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Interaction diagrams of FRP Wrapped Hollow Core Reinforced Concrete Columns

M. Barghian[1*], M. Farzam[2], P. Ramazani[3]

1- Associate Professor, University of Tabriz
2- Assistant Professor, University of Tabriz
3- M.Sc. student, University of Tabriz

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ABSTRACT

Hollow core reinforced concrete columns are usually used to decrease the cost and weight/stiffness ratio of members. These columns usually carry axial forces together with bending moment.
Fiber- reinforced polymer FRP wrapping provides a confinement to the concrete. In this study, concrete columns were analyzed with and without external confinement; and interaction diagrams were compared with those obtained from experimental results. Based on the results it was realized that external confinement with FRP composite could increase the strength of concrete column. However, the influence of the number of layers of FRP on the specimens after five Layers under loading is not so pronounced. Wrapping three layers of FRP increases columns axial strength about 30% to 40%, while it can reach up to 50% for pure bending. Strength increase with seven and nine layers is about 5% more than retrofitting with five layers. Also, increasing hole dimensions reduces columns ultimate strength. Comparing columns with circular and square hole shows that columns with circular hole have better function.

KEYWORDS:

Hollow Core Reinforced Concrete, Fiber Reinforced Polymer, FRP.

[*] Corresponding Author, Email: barghian@tabrizu.ac.ir

1- INTRODUCTION

Hollow core reinforced concrete columns are usually used to decrease the cost and weight/stiffness ratio of members [1]. These columns usually carry axial forces together with bending moment.

Fiber- reinforced polymer FRP wrapping provides a confinement to the concrete. In this study, concrete columns were analyzed with and without external confinement; and interaction diagrams were compared with those obtained from experimental results. Variables studied in this research were, the column shape, the hollow core shape and dimension and the number of wrapped fiber layers. The effect of these parameters on the bearing capacity and ductility of hollow reinforced concrete columns have been compared. To investigate of modeling verification, hollow core reinforced concrete columns were modeled by ABAQUS software under different eccentric loads and under pure bending [2]. Then the model results were compared to the existent experimental results. After observing the concordance between the two sets of results, the same column was strengthened by one, three, five and nine layers of FRP. Columns were considered in two groups: C (without external coverage) and L (confined by three layers of FRP). Columns with small and large eccentricity were studied. The results showed that confined columns with CFRP endured more flexural and axial force compared with other groups; but the strength increasing in columns subjected to the coaxial force is more than the strength increasing in columns subjected to the eccentric force. Lateral deformation capacity under the load with eccentricity was substantially increased after coating by CFRP. A sample modeling is shown in Fig. 1.

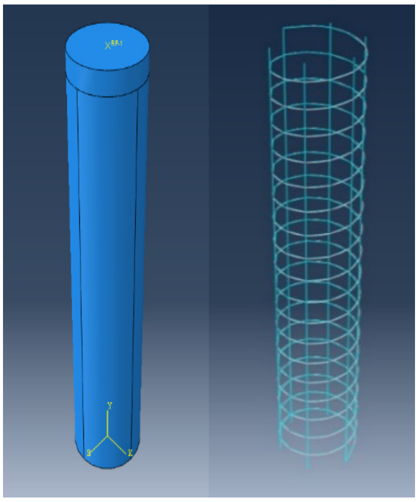

Figure 1. A sample column model by ABAQUS

2- ANALYSIS

Concrete and steel modulus of elasticity are given by equations (1) and (2) respectively.

$$Ec=2400^{1.5}(0.024\sqrt{60}+0.12)=36000\ MPa \quad (1)$$

$$Es=210000\ MPa \quad (2)$$

C3D8R element was chosen for concrete and Shell element was chosen for FRP. Figures (2) and (3) show the curves of interaction for modeling examples from the software and the experimental results.

Table 1 and 2 give the concrete and rebar plastic properties, respectively. FRP layers specifications are given in Table 3. It was observed that by confining columns with composite fiber layers, hollow circular

Table 1. Concrete plastic properties in tension and compression

Cracked strain	Yield stress (MPa)	Plastic strain	Yield stress (MPa)	Concrete damage
0	5	0	24	0
0.0007	3	0.0003	32	0
0.002	0.4	0.0006	43	0
-	-	0.0009	52	0
-	-	0.0014	60	0
-	-	0.0019	51	0.85
-	-	0.0024	33	0.55
-	-	0.0029	19	0.32
-	-	0.0035	13	0.21
-	-	0.0065	9	0.15

Table 2. Transverse and longitudinal reinforcement plastic properties

Plastic strain	Yield stress	
0	550	longitudinal reinforcement
0.1	700	longitudinal reinforcement
0	300	transverse reinforcement
0.1	375	transverse reinforcement

Table 3. FRP layers properties

E_1 (MPa)	4.6E+4
E_2 (MPa)	1.5E+4
ν_{12}	0.3
G_{12} (MPa)	1.5E+4
G_{13} (MPa)	1.5E+4
G_{23} (MPa)	1.5E+4

columns strength and ductility are increased.

