Experimental Study of Punching Shear Strengthening of Flat Slab Using CFRP

Jijo P George[1] Roshini T Mohan[2]
[1]PG Student [2]Assistant. Professor
[1,2]Department of Civil Engineering
[1,2]Sreepathy Institute of Management and Technology, Kerala, India

Abstract— In the present study, the application of carbon-fiber reinforced polymer (CFRP) to improve the punching shear strength of flat slab has been investigated. The external bonded CFRP was arranged in two orthogonal directions. In one direction FRP rod was mounted in groove and other direction CFRP strip mounded in EBROG technique. The punching shear strength of slab investigated by applies a concentrated load on the centre of slab. The concrete slab specimens were strengthened with 1 or 2 or 3 stacked bars and CFRP strips at each face of loading point in two orthogonal directions and their load–displacement relationships as well as their failure loads were compared with control slab. Experimental results showed that the external bonded CFRP on grooving method enhanced the punching shear load. The results showed the great efficiency of the method so that the punching shear capacity of flat slab with CFRP increased between 28.4 - 58% compare to control slab.

Keywords: Flat Slab, CFRP

I. INTRODUCTION

The rapid development of the building construction resulted in the need for innovative, safe and optimised structural systems; one of those structural systems is flat slab roof system. Flat slab is a two-way reinforced concrete slab supported directly by concrete columns without the use of beam and girders, and the loads are transferred directly to the supporting concrete columns. Flat slabs are especially advantageous for their ease of installation, saving in building height, shorter construction time, Flexibility in room layout and that involve multi-storey structures of wide spans. However, they lack a beam network at the column connections in flat slab, which leads to a punching shear failure within the column slab supported area.

Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces in shorter area, And the development of a diagonal crack with variable inclination, starting from the root of the column to the tension face of the slab. It is affected by the column size, slab depth, existing flexural reinforcement ratio and the concrete tensile strength. This type of failure is catastrophic because no visible signs are shown prior to failure. This results in the column breaking through the portion of the slab. This failure is one of the most critical problems to consider when determining the thickness of flat slab. Accurate prediction of punching shear is a major concern and absolutely necessary for engineers to design a safe structure. A number of solutions have been proposed to overcome this punching shear failure of flat slabs, some of which are currently being practiced already. These include application of heads and collars around columns, using rods or steel shear heads at the connection zone, and providing punching shear links around the column area. Recently, the advent of new construction materials (especially composites) has given rise to strengthening various types of structures, including the development of internally and externally installed carbon fiber–reinforced polymer (CFRP) stirrups.

The use of fiber reinforced polymers (CFRP) for strengthening became a valid alternative because of their small thickness, relative ease of application, high strength over conventional material, light weight and highly durability. The CFRP's are commonly used wherever high strength-to-weight ratio and stiffness (rigidity) are required, such as aerospace, superstructure of ships, automotive, civil engineering, sports equipment. CFRP are composite materials of two parts: a matrix and reinforcement. In CFRP the reinforcement is carbon fiber, which provides the strength. The matrix is usually a polymer resin, such as epoxy, to bind the reinforcements together. CFRP has become a notable material in structural engineering applications. It has also proved itself cost-effective in a number of field applications strengthening concrete, masonry, steel, cast iron, and timber structures.

The strengthening of flat slab is done by externally bonded CFRP sheets onto a concrete.FRP debonding is the main problem that affects the efficiency of this technique. To avoid the debonding of FRP material to introduce a new grooving method is called "externally bonded reinforcement on grooves" (EBROG). In EBROG technique the concrete on which FRP sheet to be installed is prepared by cutting a groove on the concrete surface and epoxy is filled in the groove and surface before the FRP is installed.

II. OBJECTIVES

- To strengthen flat slab with external bonded CFRP
- To analyse the punching shear behaviour of flat slab with external bonded FRP
- To check the load behaviour of slab by increasing FRP strips and rods

III. MATERIALS USED

A. Cement

Ordinary Portland cement of 53 grades was used in this thesis. The physical properties of the cement are given in table I

Physical properties	Results
Fineness	1.61
Standard consistency	34%
Initial setting time	50 min
Specific gravity	3.15
Soundness	1mm
Compressive strength of cement For 7 days	40.67Mpa

Table 1: Properties of Cement

B. Aggregates

The crushed stone coarse aggregates are used those retaining in 4.75mm sieve. The maximum sizes of 20mm coarse aggregates are used. The Fine aggregates used as M sand or manufactured sand, and it's passing through 4.75mm sieve. The tests are conducted according to IS 2386; 1963, and in gradation curve the fine aggregate is of zone 2. The obtained values are given in table II.

Physical properties	Results	
	Coarse Aggregate	Fine aggregate
Bulk density	1.69	1.78
Specific gravity	2.78	2.65
Void ratio	0.71	0.49
Fineness modulus	7.279	3.42
Uniformity coefficient	1.761	3.55
Coefficient of curvature	0.87	0.76

Table 2: Properties Of Aggregates

C. CFRP

The CFRP IS used as "Cera CFR W 100 laminate" with size 500x50x1mm, and FRP rod of size 8mm diameter.

