World Applied Sciences Journal 24 (7): 960-970, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.24.07.1156

Mechanical Behaviour of Confined Reinforced Concrete-CFRP Short Column- Based on Finite Element Analysis

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Submitted: Jul 19, 2013; **Accepted:** Aug 30, 2013; **Published:** Aug 29, 2013

Abstract: Strengthening of structural members such as column is one of the engineering concerns in which many researches have attempt to assess in various aspects. This paper presents the results of a study to have better understanding of structural behaviour of the reinforced concrete (RC) short column wrapped by carbon fiber reinforced polymer (CFRP) sheets under pure axial static load. To achieve this aim, a nonlinear finite element analysis (NLFEA) is conducted. ABAQUS/STANDARD software is used to analyse the reinforced concrete short column wrapped by CFRP and the finite element analysis results is compared to experimental results obtained from existing literature. Nonlinear material behaviour as it depends on steel reinforcing bars, plain concrete and fiber reinforced plastics is simulated using appropriate constitutive models. Different aspects of the confinement effect such as differences in cross section size, number of CFRP layers, volumetric ratio of CFRP, column size and mesh size effect are studied. The results of the study show that, externally bonded CFRP sheets are very effective in enhancing the axial strength and ductility of the concrete short columns. Inspection of the results shows that, there is good agreement between the NLFEA and the experimental test results.

Key words: Carbon Fiber Reinforced Polymer · Non-Linear Finite Element Analysis · Reinforced Concrete Short Column · ABAQUS · Volumetric Ratio · Ductility · Mesh Size

INTRODUCTION

Wrapping the RC columns is one of the engineering methods to retrofit and strengthening such structural members to expand their service life. In some specific position like construction on slope, application of the short RC column is unavoidable. Additionally, the use of CFRP to repair and retrofit the concrete due to several advantages such as light weight, easy to apply and high tension strength has become more and more popular. Indeed, the power of this method depends on a lot of different parameters such as strength of the concrete, CFRP properties, column geometry, etc. In past, performance of concrete members has been assessed experimentally and analytically. Many researches were carried out by previous experts on the retrofitting field by means of fiber reinforced polymers; [1-6]. The first experiments tested concrete cylinders wrapped with composites under uniaxial compression [7]. Li *et al*. [8] developed a constitutive model for confined concrete for retrofitting and strengthening reinforced concrete structures. They investigated behavior of cylinders with various strengths of the concrete those were confined with numbers of layers of carbon fiber reinforced plastics (CFRP) under uniaxial compression. However, Lam and Teng [9] investigated the confinement effectiveness of depends not much on unconfined concrete strength, FRP type, size and length to diameter ratio of the samples. Cho *et al*. [10] applied an analytical model for concrete model by means of multi-axial constitutive laws.

Several researches have been conducted upon large scale specimens to assess real behavior of the members. Matthys *et al*. [11] has estimated the behavior of large scale reinforced concrete column by considering the effective circumferential fiber failure strain and the effect of increasing confining action on the stress - strain curve. Also, the research showed that, increase in strength and ductility of the confined columns depends to tensile strength of the FRP. There are several researches which used large scale simulation [11, 13]. In those studies, influence of plain rebars, inadequate splicing lengths and insufficient stirrup spacing in deal with effect of CFRP on behavior of RC columns under axial load, were examined experimentally. The tests results showed that, retrofitting

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with CFRP sheets had strong influence on strength and ductility in case of continuous rebars while little improvement had been seen for lap-spliced columns [14]. There are many experimental researches in which they tested strengthening of concrete [15]. Several researches have been conducted by means of finite element modeling. Parvin and Wang [16] used the finite element method to investigate behavior of large scale concrete columns by use of finite element software MARC. They showed such columns achieved great improvement respect to their strength and ductility for potential plastic hinges. Also, they investigated that, by applying monotonic lateral load, the wrapped columns experienced a large displacement rather than conventional columns without confinement and an improving in strength as well. In addition, they concluded that, by applying the cyclic lateral loading, the column without jackets imposed to larger lateral displacement rather than FRP wrapped columns.

