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Analytical Study of Retrofitted RC Slab with Different FRPS

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Abstract— Strengthening of reinforced concrete slabs with fibre reinforced polymers has been an important subject in the present industry. Strengthening is required due to improper maintenance of structures, bad practise of code, heavy loading etc. Strengthening by FRPS is one best methods of retrofitting the slabs due to fact that it works well under the corrosive environment and it increases the service life of a structure. In growing interest for the usage of FRP'S in retrofitting technique, an analytical study is made on the different types of the fibres like Carbon, Basalt, Glass and Polypropylene have been used in strengthening of slabs as well as with different configurations. Finite element package like ANSYS 16 was used for the analysis. In the present study finite element analysis was done for total of nine slabs. Out of which one is control slab and other eight slabs are with four different fibre reinforced polymers material and with two type of configuration. The dimension of the slab used for analysing was (1040X1040X90) mm. Comparison was done with the maximum deflection, principal stress and strain and shear stress and strain for different slabs with different configuration of fibre reinforced polymers.

Keywords— Fibre reinforced polymer, Retrofitting, ANSYS, Configuration, and Polypropylene Fibre.

I. INTRODUCTION

Strengthening of reinforced concrete structures is an important subject in the present time. It is used because of the improper maintenance, heavy loading, bad practise of code and improper environmental condition. Numerous strengthening techniques were advanced within the past and used with some popularity such as steel plate bonding, outside pre-stressing, and reinforced concrete jacketing. Even though those techniques can successfully increase the element's load carrying capability, they may be frequently susceptible to corrosion harm which leads to failure of the strengthening machine. Consequently, non-corrosive revolutionary strengthening material i.e. fibre reinforced polymers (FRPs) which have the capacity for extending working life of RC structures.

Fibre reinforced plastics are majorly used for the strengthening of the reinforced concrete beams, columns and slabs. There has been a lot of study on the fibres these days due to the advantages they bring with them. The analysis is carried out in the FEM package like ANSYS. Different fibres like carbon, basalt, glass and polypropylene has been used with two different configurations like square and plus configuration.

II. LITERATURE REVIEW

H.M. Afefy, and Tarek Mohamed Fawzy studied on flexural performance of the one-way RC slab strengthened with cut-out. The slabs were strengthened with near surface mounted [NSM] steel bars and Carbon fibre reinforced polymer [CFRP] bounded externally on the tension zone and four of them. The use of thin layer of ECC material of 20% the slab general thickness inside the compression facet ensured the overall recuperation of the flexural potential due to cut-out whilst combined with either NSM steel bars or EB-CFRP sheets in the tension side.

Uyang li-jun et al in this paper mentioned a brand new fibrous composite known as continuous basalt fibre strengthened polymer/ plastic (BFRP). This paper concludes that continuous beams reinforced with one to three layers of BFRP sheets at the concrete tension faces are prone to bending failure. BFRP and beam coordinate properly without obvious debonding failure. Cracking power at mid-guide will increase with an amplitude of 10%; yield strength at mid-aid will increase with an amplitude of 16%, yield electricity at mid-span will increase with an amplitude of 7%; closing energy considerably will increase with the aid of 27%. Increasing the range of BFRP sheet layers will improve stiffness of reinforced beams after longitudinal bar yielding at manage phase

Ľuba Horbanová, Anna Ujhelyiová1**, Jozef Ryba**1**, Ján Lokaj, Peter Michlík** presented a paper on the properties of the polypropylene fibres. This paper aims on the properties of polypropylene concentrates and fibres changed by inorganic additive. Results shows at rheological properties the index pseudoplasticity of polypropylene and polypropylene concentrates had been comparable. Thermomechanical evaluation shows, that temperature of fiber deformation became better at higher drawing ratio of composite polypropylene fibers containing inorganic additives. Mechanical properties of changed fibers without stabilization and stabilized at 95°c for 1 minute performed higher values at drawing ratio 4.0. Surface modification of fibers containing inorganic components turned into important.

Ayman S. Mosallam, Khalid M. Mosalam gave an experimental and analytical research for comparing the ultimate response of unreinforced and reinforced concrete slabs repaired and retrofitted with fibre reinforced polymer (FRP) composite strips. A uniformly dispensed pressure was put on the several two-way large scale slab specimens utilizing excessive pressure water bag. Both carbon/epoxy and Glass/epoxy composite systems were used on this examine. It's concluded that, for restore programs, results indicated that each FRP systems have been effective in significantly growing the power of the repaired slabs to about 5 times that of the as-built slabs. For retrofitting applications, use of FRP systems resulted in sizeable upgrade of the structural capability of the as-constructed slabs as much as 500% for unreinforced specimens and two hundred % for metallic reinforced specimens

III. OBJECTIVES AND METHODOLOGY

1. OBJECTIVES OF THE PRESENT STUDY

- The main objective of this project is to strengthen the damaged reinforced concrete slab with different FRP’S and with different configuration.
- To study the structural behaviour of the retrofitted RC slabs with different FRP’S.
- To study the load carrying capacity of the retrofitted RC slabs with different FRP’S.
- To predict the deflection of the retrofitted RC slabs with different FRP’S under static loading.
- To have a comparison analytical study on the different configurations that can be used for retrofitting of the slabs.

