Analytical Study of Strengthening of Flat Slab with External Bonded CFRP

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Abstract - *This paper presents an analytical study on flat slab specimens strengthened by a carbon fiber-reinforced polymer (CFRP) sheets using externally bonded reinforcement on groove (EBROG) method. The flat slab strengthen by apply a new modal of FRP bar laying in one direction and CFRP strips bonded in other direction. To apply a concentrated load on the slab face to test the punching shears strength of slab. The FRP's arranged in 1or 2 or 3 FRP bars and 1 or 2 or 3 CFRP strips are mounted at each face of the loading in two orthogonal directions and their load–displacement relationships as well as their failure loads were compared with each other. The finite element analysis was carried out using ANSYS Workbench 18.1. The results of the work showed that the strengthened slab could achieve 31-57.1% strength that of compare to control slab. Hence this is a highly innovative method that can be implemented in the construction industry.*

***Key Words*: CFRP, externally bonded reinforcement, flat slab, grooving method (GM), EBROG technique**

1. INTRODUCTION

The flat slabs are slabs supported directly on columns without the addition of beams. They are a popular flooring solution in multi-storey construction due to their economy and functional advantages. The key advantages of the flat slab are reduced floor depths in comparison to other systems, making space for services and reducing building heights, and enabling economies in construction through a reduction in the material cost and construction time via use of simple and efficient formwork. However the clear advantages, flat slabs have inherent weaknesses; in particular, the connection between the flat slab and the supporting column is the most critical part due to the concentrated load coming in column and slab connections. And thus failure mode called as punching shear failure.

Punching shear failure is one of the most dangerous problems in the design of flat slabs. Punching shear is affected by the column size, slab depth and the concrete tensile strength, and this failure is brittle and sudden because concrete is unable to accommodate high tensile stresses that develop close to the slab-column connection. It is necessary to strengthen flat slabs due to insufficient punching shear strength. Over the last couple of decades, fiber reinforcing polymer (FRP) composites have been increasingly used in construction applications. FRP has many features such as a high strength to weight ratio and high resistance to corrosion. As a result, FRP strengthening approaches have received much attention from the research and practice community.

In this study to strengthen flat slab by CFRP composites apply a new technique called as grooving method. The FRP are arranged in tension side of slab. To strengthen flat slab choose FRP rod and CFRP strips in this study and finite element analysis done in ANSYS Workbench 18.1.the FRP rod bonded in groove and CFRP strip bonded in EBROG(external bonded reinforcement on groove) technique in two orthogonal directions.

The aim of this analytical study is to investigate the punching behavior of column-slab connections strengthened with CFRP. The study concentrates mainly on concrete column-slab connections without shear reinforcement, and a low reinforcement ratio, in order to enhance their cracking resistance and ultimate loading capacity.

2. OBJECTIVES

- To strengthen flat slab with external bonded CFRP
- As part of new initiatives towards increase strength and reduce maintenance, alternative materials are being considered.
- To analyse the punching shear behaviour of flat slab with external bonded FRP in EBROG technique.
- To check the load behaviour of slab by increasing FRP strips and rods in two orthogonal directions.

3. MATERIAL PROPERTIES

3.1 Concrete

The concrete used here is M25 grade concrete. The mix design was done according to IS 10262:2002and IS 456:2000

3.2 Steel reinforcement

The reinforcement is provided as meshes at bottom with a diameter of 8mm. They are Fe 500 grade placed 100 mm apart.

3.3 CFRP

The carbon fiber reinforced polymer strips are provided with dimensions of 500x50x1 mm. The FRP rods are provided in 8 mm diameter.

3.4 Epoxy resin

The epoxy resin used to bind the CFRP and concrete.

Table -1: Material Properties

Materials	Properties	Value
Concrete	Young's modulus of elasticity	28285MPa
	Poisson's ratio	0.15
	Compressive strength	32.59MPa
Steel	Young's modulus of elasticity	200000MPa
	Poisson's ratio	0.3
	Yield strength	500MPa
CFRP	Young's modulus of elasticity	230000MPa
	Poisson's ratio	0.3
	Tensile Yield strength	3900MPa
Epoxy resin	Young's modulus of elasticity	4500MPa
	Poisson's ratio	0.3
	Tensile Yield strength	30MPa

4. MODELING

The modelling of the flat slab was done through geometry, designModeler. Using different tools such as drawing tool- rectangle, circle, line etc and modifying tools - extrude, mirror, pattern, translation etc. The mesh was created with 8mm bars at 100mm centre to centre distance, and the clear cover at side ends are 50mm distance was provided. Solid slab of adequate size of 700x700x100mm was created. The epoxy is filled by create groove in slab using the extrude tool in cut material option. Later the FRP bars are arranged in groove and also CFRP strip was arranged in concrete surface by using extrude tool. The areas required for providing support were created in the modelling section at 10cm wide area is provided in the bottom portion of the slab in all four sides. In the top an area of circle with 100 mm diameter provided for the loading.