Also, Analytical models have been used as a powerful technics to assess behavior of concrete wrapped in FRP sheets. Eid and Paultre [17] have been done an analytical research in which they took into consideration, the interaction between the internal lateral steel reinforcement and the external FRP sheets to assess real confinement effect due to both steel and FRP. An analytical model was proposed to assess the effect of different configuration of CFRP confinement on wrapped concrete, by applying the uniaxial cyclic and monotonic loading in which a uniaxial stress–strain constitutive model used to simulate the behavior of RC members [18]. Another analytical model was conducted [19]. In this research some new insights on interaction mechanisms between internal steel reinforcement and external FRP strengthening and their influence on efficiency of FRP confinement technique were examined. Effect of the normal and high strength concrete confined with fiber reinforced polymers was experimentally examined [20]. Also, there is a research in which both carbon fiber polymer and aramid with different geometry of the member such as square and circular was carried out. In this research, effect of the rupture of FRP sheet and different lateral pressure was examined. The results showed that, for cylindrical cross sections, improvement of the axial load capacity for carbon and aramid was same [21]. As the finite element method is one of the powerful computational engineering tools, there are several studies those have assessed the behavior of the wrapped RC columns by using such method. In past, several researches focused on nonlinear analysis of the columns with circular cross section under axial force and biaxial moment, by means of finite element method respect to both geometric and material nonlinearities. Also, Wang *et al*. [22] reported the results of both unreinforced and reinforced columns with circular cross section, under both monotonic and cyclic axial load. Assessment of the plastic hinge condition and drift capacity of fiber reinforced polymer are the goals of the research in which three methods; simulation, experiment and mechanism analysis were carried out [23]. Comparison of the experiment and analytical assessments in case; slender columns wrapped with CFRP sheets in both longitudinal and transverse, under axial load and biaxial bending, showed that, once the CFRP applied in longitudinal direction, lateral deflection will be decreased [24]. Through the comprehensive studies on the strengthening fields, optimization of the methods is so important respect to real and practical work. The finite element method and fiber method modeling together are used to have better understanding of the behavior of such columns. In that researches the effects of length and fiber thickness were considered. It was concluded that, in compression field, with complete confinement, when the compressive strength increases, wrapping effectiveness will be increased as well. Also, higher unconfined concrete strength leads to significant effectiveness of the optimum fiber reinforced polymer. It means when strength increases, by increasing the optimum FRP, confinement effect sharply increases, [25]. Indeed, many researches were conducted by application of the finite element analysis method. They used the commercial software such as MARC, ABAQUS and ANSYS. Parvin and Wang [16] carried out a nonlinear finite element analysis to assess behavior of the fiber reinforced polymer wrapped reinforced concrete columns, subjected to combined axial and cyclic lateral loadings by using MARC software.

Several studies already examined different aspects of such members and mostly focused on normal reinforced concrete beam behavior. Consequently, many engineering software have been applied to simulate the behavior of columns under load. While, few studies have been carried out to identified properties of the circular RC short column wrapped in CFRP by using numerical finite element analysis software ABAQUS. This study addresses this gap of the previous researches and will confirm accuracy of abovementioned method for strengthening the columns in comparison with experimental results extracted from literature review. Hence, to enable better understanding of the behavior of such columns under pure axial load, a finite element model is developed by the ABAQUS/standard software. This study mostly concentrates on specific objectives, including: effect of number of (CFRP) layers on the stress-strain curve, mechanical properties of reinforced concrete short column, the effect of different cross sections and height of RC column wrapping by external CFRP sheets on the mechanical behavior of RC short column.

Finite Element Analysis Model

Confinement Mechanism: In general, the lateral confinement provided by a CFRP sheets is passive. Indeed, the jackets act after concrete starts expansion. Once the column is compressed due to Poisson's effect in concrete, it tends to develop its aspects in three dimensions, hence the fiber reinforced polymer is loaded in the hoop direction and then it acts as an active confinement. After that, because of brittle behavior of the CFRP Figure 3, the action will be continued until the rapture of jacket. Generally, to measure the compressive strength of the confined concrete, the strain in lateral failure is considered. As in present study a short column is considering, hence the slenderness has not considerable effect. According to ACI definition, a column which is not braced against side sway is considered as a short column if: kL/ r < 22.