2. METHODOLOGY OF THE PRESENT STUDY

- Characterisation of the different fibres used in this project i.e. to find out the mechanical properties of the fibres to define the fibres in the ANSYS software.
- Creating the models with different configurations of FRP’S in the ANSYS software to do an FEM analysis.
- Applying the suitable support conditions and loadings.
- Analysing the models and to get the results relating to load carrying capacity, flexure strength, stresses in the slab, deflection using ANSYS.
- Validating the results of the ANSYS software with the experimental results from literature review.

IV. MODELLING

This chapter deals about the modelling of the reinforced concrete two-way slab in ANSYS 16.0 software. Modelling happens to be adding of material required for the analysis, drawing the reinforced concrete slab according to the suitable dimensions, creating the contacts, meshing of the structure, support conditions, loading conditions and adding the required output parameters.

1. ENGINEERING PROPERTIES

The various properties of the material used in the project were added. Concrete used was M25 grade concrete with poisons ratio of 0.2 with modulus of elasticity of 24834.83 MPa. Reinforcing steel used was Fe415 grade with poisons ratio of 0.3.

The modulus of elasticity of different fibres used was found out from the characterisations of the fibres.

Parameters	Density in Kg/m^3	Elastic modulus in MPa	Poisons ratio
Concrete	2500	24834.83	0.2
Reinforcement steel	7850	200000	0.3
Carbon fibre reinforced polymer	1950	125000	0.3
Basalt fibre reinforced polymer	1796	45000	0.32
Glass fibre reinforced polymer	1800	95000	0.3
Polypropylene fibre reinforced polymer	960	5000	0.33

Table 1: different elements used with their properties

2. GEOMETRY

The dimensions of the reinforced concrete slab used were (1040 x 1040) mm with thickness of 90 mm. The reinforcement used was 8 mm diameters bars at 200 m centres both ways. This was modelled in ANSYS 16.0 software in the geometry option. In this tab, the required geometry was drawn and extruded. Pattern option is used for creating the reinforcement at 200 mm centres. FRP was added below the slab in the square configurations of (300 x 300) mm and plus configurations of (900 x 100) mm in both x and z direction. Total of 9 slabs specimens were made. One control slab, 4 slabs with square configurations and 4 slabs with plus configurations.

