AN EXPERIMENTAL INVESTIGATION AND FINITE ELEMENT MODELING OF RCC COLUMNS CONFINED WITH FRP SHEETS UNDER AXIAL COMPRESSION

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Abstract—*Concrete is a commonly used building material. Poorly confined columns are recognized to behave in a brittle manner, exhibiting little deformation capacity. Increased loads, column deterioration, or seismic retrofit may require that additional confinement be provided to these columns to ensure adequate force and deformation capacity. The construction industry has considered using concrete confined by FRP. Applying composite materials to reinforced concrete has attracted much attention due to their lightness, rust resistance, high tensile strength and good flexibility. The material properties of composite materials greatly differ from those of steel.Fiber reinforced polymer (FRP) composites are thin laminates that are externally bonded to structural members using epoxy adhesive. The FRP significantly increases the members load carrying capacity. These structural strengthening systems are made of high strength fibers (such as Armid, Glass and Carbon) embedded in a resin matrix. The resin protects the fibers, maintains their alignment, and distributes the loads evenly among them. FRP's, which have been extensively used in industries such as aerospace, automotive, and sport equipment, are now becoming a mainstream technology for the structural upgrade of concrete structures.*

Keywords— Glass fiber, Epoxy resin, Concrete, Column, Compressive and Flexural strength.

1. INTRODUCTION

1.1 General

A brief description of commonly available fiber reinforced polymers (FRP's) and their properties are presented in this chapter. Applications of FRP, advantages and drawbacks of FRP including its use in confining concrete are also reviewed.

1.2 Fiber Reinforced Polymers

Fiber reinforced composite materials in civil engineering structures have progressed at a very rapid rate in recent years. These high-performance materials, which consist of high-strength fibers embedded in a polymeric matrix, have unique properties which make them extremely attractive for structural applications. Fiber reinforced composites are non corrosive , have high strength to weight ratios, posses good fatigue behavior and low relaxation, are electromagnetically neutral, and allows easy handling and installation. Moreover, as the fiber types (glass, carbon and aramid) and fiber volumes can be combined in innumerous ways with a large variety of matrices, their overall mechanical properties can be tailored to provide optimum solutions to a wide range of structural problems.

B.ADVANTAGES OF FRP

- FRP improves overall durability and shear strength.
- Prevents plastic shrinkage cracks.
- Increases toughness, fatigue resistance, freeze thaw resistance.
- Increases tensile strength, flexural strength and impact resistance.

C.1.4 DISADVANTAGES OF FRP

- High cost of fabrication of composites.
- They are not isotropic, that is their properties are not same in all direction, so they require more material parameters.
- Lack of long term performance data.

D.1.5 METHODS OF STRENGTHENING COLUMNS

1.5.1 General

The methods of strengthening can be classified in to the following three categories in terms of the method adopted for constructing the FRP composites:

- Wrapping (various wrapping schemes are shown in Fig. 1.1.)
- Filament winding
- Prefabricated shell jacketing

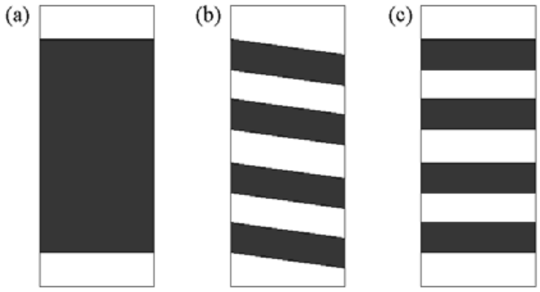
E.FIG 1.1 TYPICAL FRP WRAPPING

FRP wrapping methods for RC columns:

- Full wrapping using FRP sheets;
- Partial wrapping using FRP straps n discrete rings;
- (c) Partial wrapping using FRP straps in a continuous spiral.

F.1.5.2 WRAPPING

In situ FRP wrapping has been the most commonly used technique for column strengthening using FRP composites. In this method, unidirectional fibre sheets or woven fabric sheets are impregnated with polymer resins and wrapped around column in a wet lay-up process, with the main fibers oriented in the hoop direction. A column can be fully wrapped with FRP sheets in single or multiple layers. It can also be partially wrapped using FRP straps in a continuous spiral or discrete rings. The compressive strength enhancement of concrete due to the external wrapping of FRP was first demonstrated by Fardis and Khalili (1981, 1982).