Material Characteristics: Finite element models for CFRP confined RC short column are presented. First the material characteristics are identified, then material properties which are required to insert in software are defined. In this study, the ABAQUS/CAE is used for modeling of concrete column, reinforcement and CFRP sheet. The nonlinear analysis is developed by means of Abaqus/Standard to simulate the nonlinear behavior of the confined column. The three dimensional analysis is conducted to have realistic model. The model general configuration is a vertical column fixed to bottom, which is restrained in all directions. The section sizes (diameter) are differed on D=150, 250,300,450 and 600mm, where H is the section height differs on 450mm and 750mm. The steel tie reinforcement is 4.76mm in diameter with a spacing of 75 mm for all specimens as required by the ACI 318-05 Eq. (10-5). For all the columns, four longitudinal bars are set with 10mm dimension. Also, percentage of the steel is ρ=1.56% respect to column sizes according to ACI recommendation. A pure axial compressive load, P, is acting at top of the column, by using of incremental steps in the software. Since the response of the column will be in plastic zone, to model the nonlinear behavior of the RC column under pure compressive axial load, the finite element software, ABAQUS/standard, is used in this study.

A plastic damage model is used to model the concrete behavior as recommended by ABAQUS manuals. This model considers the main two failure modes of the concrete are tensile cracking and compressive crushing (ABAQUS manual 6.9). After whole model geometry definition, the material properties should be introduced. First, elastic behavior of material is set. Hence, the elastic parameters such as: Young's modulus of concrete, Ec and Poisson's ratio, ν, are inputted. From experimental results Ec and fct are calculated by:

☻ (1)

☻ (2)

where f'_c is given in MPa. The popular stress-strain relationship is used to make the uniaxial compressive simulation of the concrete column which is proposed previously [26]. The equation is given by:

☻ (3)

where:

☻

Also: ε_0=0.0025, Rε=4, Rσ=4 as reported in [27]. In this study, the Poisson's ratio of concrete is assumed to be ν_c =0.2. Also an elastic, perfectly plastic behavior is considered for the steel bars as recommended in several previous researches. The elastic modulus, E_s and yield stress, f_y, were measured in the previous experimental studies. Young's modulus and yielding stress is set to E_s = 209 GPa and f_y = 410 MPa respectively. These values were used in the finite element model (FEM). A Poisson's ratio of 0.3 is used for the steel reinforcement. The perfect bond between steel bars and concrete is considered. Indeed, as the CFRP behavior is orthotropic, the CFRP material is inputted as a linear elastic orthotropic material in the model. Indeed, it is necessary to introduce properties of the CFRP for each direction separately. Hence, the elastic modulus in main direction is set to 165GPa, getting from manufacture data, in the fiber direction tensile strength equals to 3790 Mpa, ultimate

