FINITE Element Analysis of RC Slab with or without Opening Strengthened with FRP Wraps

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ABSTRACT
Every structural element has its own importance. Slabs are important because through these loads are to be transferred. Thus before any construction it is necessary to test every structural component. The testing of various components is done by different ways i.e. analytically, experimentally, & numerically. Here in this study, the importance of numerical method over experimental method is studied. Since the cost of material is very high so to analyze the structure experimentally before construction is very costly. Thus it is healthier to use numerical method for analyzing. It is time efficient & cost effective. Now, for the numerical analysis finite element method is being used. In the present work, ANSYS[1] tool is used for Finite Element Technique.

Keywords
Finite Element Method, CFRP, GFRP

1. INTRODUCTION
Slabs, a reinforced-concrete structural member that is very wide compared to depth spanning between beams, girders & columns. Concrete slabs are widely used for floors, roofs & bridge decks. When a slab is supported on four sides with reinforcing bars is called a two-way slab. This type of slabs is generally designed by empirical methods. The slab will deflect in both directions, and the loads on the slab are transferred to all supports. There are different types of two-way slabs. The two way slabs are further divided to 3 different systems: flat plates, flat slabs, & two-way beam-supported slabs. The simplest type of two-way slab is known as a flat plate. The slabs effect on the overall economy of the structural system. Thus it is necessary to design them in such a way that keeping the economy in minds the strength of slabs can be increased.

2. INTRODUCTION TO FEM
Finite Element Method (FEM) is a technique in which not only structural element even electronic instruments & mechanical instruments are being tested. This method comes under numerical methods. FEM uses different methods for analyzing process. The basic concept on which FEM works is that it divides system into number of components which are known as finite elements. The process is known as meshing. Without meshing it is not possible to analyze in FEM. Also this is the reason that FEM differs from other methods.

3. LITERATURE REVIEW
The literature view presented below describes about the finite element method, the properties of different fibre laminates, method to use fibre laminates on structural elements.

Kenneth w. neale (2011)[3] presented the non linear behavior of various structural members strengthened with FRP. The analysis was done by using finite element method. In this study the different modeling approaches were carried out. The flexural & shear behavior of both beam as well as two way slab were considered. Both the beam & slab was strengthened using two different schemes. FRP was applied using mechanical fastened method & externally bonded scheme. The main attention was paid to the choice of model for which the results of numerical analysis would match the experimental results. The results that had to compare were load carrying capacity, load-deflection curve, failure modes. The numerical phenomenon showed that the useful insight phenomenon as compare to experimental.

Nura Jasim Muhammed (2012)[5] introduced to strengthen the RC slab where there is need of providing the cuts in existing structures. Since there are several approaches but it is good to select the approach that is cost effective. The paper deals with the CFRP sheets & the steel fibres used as a strengthening material. In this study eight slabs were studied out of which 3 slabs were controlled. The 3 controlled slabs were without opening, with square opening & with rectangular opening respectively. Next the 3 slabs were modeled using steel fibres without opening, with square opening & with rectangular opening respectively. Then the two slabs were modeled using CFRP laminates with square & rectangular opening respectively. The slabs were loaded uniformly with simply supported edges. The results showed that the CFRP increased the load carrying capacity by 30% instead the glass fibres increased the load carrying capacity by 20%.

Mustafa Basheer Mahmood, et al, (2013)[4] studied the numerical behavior of controlled RC slab strengthened with CFRP laminates using ANSYS. ANSYS is software used for the analysis of various structural & non structural elements using finite element method. In this study first the RC slab without CFRP laminate was analyzed & then the RC slab was strengthened with CFRP laminates. The finite element analysis was done & then the results were compared with experimental results. It had been showed that there was a little difference in the results of experimental & numerical study.