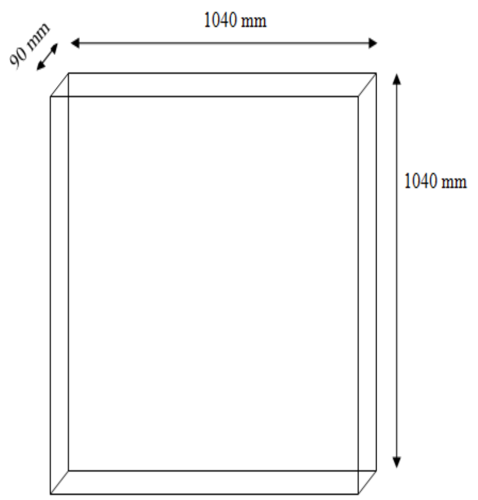


Fig.1: Dimensions of Slab

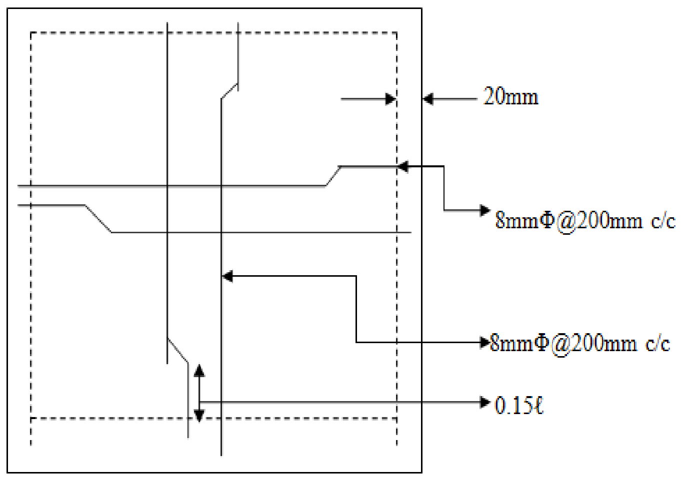


Fig. 2: Reinforcement details of the two way slab

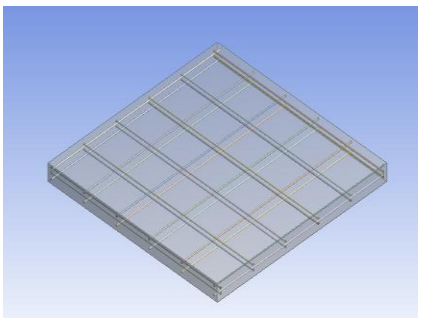


Fig. 3(a)

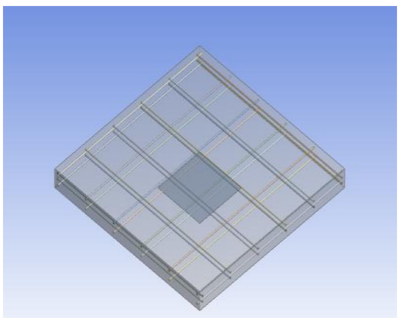


Fig. 3(b)

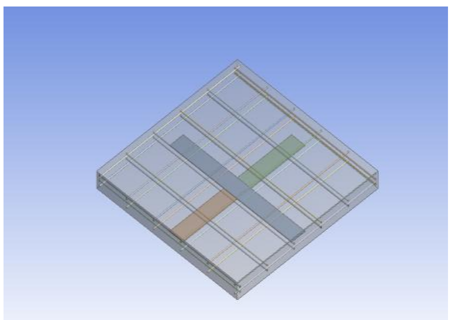


Fig. 3(c)

Fig. 3(a), 3(b) and 3(c): RC slab with reinforcement and different configuration

3. CONTACTS

Manual contact was made between the elements. The contact between bottom rebar's in both directions x and z directions was made. The contact between top rebar's was made in x and z direction. Later both the rebar's was contacted with concrete body. Lastly contact between concrete body and FRP body was made.

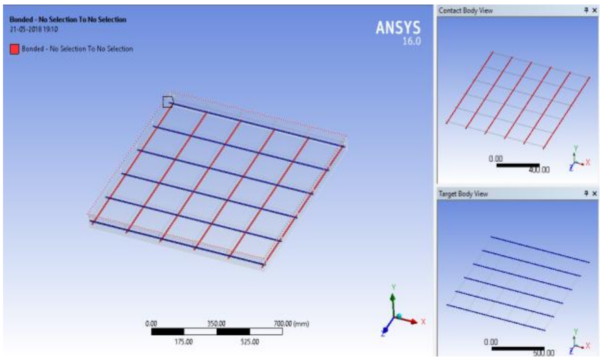


Fig. 4: Contact between reinforcemnet

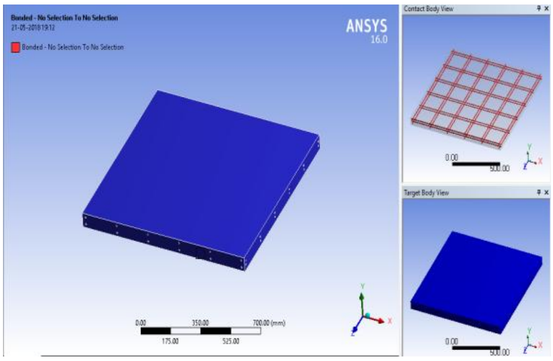


Fig. 5: Contact between concrete and reinforcement

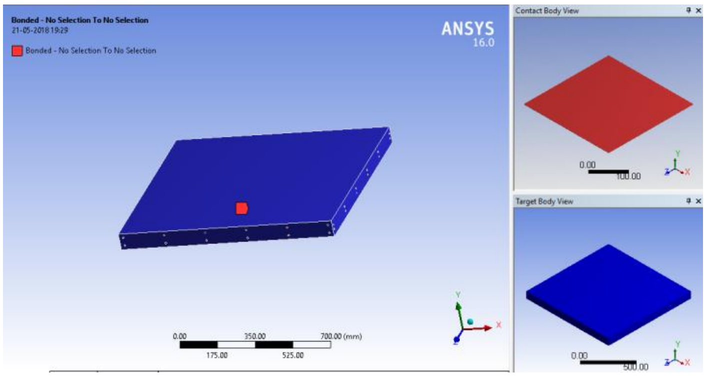


Fig. 6: Contact between concrete and FRP

4. MESHING

The model was meshed to smaller units. Meshing size of 15 mm was used in the project. It is important in the finite element method that nodes of different bodies match with one another. Tetrahedron meshing was used to create the mesh for different bodies. Method sizing option is used for sizing to the bodies. Meshing helps to get the results precisely in the finite element method.