G.1.6SUMMARY

In this chapter properties of various FRPs and their applications are discussed with an emphasis on confinement of concrete columns using FRPs.

H.2.0 SUMMARY OF LITERATURE REVIEW

As can be observed from the above discussion, the majority of previous research efforts related to concrete under pure axial loading have focused on plain concrete confined with FRP. This project will build upon that knowledge base by extending the testing to axially load RC columns, as described in the next section.

3.0 Summary of Methodology

The concrete were moulded, cured and tested according to the methodology mentioned above and also the analysis and discussion of the study are carried out in accordance with the object stated previously.

I.4.0 MATERIALS AND METHODS

4.1General

For developing rich mix, it is important to select proper ingredients, evaluate their properties and understand the interaction among different materials for optimum usage. The materials used for this investigation were the same as that used for the normal cement mortar mix such as cement, fine aggregate (FA) and water.

4.2MATERIALS USED

4.2.1 E-GFRP

In the specimens receiving glass fiber lamination, the required layers of the standard E class GFRP system are incorporating. Regardless of the number of the GFRP layers, the entire jacket was made of one continuous sheet of fabric that was cut to the proper length and width. An additional GFRP length of 50mm was provided for overlap splice. The test results of the GFRP sheets obtained from manufacturer.

Figure 4.1 E-GFRP woven roving sheets

Table 4.1 Properties of E-GFRP

Technical data	E-glass
Thickness	2 mm
Poisson ratio	0.65
Elastic modulus	73000 N/mm2
Tensile strength	3400 N/mm2
Sheet weight	880 g/m2
Density	2.6 g/cm3
Matrix type	woven rovings

4.2.2 Epoxy Resins

Epoxy resins are excellent binding agents with high tensile strength. The epoxy components are mixed just prior to application. The product is of low viscosity and can be injected in small cracks too. The higher viscosity epoxy resin can be used for surface coating or filling larger cracks or holes. Araldite GY 257 is used as a base and Aradur HY 140 is used as a hardener. The Mix ratio of base and hardener is 2:1.

Table 4.2 Properties Epoxy Resins

Material Properties	Values in N/mm2
Compressive Strength	80
Tensile Strength	17
Young’s modulus	5000
Flexural strength	28

4.3 TEST ON MATERIALS

Fineness modulus of F.A = 2.38
Fineness modulus of C.A = 4.16
Specific gravity of cement = 3.14
Specific gravity of F.A = 2.63
Specific gravity of C.A = 2.61

4.4 MIX DESIGN

Table 4.4 Mix Proportions

Water	Cement	Fine Aggregate	Coarse Aggregate
186	465 kg/m3	588 kg/m3	1134 kg/m3
0.4	1	1.2	2.4

The mix proportion chosen for this study is M30 grade (1:1.2:2.4) with water-cement ratio of 0.4. Cubes of standard size 150x150x150mm of total 9 no. and cylinders of standard diameter 150mm and height 300mm of total 9 no. are casted and cured for 7,14 and 28 days and tested as per code IS: 516-1959 and IS: 5816-1999.

4.5 Date Of Casting And Testing

[1] **Age of testing**	[2] **Date of casting**	[3] **Date of testing**
[4] 7 days	[5] 27.08.2015	[6] 03.09.2015
[7] 14 days	[8] 27.08.2015	[9] 10.09.2015
[10] 28 days	[11] 27.08.2015	[12] 24.09.2015

J.6. RESULT AND DISCUSSION

6.1 COMPRESSIVE STRENGTH TEST

1. Conventional Concrete Cube

[13] **S.** [14] **No**	[15] **Size** [16] **(mm)**	[17] **Age of** [18] **Loading** [19] **In Days**	[20] **Average Comp.** [21] **Strength** [22] **(N/mm2)**
[23] 1.	[24] 150x150	[25] 7	[26] 12.20
[27] 2.	[28] 150x150	[29] 14	[30] 19.77
[31] 3.	[32] 150x150	[33] 28	[34] 24.83

2. CONVENTIONAL CONCRETE CUBE WITH FRP

[35] **S.** [36] **No**	[37] **Size** [38] **(mm)**	[39] **Age of** [40] **Loading** [41] **In Days**	[42] **Average Comp.** [43] **Strength** [44] **(N/mm2)**
[45] 1.	[46] 150x150	[47] 7	[48] 13.95
[49] 2.	[50] 150x150	[51] 14	[52] 23.84
[53] 3.	[54] 150x150	[55] 28	[56] 27.76