H.U. Khan, et al, (2014)[2] discussed about the comparison of experimental results with numerical one. Since the analytical determination is a difficult task so it is good to compare the experimental results with numerical results. The analytical results contain empirical formulas that are difficult to understand. In this study the beam is modeled using discrete technique in ANSYS. Elements used in the modeling were solid 65 for concrete & link 8 for reinforcement. The results showed that the numerical values were very close to the experimental ones.

Sheetal Gawas, et al, (2014)[1] had taken the finite element analysis of two way reinforced concrete slab with central opening. In this study the variation of stress & displacement

with different boundary conditions was carried out. Four cases were considered in which one case having all edges simply supported, one case having all edges fixed, one case having two adjacent edges fixed & two adjacent edges simply supported, last case having two opposite edges simply supported & two opposite edges fixed. ANSYS 10 was used for finite element analysis. Non linear parameters were found using multilinear isotropic stress strain curve. Solid 65 was used for concrete model & link 8 was used for reinforcement. The study showed that the slab with all edges simply supported had least stress & maximum displacement while the slab with all the edges fixed had least displacement & maximum stress.

4. PROBLEM FORMULATION

With the literature review studied, the problem has arisen for the numerical study of slab provide with FRP laminates. The two way slab having size of (0.450*0.450*0.040)m is taken. The reinforcing bars having diameter 0.006 m is provided at 0.075 m spacing. The concrete used for this study is of grade M30. The yield strength of steel was calculated from experimental2 analysis is 387000kN/m2. Then the two slabs were taken for circular & square opening having size 0.075mm at an eccentric distance of 0.075mm. Then the slabs with opening are provided the FRP laminates around opening to recheck the ultimate load carrying capacity. Two types of FRP laminates are taken. With the use of numerical study, ultimate load carrying capacity for all the slabs, crack pattern & load deflection curve is found that is further compared with experimental results[2].

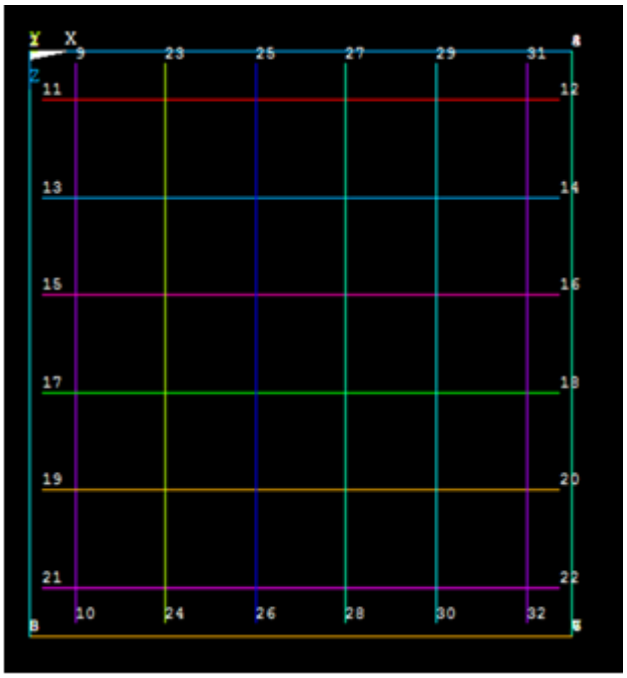

Fig 1: Top View of Slab

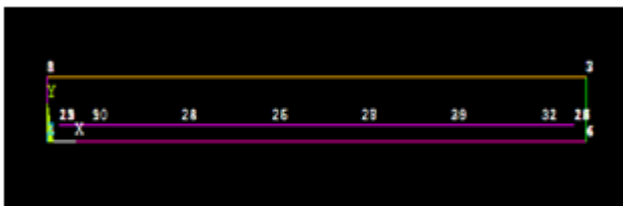

Fig 2: Front View of Slab

Table 1. Showing the Description of Slab Specimen in Brief

Slab Name	Description
S1	Control slab
S2	Slab with square opening of size 0.075*0.075 m at an eccentricity of 0.075m
S3	Slab with circular opening of diameter 0.075 m at an eccentricity of 0.075 m
S4	Slab with square opening wrapped with CFRP
S5	Slab with circular opening wrapped with CFRP
S6	Slab with square opening wrapped with GFRP
S7	Slab with circular opening wrapped with GFRP