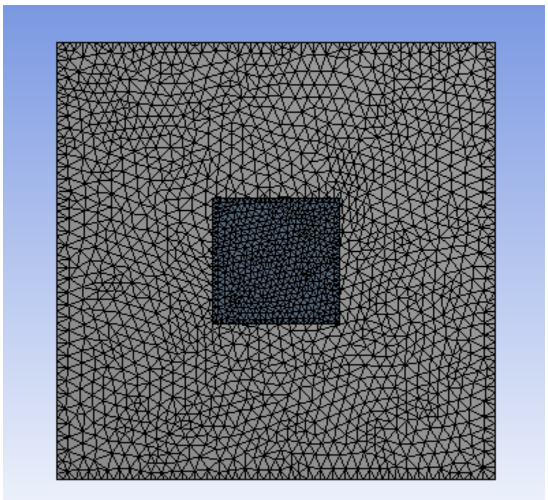


Fig. 7: Meshing of RC Slab with square configuration

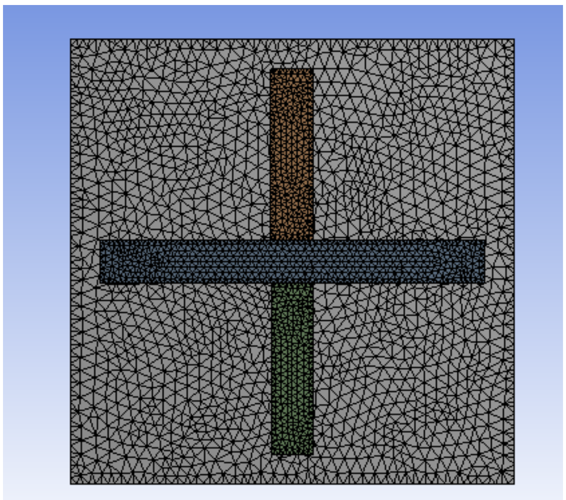


Fig. 8: Meshing of RC Slab with plus configuration

5. SUPPORT AND LOADING CONDITION

Simply support condition was used as the support condition for the analysis in ANSYS 16. It was added to all the four sides of the slab. Uniform constant pressure was used as a loading condition. Pressure was applied to the slab in the form stepped loading so to create a phenomenon of laboratory testing. A load of 250 kN/m^2 was applied.

V. RESULTS AND DISCUSSION

The results are studied from the FEM software ANSYS 16.0. The results of the various models were studied under different parameters. Parameters such as total deformation, maximum principal stresses and strains, Von-Mises stresses and strain, shear stresses and strain were selected. Contours of different parameters listed above from ANSYS 16.0 software follows the colour like red being the maximum value and blue being the minimum value. Total of 9 models were analysed. 1 control slab, 4 models with square configuration and 4 models with plus configuration.

1. TOTAL DEFORMATION

Static analysis was carried out in the ANSYS in the form of uniform intensity pressure and the variation of deflection is as shown below fig. 9. Slab without any FRP laminate was analysed for the comparison study.

The maximum total deformation for applied intensity of loading for BFRP Square is found to be 1.296 mm. The reduction in the total deformation is due to the application of BFRP to the Slab section.

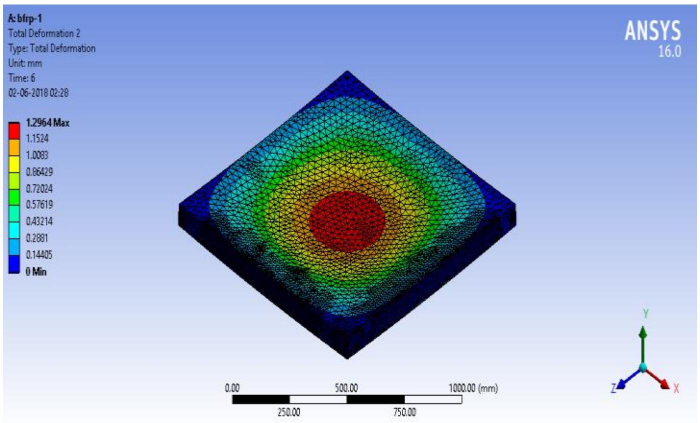
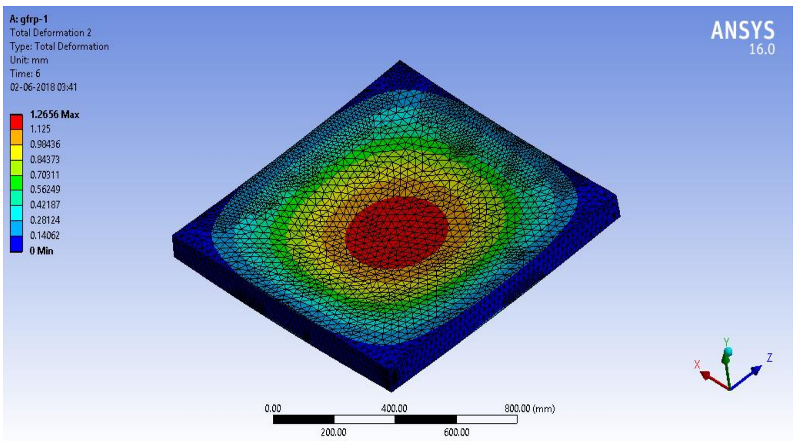