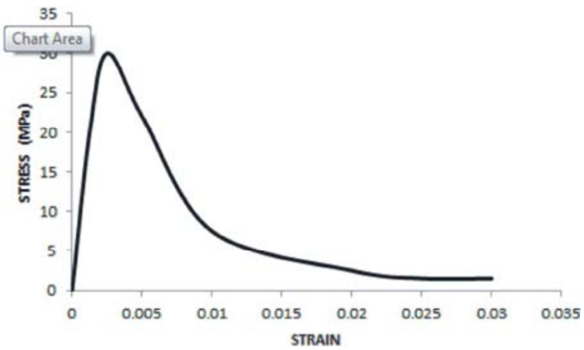


Fig. 1: Stress-Strain relationship for concrete under uniaxial compression

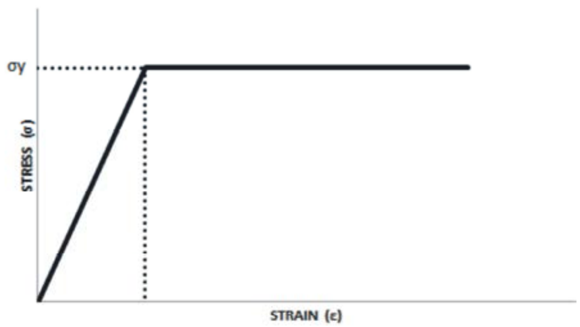


Fig. 2: Stress-Strain relationship for steel as used in NLFEA

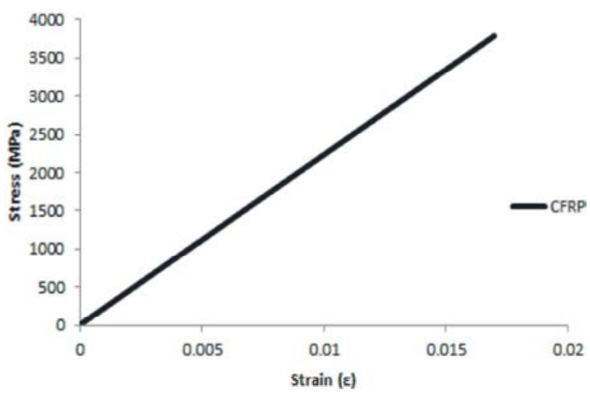


Fig. 3: CFRP stress-strain relationship

tensile strain is considered, 0.017 mm/mm and thickness of the CFRP, 0.165mm. For the orthotropic material model, in engineering constant in the ABAQUS software, the Young modulus, E_{11} is 228 GPa and Poisson's ratios, $\nu_{12} = \nu_{13} = 0.3$, for another directions, $E_{22} = E_{33} = 9.65$ GPa, as engineering constants. Shear modulus is set to $G_{12} = G_{13} = 5.2$ GPa. Also, two other directions have shear modulus and Poisson's ratio as G_{23} and ν_{23} 3.4 and 0.45, respectively. The CFRP ultimate strain (ε_{ult}) in the experimental work will be used later for the failure criterion.

Concrete is modeled using a solid eight-node element (C3D8R) with linear reduced Gauss integration points. Three dimensional truss elements are applied to model both transverse and longitudinal reinforcements. As recommended in ABAQUS manual, CFRP sheets are modeled with four-node shell elements. Also, because of brittle behavior of the carbon fibers reinforced polymer, the linear elastic behavior up to rupture is assumed for CFRP. Columns were divided in 5 groups by different dimensions which differ on D= 150,250,300,450 and 600mm with two different columns length L=450mm and 750mm. Consequently three unconfined concrete strength were applied in the numerical study: 20, 28 and 40 MPa. Columns are named as: (RC150S20L1), reinforced concrete (RC) with 150mm dimension, strength(S) 20MPa and 1 layer (L) wrapped CFRP composite. All the RC columns have fixed support, hence there are not any displacement and rotation in the x, y and z directions.

Validation study is confirmed by comparison between numerical modeling results and experimental results which is conducted upon assessment of the behavior of the reinforced concrete columns confined with CFRP composites by Chastre and Manuel [4]. Also, the numerical results of current study on the behavior of CFRP confined short reinforced concrete columns subjected to axial compression load is validated by experimental data of other researchers [20, 21, 24, 28]. To achieve this goal, a simulation with same properties by means of the numerical finite element approach is conducted. The columns sizes differ as: diameters D=0.15m and 0.25m, height 0.45m and 0.75m and they subjected to an axial compression load. Properties of series C4 and C10 proposed by authors and characteristics of the material which were applied in experimental work are available in Tables 2 and 3. The specimens were loaded under 5000KN pressing and it was continued after failure until 150KN force [4] in which it is assumed that the entire section of the column is under compression. The applied load effects on the top of the concrete section and it does not influence on CFRP sheet. The concrete column cross section is under uniform stress; consequently whole body has uniform lateral dilation, which is observed from previous experimental researches.

Accordingly, an axial compression load-axial strain curve is plotted comparing the numerical and experimental results to validate the accuracy of the model. Refer to Figure 5, it can be seen there is a desired agreement between FEA and existing experimental results for CFRP

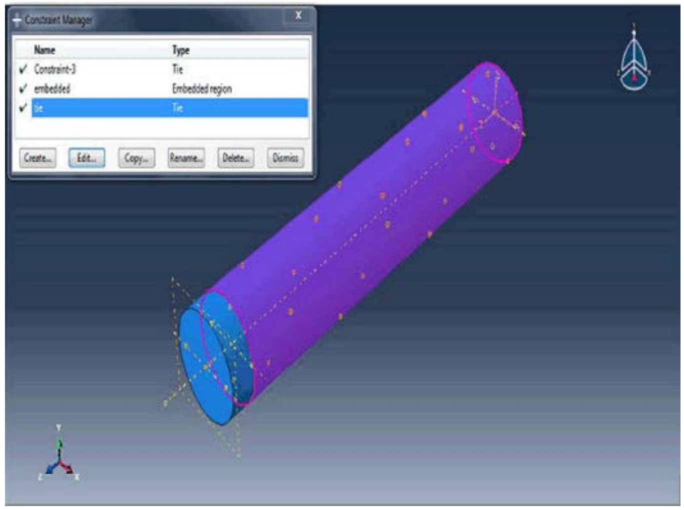


Fig. 4: Short column structure for model verification (interaction between layers and position of plate)