4.1 Finite Element Procedure

4.1.1 Preprocessing

ELEMENT TYPES

SOLID-65[4]

There can be many other elements that can be used to model concrete but literature suggests only Solid-65. This is because Solid-65 has a special property that differs it from other three dimensional & eight nodal element is that it can inherent 4 more elements in it. So to model the concrete Solid65 element was used. Looking on the geometry it can be said that it is having three dimensional property along with 8 nodes. Also it can be translate in all the three directions.

LINK-180[4]

Geometry of Link-180 defines that it can be used to model steel reinforcement. It can be translate in all the 3 directions. Since it is having diameter & length so it is also three dimensional element.

SOLID-185

Looking on the pictorial view of SOLID 185 it can be seen that it is 3-D element. It can be translate in 3 directions. Geometrical view tells that it has 8 nodes.

Table 2. Showing the real constant & material properties

Element	Real constant	Modulus of elasticity, E(N/mm^2)	Poision ratio
SOLID 65	**0**	27360	0.12
LINK 8	28.2mm^2	2e5	0.33
SOLID 165(CFRP)	0	2.3e5	0.2
SOLID 165(GFRP)	0	0.8e5	0.22

MODELLING PROCEDURE

The square slab is modeled using block volume of dimension (0.450*0.450*0.04) m. the thickness of slab is taken along y-axis. The reinforcement is modeled using joining the keypoints. The hole in a slab is provided using subtract Booleans.

MESHING PROCEDURE

The slabs were meshed using mapped hex meshing. Reinforcement & the concrete were meshed differently. But the slab with hole can-not be meshed using mapped hex, thus it is convenient to mesh it using sweep hex meshing. The meshing size is set so that the nodes of meshed concrete can be overlapped with nodes of reinforcement.