Fig. 1: CFRP Strips

D. Epoxy Resin

The "Cera bond EP CFR" is used as adhesive material for bonding FRP on concrete.

E. Water

In the concrete mix portable water that is free from oils and other impurities is used. The water used has no acidic or alkaline content in it.

IV. Experimental Investigation

The experiment consisted of testing four specimens with dimensions of slab samples 700 x 700 x 100 mm, and 8mm diameter Fe 500 steel reinforcement bars were used. The reinforcement bars were provided at 150 mm spacing. The mix design for M25 grade concrete is done according to IS 10262: 2009. The flat slabs strengthen by a newly introduced method, named as grooving method (GM). The groove provided in two orthogonal directions (x and y axes) of slab plan and then mounting the external FRP bar in groove at one direction (EBRIG) and FRP strip on another direction in EBROG(externally bonded reinforcement on groove) method. The slabs are denoted in S1, S2, S3, S4, (table III) and one slab used as control slab the remains slabs are strengthen by FRP. The crack patterns, the deflection occurred during the cracking and ultimate load, maximum deflection, and load-deflection curves were recorded throughout the test.

S1	control slab
S2	slab with 1 bar and 1 strip at each side of loading
S3	slab with 2 bars and 2 strips at each side of loading
S4	slab with 3 bars and 3 strips at each side of loading

Table 3: Specimen Denominations.

A. Strengthening Application

The concrete specimens were removed from the mould just one day after casting and cured in a water bath at a fixed temperature for 28 days. After the curing the specimens were taken out of the water for drying in air at laboratory conditions. The slab surface prepared by cutting groove in x and y directions, and area in which the FRP bonded was cleaned and smoothened thoroughly to remove cement laitance, loose materials, and contaminants (i.e., dirt, oil, etc.). The two components of the epoxy adhesive Cera bond EP CFR (A: dark grey colour and B: yellow colour) were mixed appropriately at 3: l proportions. The mixing process continued until the mixture became homogenous in consistency and a uniform grey colour. Then epoxy adhesive applied to groove and surface of slab then FRP rods stacked in grooves in one direction and FRP strips are stacked surface of concrete by EBROG technique. The FRP rods have 8mm diameter and CFRP strip in 50mm width, 500mm length and 1mm thickness. Specimens strengthened with 1 or 2 or 3 stacked bars at each face of loading point in one direction and 1 or 2 or 3 EBROG-FRP strip(s) at each side of loading point in another orthogonal direction (Fig. 2). All the strengthened slabs were cured for at least five days before testing.

a) b)

c)

Fig. 2: specimens: a-S2,b-S3,c-S4

B. Testing Procedure

The static axial concentrated load is applied at the centre point of the slab specimens using a loading frame with hydraulic jack. The load is applied by handily operated hydraulic jack with capacity of 100T mounted at the mid-span and two linear variable differential transducers (LVDTs) are installed and connected to a data logger to obtain an accurate force and deflection reading. Crack initiation and propagation were also monitored by visual inspection during the tests.

Fig. 3: Experimental setup

V. RESULTS AND DISCUSSIONS

The four samples is tested, and to find out the maximum load and deflection of the samples. The graph between load and deflection is plotted. The ultimate loads of samples and percentage of increasing loads from control specimen is plotted.