Fig. 9: Total deformation for BFRP Square Configuration

The total deflection for GFRP with Square and Plus configuration with static intensity of loading is found to be 1.26 mm. On comparison with plus configuration and square configuration there was small reduction in the deflection in plus configuration than in plus configuration.



Fig, 10: Total deformation for GFRP Square Configuration

2. PRINCIPAL STRESS AND STRAIN

Principal stresses and strains was analysed for the control slab and slab with different FRP composites. Principal stresses and strain were found out to know failure criteria of the slab. Slabs with FRP and without FRP was analysed in the ANSYS 16.0. Loading was in the form of pressure applied throughout the slab. Simply support on all four was taken.

For the slab with BFRP laminated in square configuration principal stress and strain were found to be 56.61 MPa and 0.0023962 respectively. The area where the slab is laminated with BFRP, the stresses are reduced when compared with control slab.

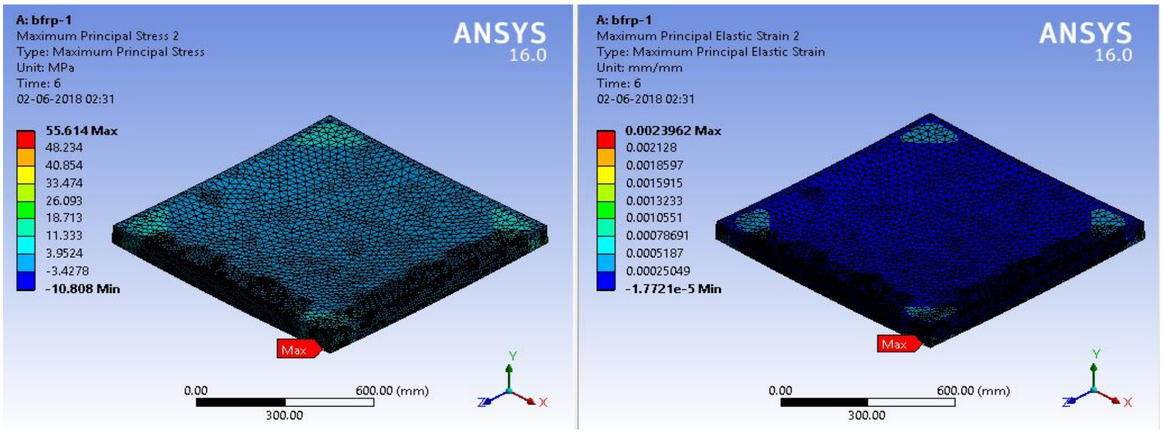


Fig. 11: Maximum principal stress and strain for BFRP square configuration

Finite element analysis was done to the slabs with GFRP laminated. The maximum values of principal stress and strain were found to be 54.84 MPa and 0.0023 respectively.