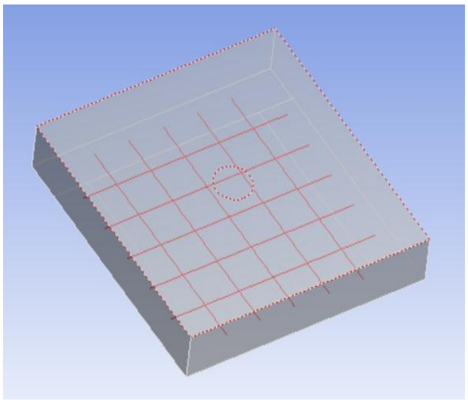

Fig-1: Slab S1

There are four models created and it's denoted as S1, S2, S3 and S4. S1 is the model of the slab without CFRP in it. S2 is the model in 1 FRP rod and 1 CFRP strips provided in each side of loading in two orthogonal directions. The S3 & S4 model have 2 & 3 FRP rods and 2 & 3 CFRPs provided in each side of loading in two orthogonal directions. The same support conditions and loading conditions provided for all the four types of slabs. And materials properties are same for the models.

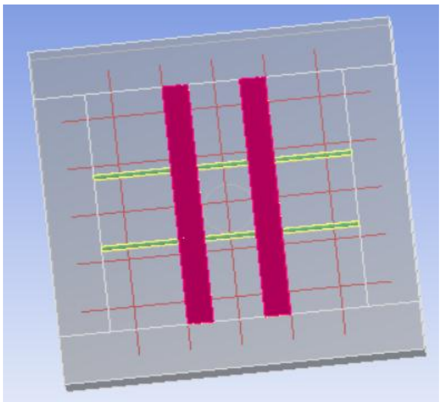

Fig-2: Slab S2

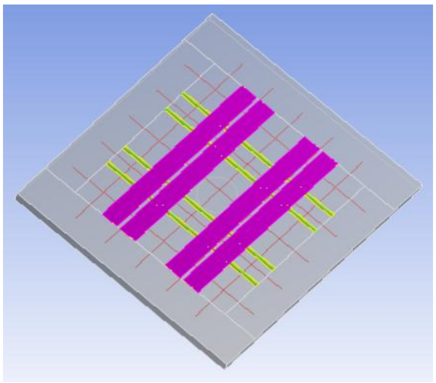

Fig-3: Slab S3

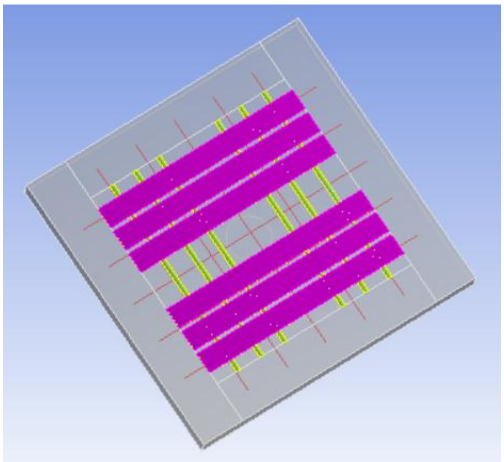

Fig-4: Slab S4

4.1 Meshing

The models are linked to the materials in order to show the characteristics of the material. After the modelling assigned the material to respective geometry, the local coordinate system of each is fixed with global coordinate system. The connections are provided between each component of the model such as connection between concrete and reinforcement, concrete and epoxy, epoxy and CFRP etc. Meshes are provided in finite element analysis more accurate result can be obtained.