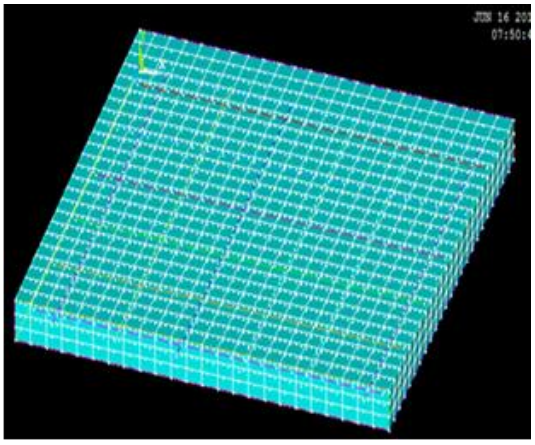

Fig 3: Meshed model of slab S1

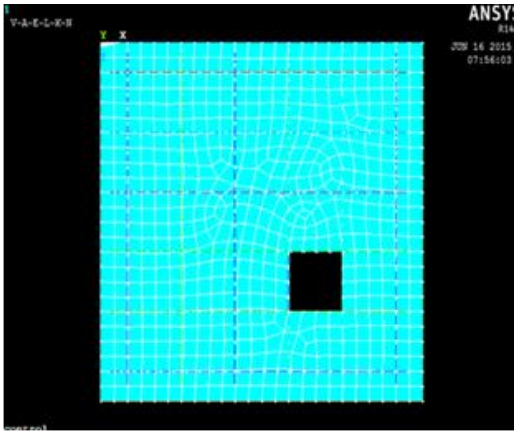

Fig 4: Meshed model of slab S2

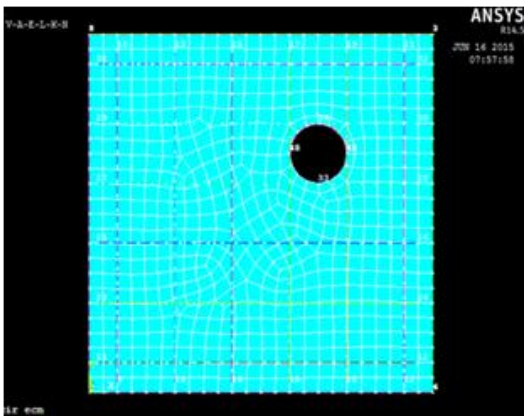

Fig 5: Meshed model of slab S3

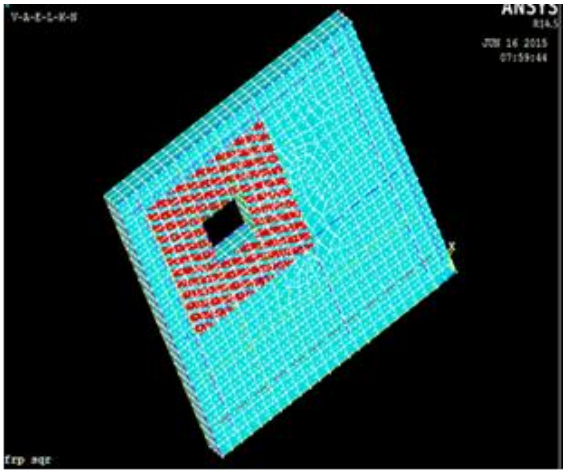

Fig 6: Meshed model of S4

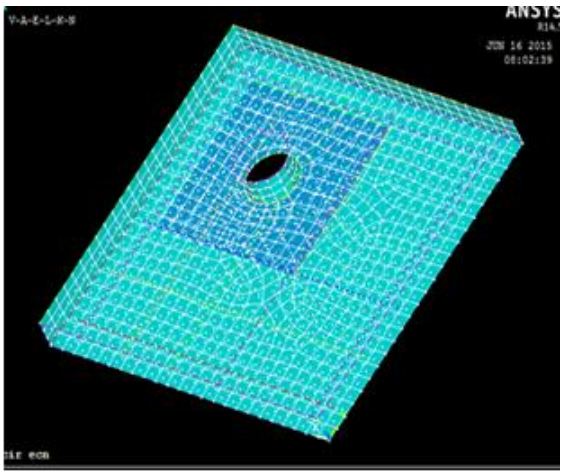

Fig 7: Meshed model of S5

4.1.2 Solution

The experimental work followed by the present work defines the slab is simply supported on all the four sides. The load applied on the slab is uniform. So it was convenient to use pressure for the applied load. The direction of applied load is negative y-axis. & the direction of boundary condition is positive y-axis.

4.1.3 Post processing

The nodal solution & crack pattern can be obtained.

5. CONCLUSIONS

The following conclusions can be drawn from the ansys results so obtained:

1) The results from the ANSYS show good agreement with the experiment results.

2) It is observed that load carrying capacity of solid slab is 24% more than slab with openings.

3) It can be said from the obtained results that deflection of slab with circular opening is 25.6% less when it is strengthened with CFRP.

4) It is observed from the results that deflection of slab with square opening is 24% less when it is strengthened with CFRP.

5) It is observed that load carrying capacity of slab strengthened with CFRP is 20% more than the capacity when strengthened with GFRP.

6. FUTURE SCOPE OF WORK

From the literature review and the present work done in this thesis has provided useful for future application of a finite element method for analysis. FEM model helps in comparing the results with experimental results data. Modeling the RC slab model in FEM based ANSYS software gives good results which can be included in future research. Further the numerical analysis can be done on the different patterns of FRP. Also, the results of ANSYS APDL can be compared with ANSYS workbench.

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