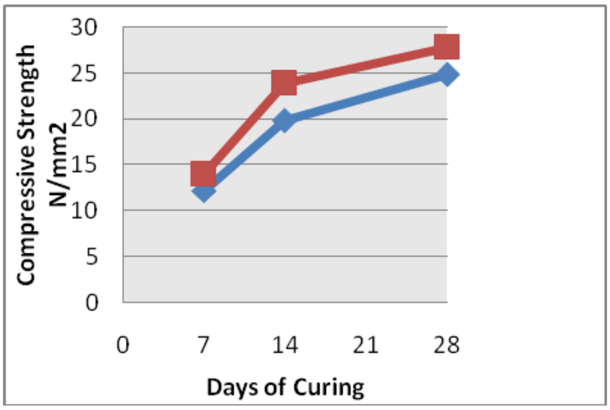
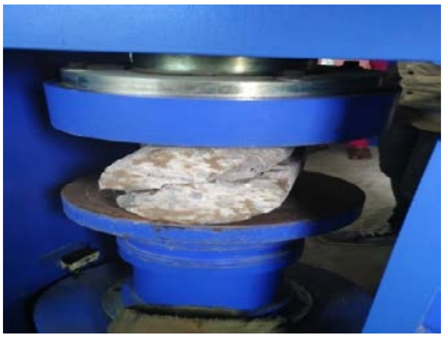


Figure 6.1 Comparison of Compressive Strength

6.2 SPLIT TENSILE STRENGTH TEST



1. Conventional Concrete Cylinder

[57] **S.** [58] **No**	[59] **Size** [60] **(mm)**	[61] **Age of** [62] **Loading** [63] **In Days**	[64] **Average Comp.** [65] **Strength** [66] **(N/mm2)**
[67] 1.	[68] 150x300	[69] 7	[70] 1.60
[71] 2.	[72] 150x300	[73] 14	[74] 2.92
[75] 3.	[76] 150x300	[77] 28	[78] 3.44

2. Conventional Concrete Cylinder with FRP

[79] **S.** [80] **No**	[81] **Size** [82] **(mm)**	[83] **Age of** [84] **Loading** [85] **In Days**	[86] **Average Comp.** [87] **Strength** [88] **(N/mm2)**
[89] 1.	[90] 150x300	[91] 7	[92] 3.01
[93] 2.	[94] 150x300	[95] 14	[96] 3.81
[97] 3.	[98] 150x300	[99] 28	[100]4.57

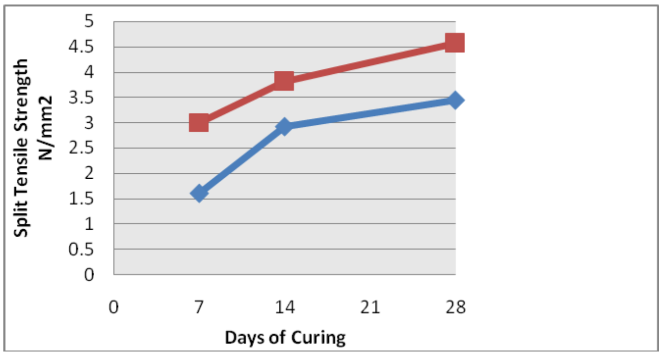


Fig 6.2 Comparison of Split Tensile Strength

6.4 DISCUSSION

From the analysis of the result of compressive strength and split tensile strength of conventional concrete and GFPR concrete are

- The Compressive Strength of FRP is more than 12.30% of the Conventional Concrete for 28 days Curing
- The Split Tensile Strength of FRP is more than 29.34% of the Conventional Concrete for 28 days curing.