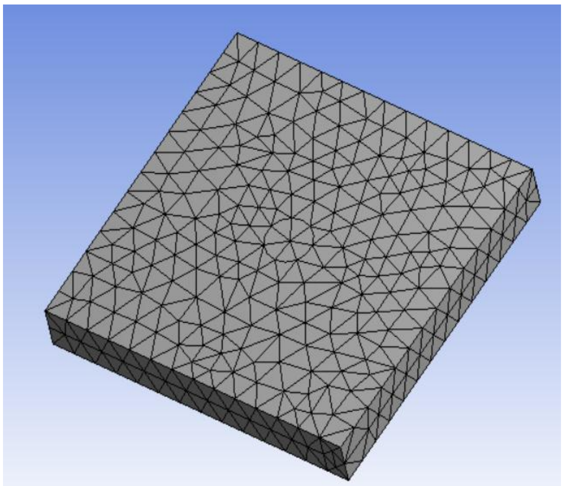

Fig-5: Meshing of model

5. ANALYSIS

The finite element analysis of the four models was done. In order to provide the loading in steps the auto time stepping was done with steps and sub steps. The solver type used was direct. The concentrated load applied on the model. The simply support condition provided on all four sides in 100mm width space. The total deformations, force reaction, stress and strain etc was computed after the analysis of model. The analysis of all models was completed with no errors and minimum number of warnings.

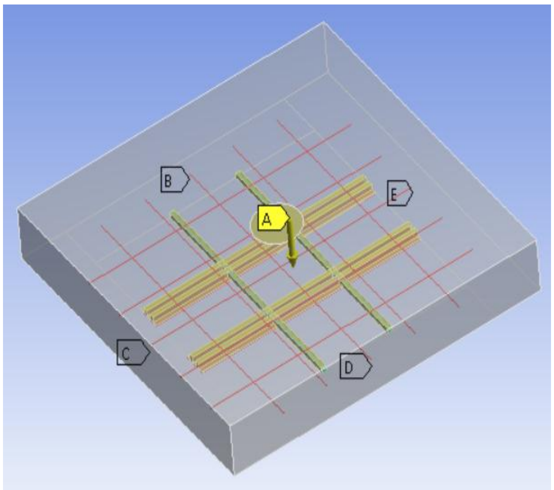

Fig-6: Load condition of model

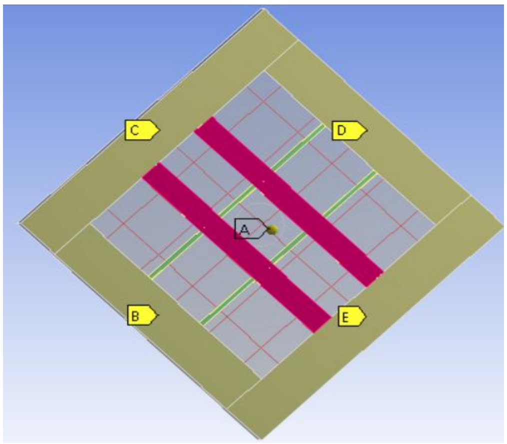

Fig-7: Supports conditions of model.

6. RESULTS AND DISCUSSIONS

The ultimate load, stress distribution, strain distribution and maximum deformation of the four models are analysed. The load deformation graph is plotted and also ultimate load of four modals is plotted.