A single layer of carbon FRP increases very low strength. Three layers has a good strength effect

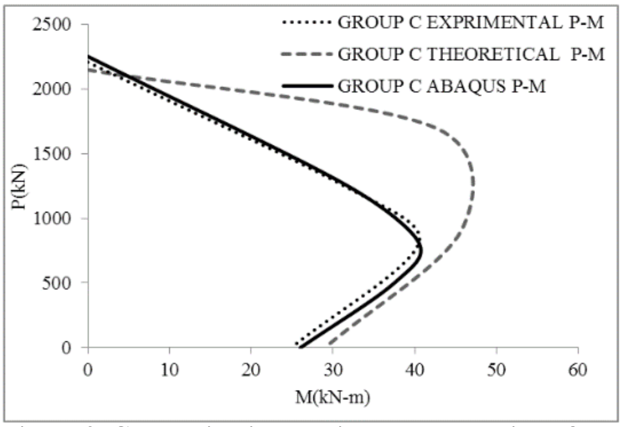

Figure 2. Comparing interaction curves obtained from test and model by ABAQUS (without coating)

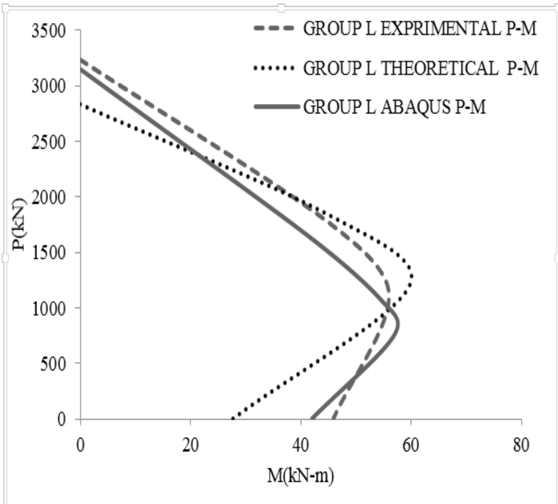

Figure 3. Comparing interaction curves obtained from test and model by ABAQUS (with 3 layers FRP coating)

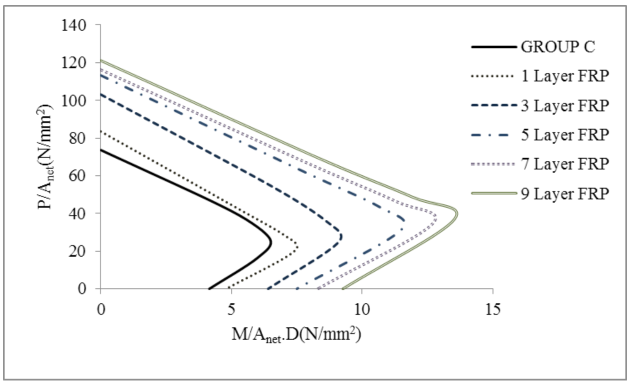

Figure 4. Comparing the effect of resistance of the coating layers of a circular column with a circular hole

comparing with a single layer. So that the axial loading of three-layer and five-layer wrapping show the strength increasing of 40% and about 50%, respectively. As it is seen from Fig. 4, five layer coating shows less strength increasing under axial loads and low eccentricities comparing with pure bending and high eccentricities.

3- CONCLUSION

Based on the results it was realized that external confinement with FRP composite could increase the strength of hollow (circle and square) concrete column. However, strength is not proportional to the increase in the number of layers, so that wrapping a layer of coating increases very low resistance. The three and five-layer coating, strengthening increasing is significant. Increasing the number of layers to more than five, has no significant effect on the strength increasing. A cover layer increases the strength of columns about 8% to 10%, three layers increases about 30% to 40%, five layers increases about 40% to 53%, seven layers increases about 43% to 57% and nine layers increases about 51% to 64%. The results showed that by increasing in the size of the hole, the strength is decreased. Except in the case of loading eccentricity of 75mm (in which, the ultimate load of the column with square hole of to the side s with a square hole of 80 mm side length is higher than the other models) the results follow the expected trend. The performance of square columns is improved similar to circular columns when they are wrapped with FRP coating. The strength is increased by increasing layers numbers. For the eccentricity of 75 mm, square columns wrapped in a layer have close results to square columns wrapped in three layers. Three and five-layer have logical strength improvement, while the improvement in strength is not considerable in the presence of seven and nine layers coating.

The influence of the number of layers of FRP on the specimens after five Layers under loading is not so pronounced. Wrapping three layers of FRP increases columns axial strength about 30% to 40%, while it can reach up to 50% for pure bending. Strength increase with seven and nine layers is about 5% more than retrofitting with five layers. Also, increasing hollow section dimensions reduces columns ultimate strength. Comparing columns with circular and square hole shows that columns with circular hole have better function.

4- REFRENCES

[1] Hsu, HL.; Liang, LL.; “Performance of hollow composite members subjected to cyclic eccentric

loading", Earthq Eng Struct Dyn, 32, pp: 443. – 61, 2003.

[2] Yazici, V.; Hadi, M.N.S; "Axial Load-Bending Moment Diagrams of Carbon FRP Wrapped Hollow Core Reinforced Concrete Columns", JOURNAL OF COMPOSITES FOR CONSTRUCTION © ASCE / JULY/ AUGUST, 2009.