Table 1: Axial compression test on CFRP confined plain concrete and reinforced concrete columns [4]

Series Name	Diameter (mm)	NO. CFRP	Reinforcement	Max. Axial Load (KN)	ε_{cc} (%)	ε_{cu} (%)
C4	150	2	-	1339.6	1.28	0.85
C10	150	2	Longitudinal 6Ø6mm Transvers Ø3@100mm	1485.7	1.31	0.9

Table 2: Properties of materials [4]

Material	Type	f_{co}(MPa)	f_y(MPa)	t_{ply}(mm)	E_f (GPa)	f_{fu}(MPa)	ε_{fu}%
Concrete	1st,2nd series	38	-	-	-	-	-
Steel	Ø3,Ø6,Ø12	-	323,391,458	-	-	-	-
CFRP	A,B	-		0.167,0.176	226,241	3339,3937	1.44,1.54

Table 3: Number of elements and nods for different size

ID	H(height) (mm)	Diameter (mm)	Nodes	Elements	Mesh size
RC150S28L1	450	150	4370[a]	42750[a]	0.01
			46828[b]	43650[b]	
RC150S28L1	450	150	512[a]	480[a]	0.03
			2192[b]	1800[b]	
RC150S28L1	450	150	190[a]	171[a]	0.05
			590[b]	432[b]	
RC150S28L1	450	150	60[a]	50[a]	0.1
			96[b]	50[b]	
RC250S28L1	750	250	12008[a]	11850[a]	0.01
			192964[b]	184425[b]	
RC250S28L1	750	250	1378[a]	1325[a]	0.03
			8762[b]	7750[b]	
RC250S28L1	750	250	512[a]	480[a]	0.05
			2240[b]	1845[b]	
RC250S28L1	750	250	144[a]	128[a]	0.1
			351[b]	240[b]	

[a]CERP sheet
[b]Concrete core

confined concrete columns in terms of axial load-axial strain. Once the model has been calibrated with experimental data, the rest of the numerical works are performed.

In addition, Figure 5 shows a slight slope when the steel bars start to yield. Indeed, in this position the bond between concrete and reinforcement is decreased.

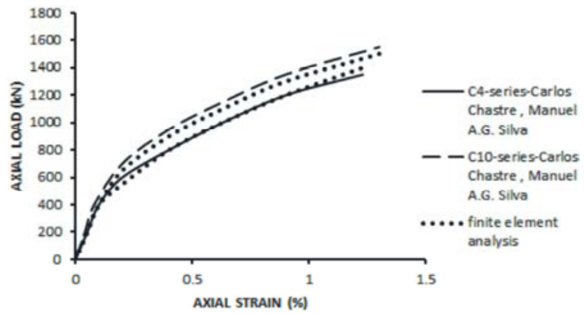


Fig. 5: Comparison between finite element method and experimental

RESULTS

Effect of Number of Applied CFRP Layers: By applying the one to five numbers of CFRP layers, which are externally wrapped around the outer face of circular short columns, here are results on effects of number of layers in terms of the mechanical behavior (stress-strain curve) of such columns. Figures 6 and 7 show the results of two different compressive strength 20 and 40 MPa for concrete.

As it shown in Figures 6 and 7, increasing in number of CFRP layers has a significant effect on behavior of such columns, which was expected due to confinement effect. Indeed, for both strength by increasing the CFRP sheet after yield point, ultimate strength will be increased which is more significant in case 40MPa respect to 1 to 3 layers increase. This action can show the influence of CFRP (which is brittle in nature) to control the expansion increase of concrete. Hence, it can be concluded that, the second part of graph has an accurate shape respect to the overall behavior upon stress-strain curve for enhancement of the plasticity portion on the curve. In addition, by comparing the result for 20 and 40 MPa concretes strength, in both cases increase in ultimate strength and strain is obvious.