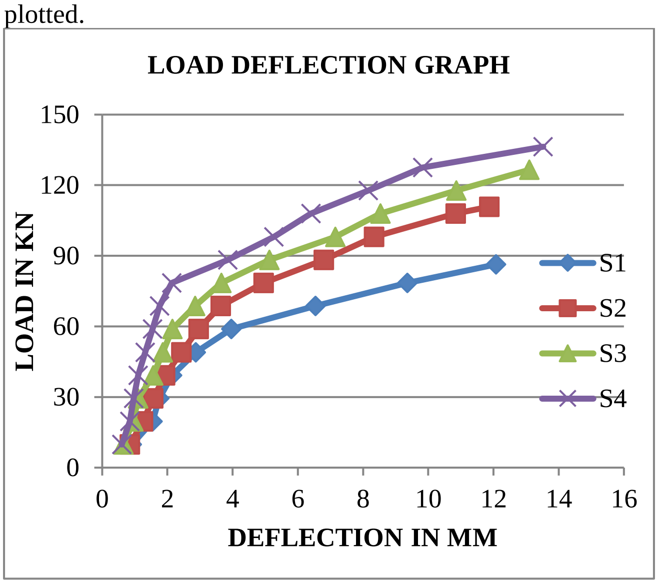

Fig. 4: Load deflection graph

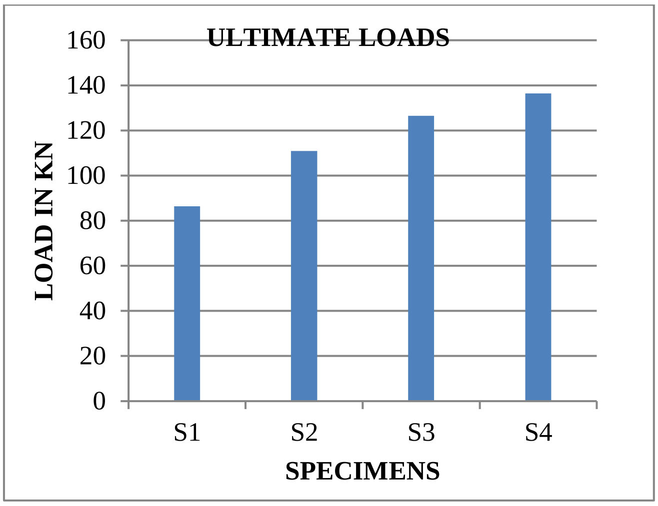

Fig. 5: Ultimate loads

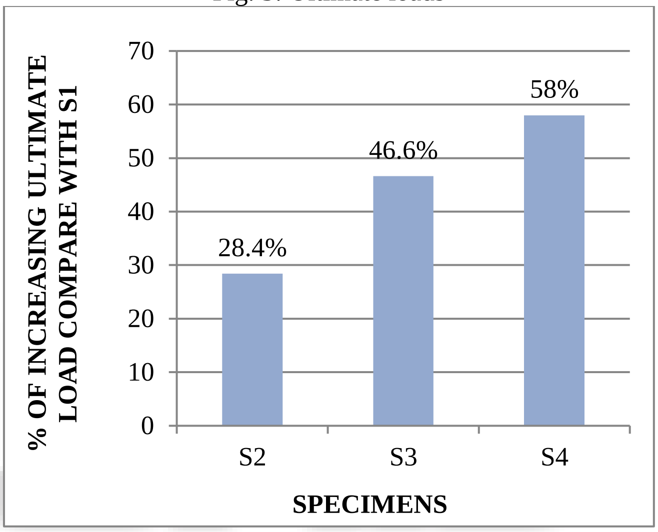

Fig. 6: % of increasing loads.

The punching shear load carrying capacity of control slab S1 and slab with CFRP S2 are observed and there is 28.4 % increase in the load carrying capacity of S2 in comparison with S1. S3 and S4 have 46.6% and 58% increased in comparison with load of S1. The percentage of increase in load 28.4% in compare with S1 and S2, 18.2% compare with S2 and S3 and 11.4% compare with S3 and S4. It was observed that punching shear load carrying capacity is increase from 1 bar and 1 strip at each side of loading to 3 bars and 3 strips at each side of loading, but the percentage of increasing load is reduced.

VI. CONCLUSIONS

In this study to strengthen flat slabs against the punching shear, the EBRIG method is used for the FRP bar and the EBROG methods are applied for the CFRP sheets without any shear reinforcement against punching shear. The main conclusions drawn from this study can be summarized as follows:

- This new technique of using a composite of CFRP with epoxy and externally attaching it to the slab surface was found as an effective, easy, and practical way of strengthening reinforced concrete flat plates and enhancing their capacity against punching shear failure.

- All types of strengthening composite configurations achieved an incremental increase in the ultimate punching shear load capacity and a decrease in the corresponding failure deflection.
- The increase in punching shear capacity 28.4% to 58% was observed.
- The FRP is placed most as possible at the shear zone if away from loading the percentage of increasing load reduced.
- The EBROG shearing method is more efficient method to strengthen the flat slab against punching shear.

ACKNOWLEDGMENT

Author wishes to express sincere thanks & gratitude to all people who have invested their time and helped directly or indirectly for the completion of this project work.

REFERENCES

[1] Amirreza Moghaddas and Davood Mostofinejad, “Empirical FRP-Concrete Bond Strength Model for Externally Bonded Reinforcement on Grooves”, *(ASCE)CC.1943-5614.0000924. © 2018*
[2] Ardalan Hosseinia, Davood Mostofinejada &Seyed Masoud Shamelia, “EBROG and EBRIG methods for strengthening of RC beams by FRP sheets*” European Journal of Environmental and Civil Engineering, 2014*
[3] Davood Mostofinejad, Seyed Masoud Shameli, “Externally bonded reinforcement in grooves (EBRIG) technique to postponede bonding of FRP sheets in strengthened concrete beams*”, ScienceDirect, 2012 Elsevier Ltd.*
[4] Niloufar Moshiri2, “Compressive Strength of CFRP Composites Used for Strengthening of RC Columns: Comparative Evaluation of EBR and Grooving Methods” *ASCECC.1943-5614.0000545. © 2014 American Society of Civil Engineers.*
[5] Rojin Azizi1 · Sayed Behzad Talaeitaba1, “Punching shear strengthening of flat slabs with CFRP on grooves (EBROG) and external rebars sticking in grooves”, *International Journal of Advanced Structural Engineering :(2019)*
[6] S M Banijamali “Reviewing the FRP Strengthening Systems”, *American Journal of Civil Engineering, :2015*