7. FEM MODELING

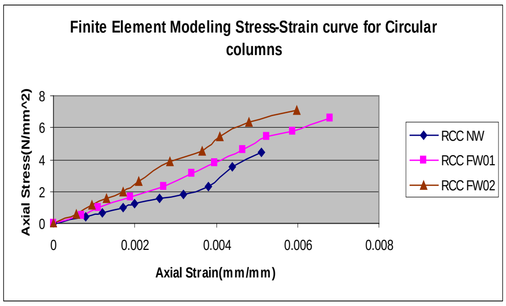


Figure 7.1: Stress-Strain curve Circular columns

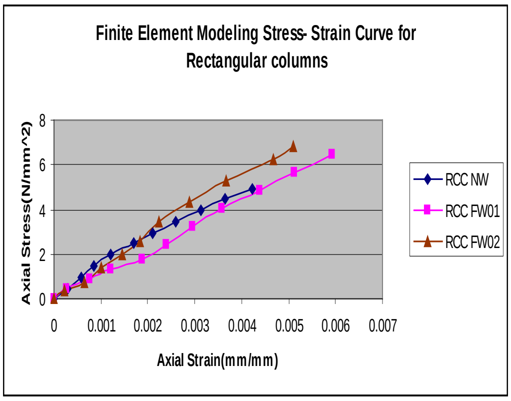
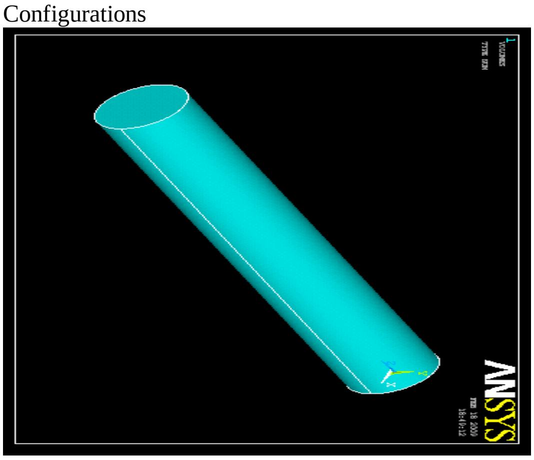
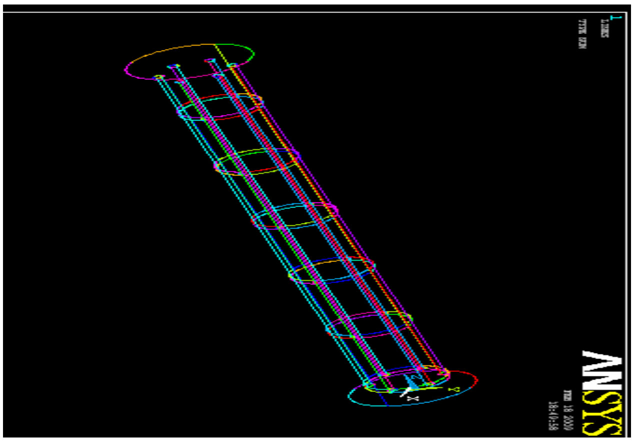
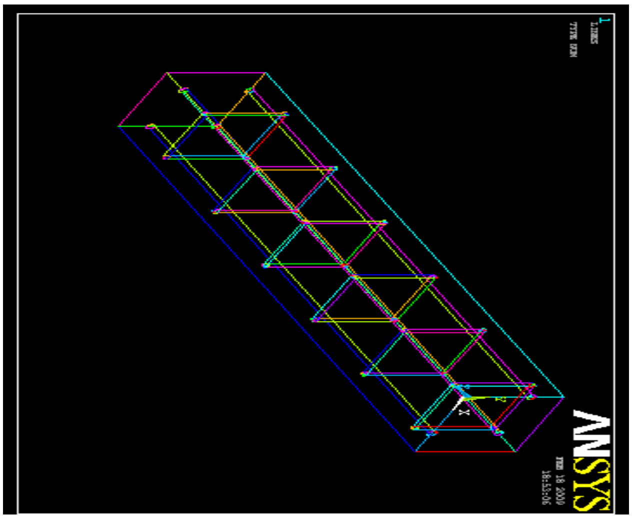


Figure 7.2: Stress-Strain curve square column

7.1 FEM Models, Stress-Strain Relations and Axial Compression Configurations







8. CONCLUSION

From the study performed on concrete columns confined by GFRP, it is concluded that this method of confining concrete is effective in significantly improving the performance of concrete columns

The following conclusions can be drawn form the results of this study:

- Square columns: Percentage increase in ultimate load is 18 and 34.5 for single and double layer wrapping respectively, when compared to without confined concrete column.
- Rectangular columns: Percentage increase in ultimate load is 17.3 and 33.8 for single and double layer wrapping respectively, when compared to without confined concrete column.
- Circular columns: Percentage increase in ultimate load is 24.5 and 45.6 for single and double layer wrapping respectively, when compared to without confined concrete column.

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