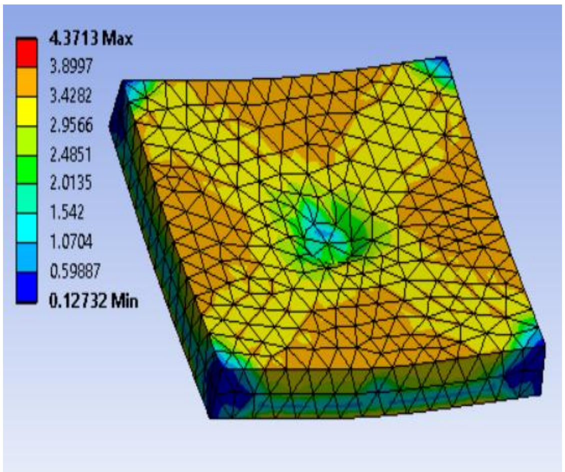

Fig-8: Equivalent stress of slab S1

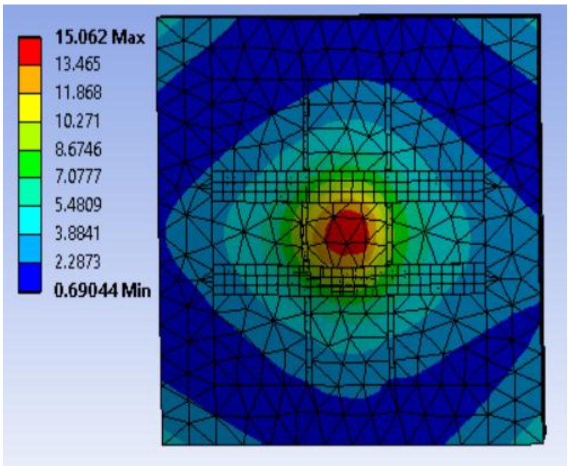

Fig-9: Total deformation of slab S2

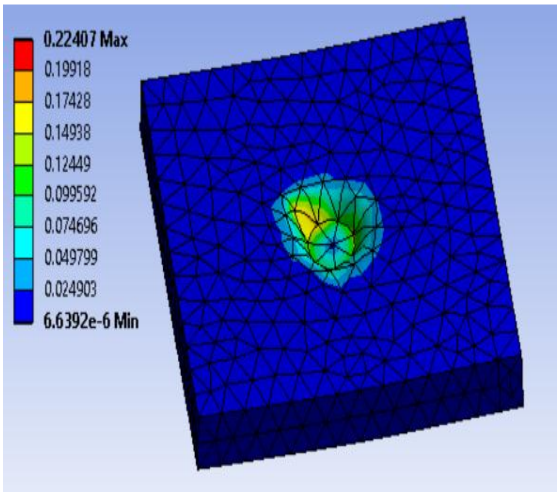

Fig-10: Equivalent total strain of slab S4

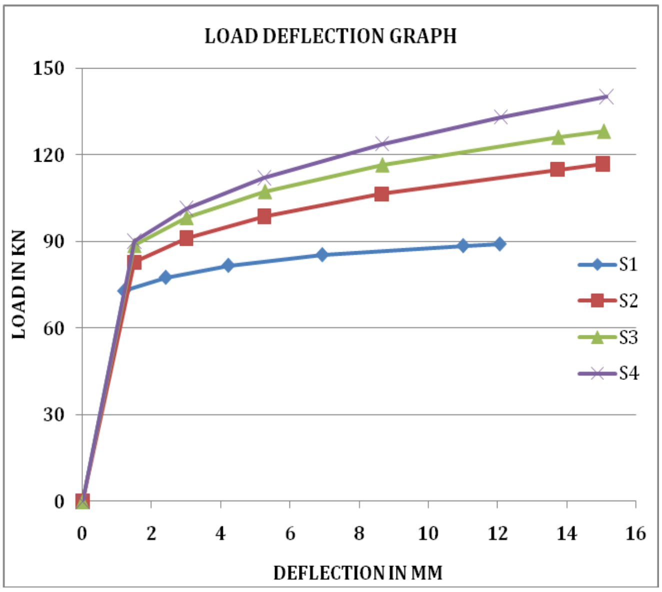

Chart-1: Load defelection graph

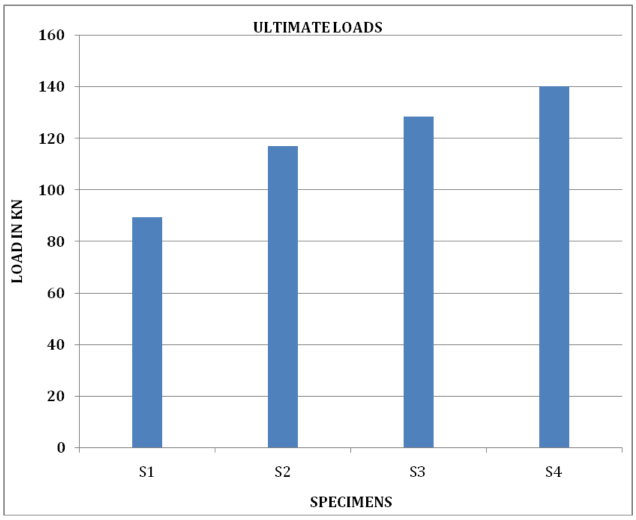

Chart-2: ultimate load of slabs

The punching shear capasity of four slabs are analysed. The punhing shear load of control slab S1 and slab with CFRP of 1 rod and 1 strip at each side of loading slab S2 are observed and there is 31 % increase in the load carrying capacity of S2 in comparison with S1. The slabs S3 & S4 have 43.8% and 57.1% increased loads in comparison with S1. 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. Maximum deformations of the slabs with CFRP are observed to be greater than the slab without CFRP.

7. CONCLUSIONS

The punching shear capacity of flat slab with CFRP was analyzed in ANSYS software with a new method known as grooving method. In this method FRP bar mounted in groove and the EBROG methods are applied for the CFRP sheets without any shear reinforcement against punching shear. The punching shear capacity of flat slab increased at 31% to 57.1% was observed. The EBROG shearing method is more efficient, easy, and practical way of strengthening reinforced concrete flat slab against punching shear without using shear reinforcement.

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