Member Size Effect: In this section the effect of different size (cross section and height) of the circular RC short columns are assessed. After modeling the columns by ABAQUS software and study the stress strain curve, a comparison study is hold on the effect of different confinement ratios. Figure 8 shows stress–strain curves for two different cross sections of the RC columns with: H=750, D=250 mm and H=450, D=150 mm. By applying same number of layers (two CFRP jackets), it can be seen that, the confinement is less effective for the columns with larger diameter in terms of ultimate strength. For the case

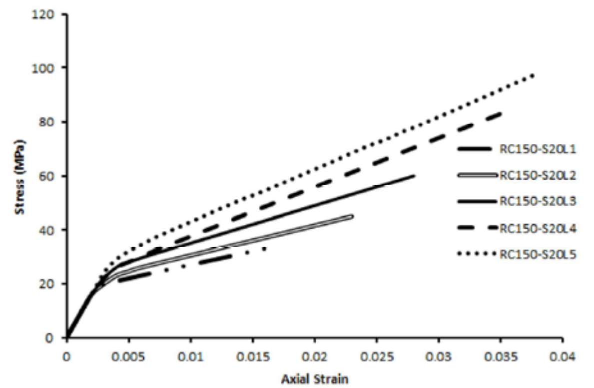


Fig. 6: Stress-Strain curve for RC column with different number of CFRP layers

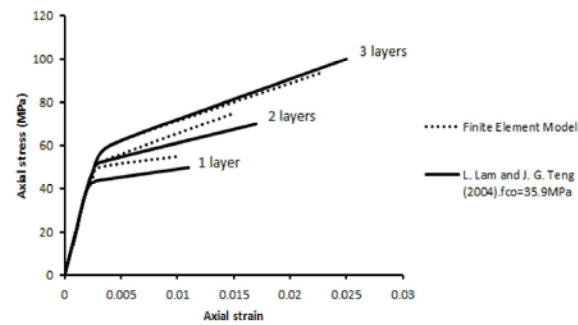


Fig. 7: Comparison of experiment and finite element method for one to three layers

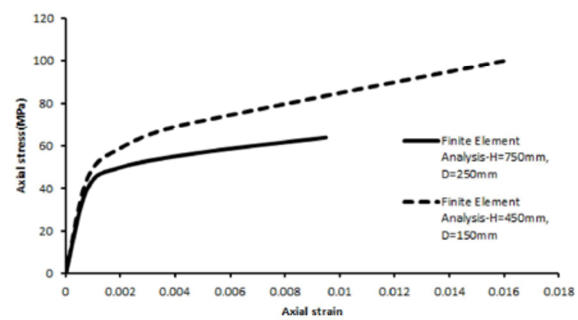


Fig. 8: Stress-Strain behavior for different cross sections and height of column, with two layers of CFRP jackets

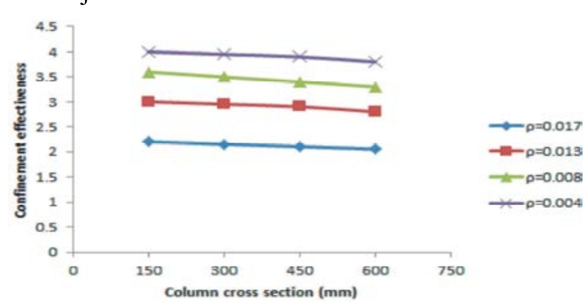


Fig. 9: Effect of different cross section of RC column respect to confinement effectiveness

of larger column with dimension of 250 mm, the maximum axial stress reach to 62MPa, at a strain of 0.0095, while the column with small diameter D=150 mm has an ultimate stress of 100MPa at strain of 0.0162. The results indicated that, the NLFEA is in good agreement with the experimental stress–strain curves reported [2, 3, 5, 6].