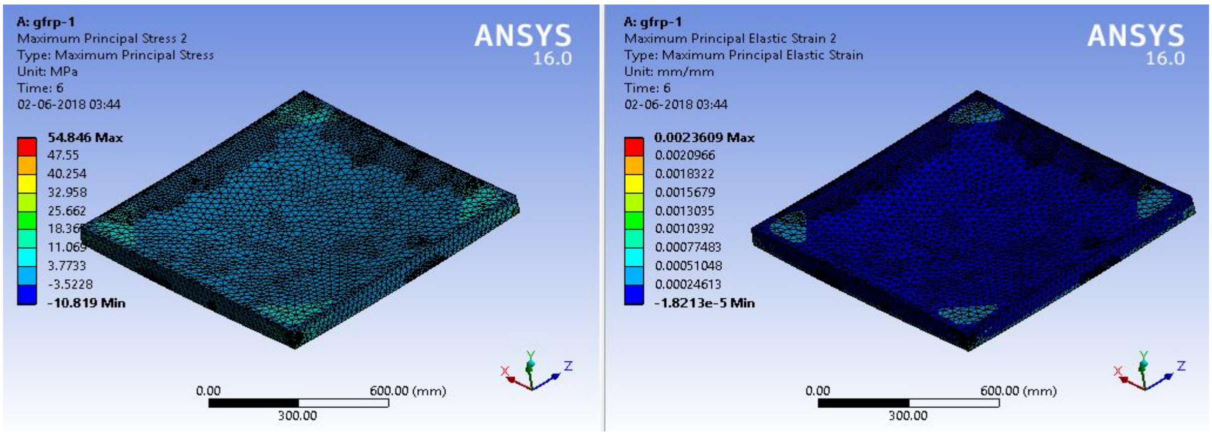


Fig. 12: Maximum principal stresses and strain for GFRP square configuration

3. VON-MISES STRESS AND STRAIN

Von-Mises stresses and strain were found for the study of failure criteria. Static analysis was done in the FEM software like ANSYS 16. Loading was in the form of uniform pressure applied throughout the slab.

When the slab specimen is laminated with BFRP in square configuration, the values for the Von-Mises stress and strain was found to be 99.79 MPa and 0.004 for square configuration respectively.

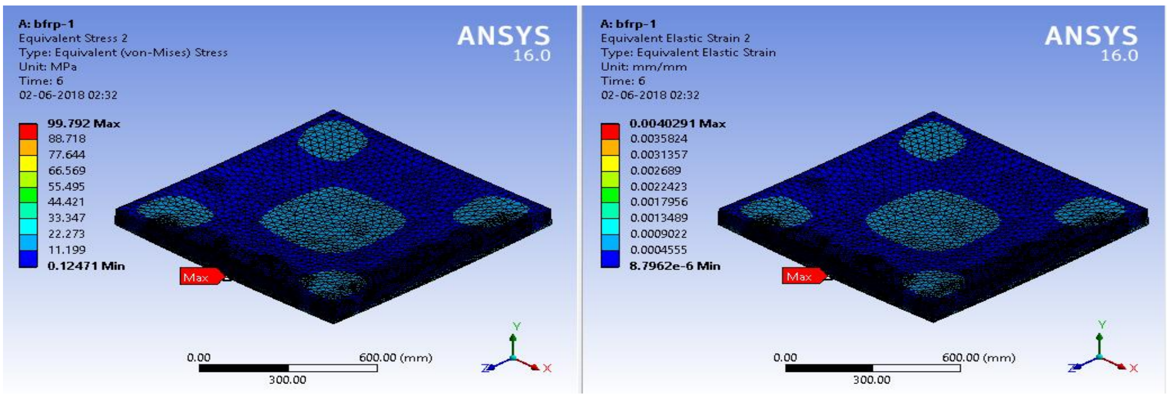


Fig. 13: Von-Mises stress and strain for BFRP square configuration

The maximum values of Von-Mises stress and strain for the slabs with GFRP laminate in the square configuration were found out. For square configuration the maximum values are 99.66 MPa and 0.004 respectively.

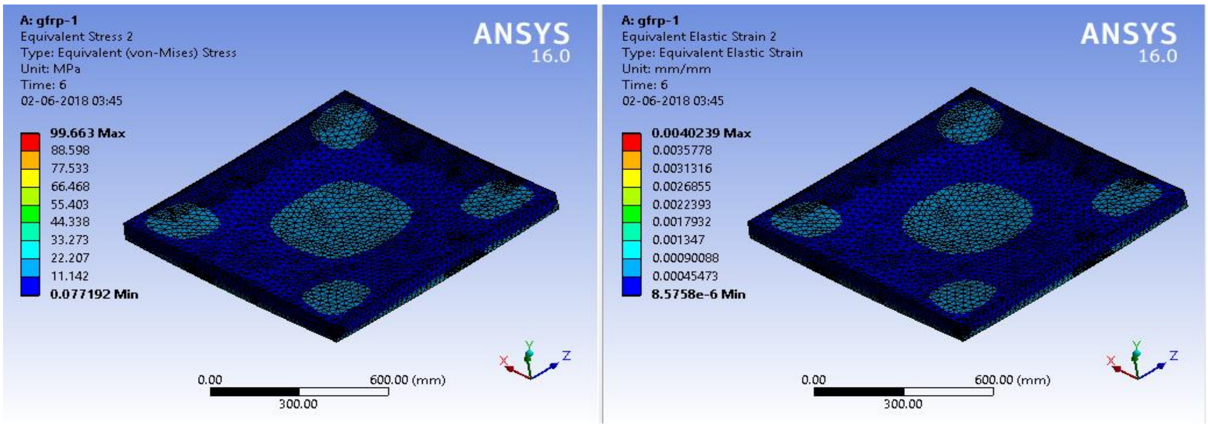


Fig. 14: Von-Mises stress and strain for GFRP square configuration

4. SHEAR STRESS AND STRAIN

Shear stress is studied in this present study for the failure criteria. Slabs specimen with and without FRPS are analysed in the Fem software like ANSYS 16 and the following results were obtained.

