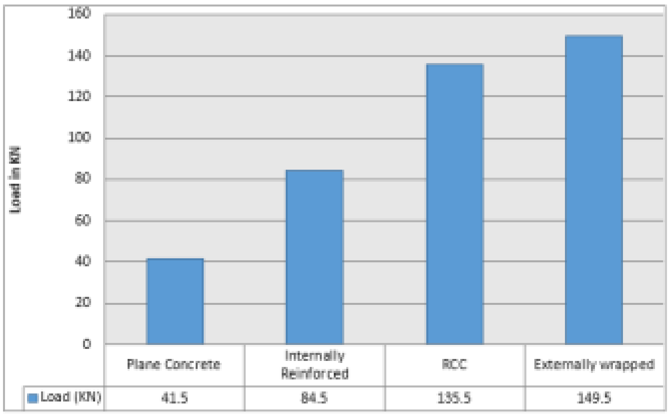

Fig 2: Comparison of Ultimate Load Taken by Different Footings

6. CONCLUSIONS

From the above result analysis, I conclude that the carbon fiber reinforced footings take 37% lesser load compared to the conventional R.C.C footings. Externally carbon fiber wrapped footings takes 11% more load compared to the conventional R.C.C footings. From the analysis we conclude that external carbon fiber wrapped footings provides more strength compared to R.C.C footings and Carbon fiber reinforced footings.

From the above result analysis, I conclude that the carbon fiber reinforced and carbon fiber wrapped footings have lesser self-weight compared to the conventional R.C.C footings. From the above cost analysis, I conclude that the carbon fiber reinforced footings are 28% costlier than the conventional R.C.C footings. Externally carbon fiber wrapped footings are 60% costlier than the conventional R.C.C footings.

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