The maximum values of shear stresses and strain for the slab with laminated with BFRP in the square were studied in the project. The values were found to be 24.27 MPa and 0.0023 for the square configuration.

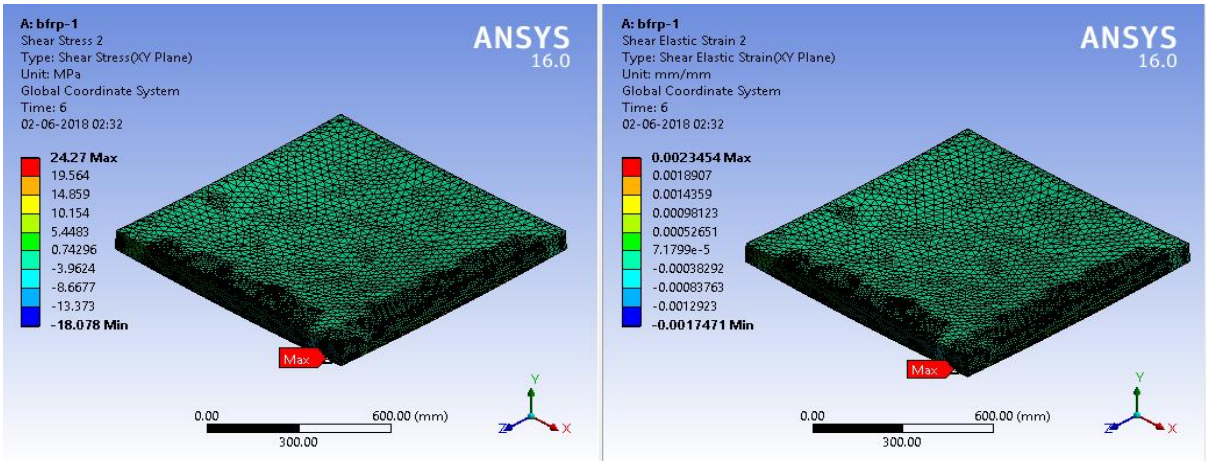


Fig. 15: Shear stress and strain for BFRP square configuration

The slabs with GFRP laminate in the form of square and plus below slab was analysed and shear stress and strain values were found out. The maximum value for the GFRP laminate slab with square configuration was 23.73 MPa and 0.0022 respectively.

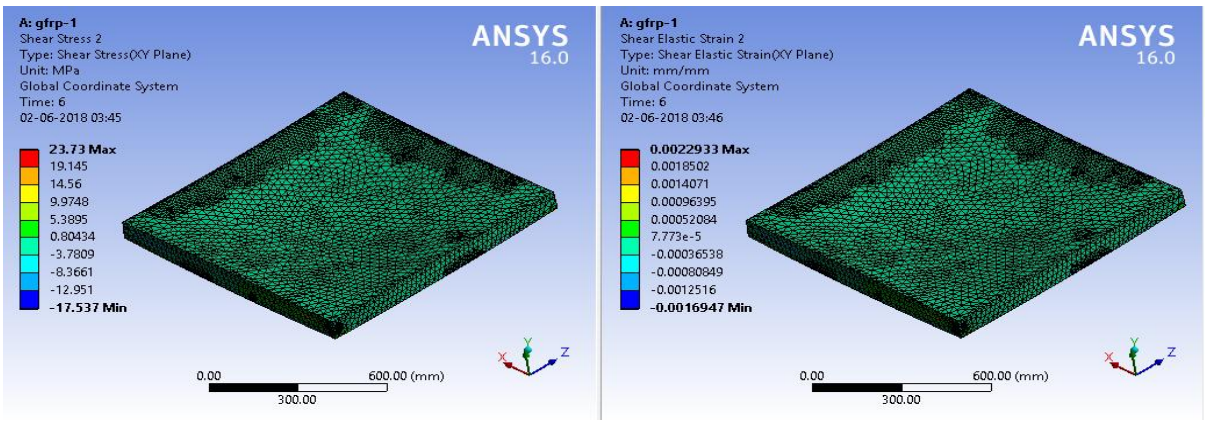


Fig. 16: Shear stress and strain for GFRP square configuration

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5. TABULAR COLOUM OF ALL RESULTS OBTAINED

The below table explains about the maximum values of various output parameters selected for the present study. Output parameters like total deformation, principal stress and strain, Von-Mises stress and strain, shear stress and strain were selected.

Parameters	Control slab	cfrp-square	cfrp-plus	gfrp-square	gfrp-plus	bfrp-square	bfrp-plus	ppfrp-square	ppfrp-plus
Total deflection(mm)	2.1797	1.2601	1.258	1.2656	1.264	1.2964	1.295	1.309	1.308
Maximum principal stresses(MPa)	18.28	54.57	54.05	54.86	54.26	55.61	55.34	55.14	55.81
Equivalent(von-Mises)stresses (MPa)	25.23	99.645	100.56	99.66	100.46	99.792	100.05	99.83	99.95
Shear stresses (MPa)	5.495	23.63	23.25	23.73	23.38	24.27	24.108	25.5	24.42
Maximum principal elastic strain(MPa)	0.00065	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0024	0.0024
Equivalent(von-Mises)elastic strain (MPa)	0.0010	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040	0.0040
Shear elastic strain (MPa)	0.0005	0.0022	0.0022	0.0022	0.0022	0.0023	0.0023	0.0023	0.0023

Table 2: Results of all slabs specimens

6. GRAPHS OF LOAD VERSUS DEFLECTION

The below fig.17(a) and fig.17(b) gives the comparison study on various FRPS used in the present study with different configuration used. Fig. 17(a) explains about the slabs with different FRPS with square configuration. Fig. 17(b) explains about the slabs with different FRPS used with plus configuration. It can be seen from both the graphs that the slab laminated with CFRP square configuration and plus configuration were found to be more effective in taking up the load compared to other FRPS.

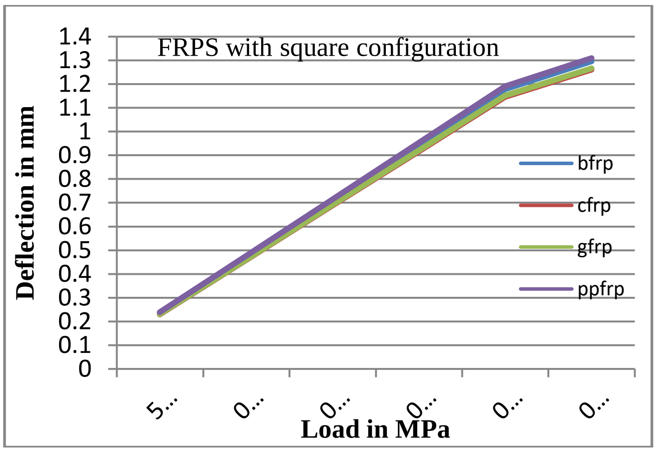

Fig. 17(a)

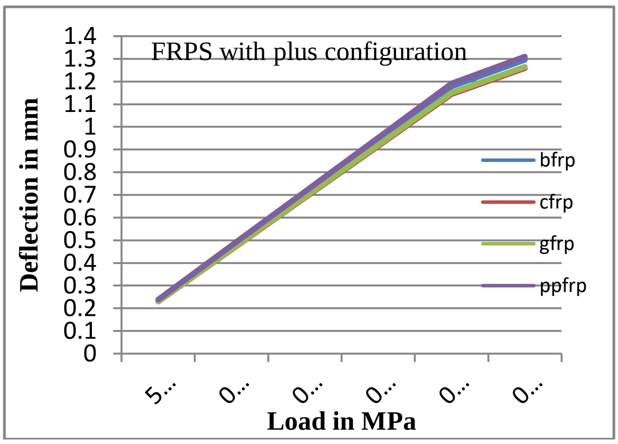

Fig. 17(b)

Fig. 17 (a) and Fig. 17(b): Load-deflection graphs for all FRPS with square configuration and plus configuration.

VI. CONCLUSION

Conclusion of present study is as follows

A. Strengthening by fibre reinforced polymers to structural elements like reinforced concrete slabs and beam was found to be more effective as it brushes away the problem of corrosion.
B. The stress distribution contours due to application of static load has been obtained from the finite element analysis carried out in ANSYS software.
C. The load carrying capacity of the RC slab with FRPS has been increased. Among all the FRPS used, carbon is found to be most effective in increasing the load carrying capacity of the RC slab.
D. The principal stress and strain was found to be decreased in the region of FRP applied. Compared with square and plus configuration of different FRPS used, CFRP with plus configuration was found to effective.
E. The Von-Mises stress and strain was decreased in the region the FRP applied. When compared with square configuration and plus configuration, CFRP with square configuration was found to be effective.
F. CFRP with plus configuration was found to be effective for shear stresses and strain compared to the other types of FRP used.

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