Figure 9 indicates that, for the same CFRP volumetric ratio, the level of confinement effectiveness decreases when the cross section area increases. Also, Figure 9 denoted that, by increasing the level of the volumetric ratio, the confinement effectiveness sharply increases. Volumetric ratio is given blow:

☻ (4)

where n is number of CFRP sheets. t_f is thickness and D refers to cross section diameter. For fixed volumetric ratio (0.017), slightly decrease in confinement effectiveness can be seen which is 2.25 for 150mm diameter and 2.09 for 600mm cross section. Figure 9 indicates that, for lower volumetric ratio (0.008), the confinement effectiveness sharply decreases by increasing cross section. It is 3.6 for 150mm cross section and decrease to 3.4 for 600mm diameter. Inspection of Figure 9 reveals that, there is significant increase in confinement effectiveness when the volumetric ratio increases. Indeed, for 150mm cross section, confinement effectiveness is changed from 2.25 to 4, for volumetric ratio of 0.004 and 0.017 respectively. For 600mm column diameter the confinement effectiveness varies from 2.09 to 3.75 for 0.004 and 0.017 volumetric ratio respectively. These results are in good agreement with previous experimental and analytical researches.

Ductility of Confined Reinforced Concrete Columns: The concept of ductility is defined as the ability of a structural member to bearing the inelastic deformation without significant reduction in the load carrying capacity. Figure10 shows the ductility of different RC short columns respect to different strength and number of CFRP layers.

Figure 10 reveals that, the ductility significantly increases once the numbers of applied layers are increased. For RC column with 20MPa strength and 1 layer CFRP, ductility percentage equals to 1.25%, while for the same strength, the ductility increases for 2 layers and little reduction is occurred for 3 applied layers and then slightly increases for 4 and 5 layers. For the case of 40MPa strength, with 1 layer jacket, the ductility is 0.55 and slightly increases until 3 layers with 1.2%, after that the ductility has sharply increase until it reaches 2.2 for 4 layers CFRP. Additionally, increase in ductility is directly depends to decrease of compressive strength. The results clearly show that, low strength concrete columns exhibited larger ductility than high strength concrete columns, whereas the strength differs from 20MPa and 40 MPa which is in good agreement with previous researches.

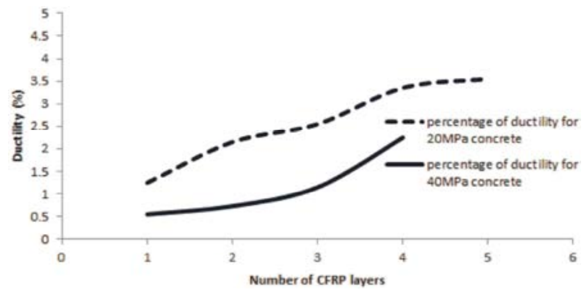
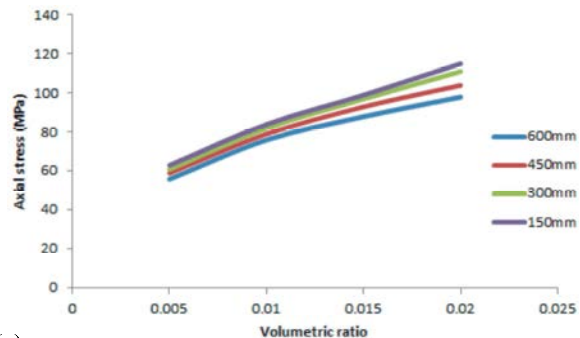
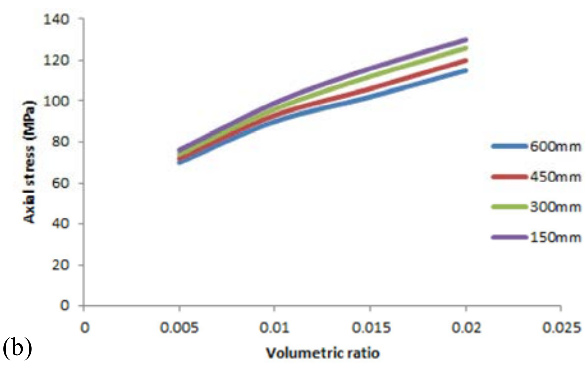


Fig. 10: Ductility versus number of CFRP layers for 150mm dimension column with different strength



(a)



(b)

Fig. 11: Axial stress versus ρ (volumetric ratio of CFRP sheets), in terms of column size, (a) for 28MPa and (b) for 40MPa

Volumetric Ratio: Figures 11 (a) and (b) show the axial stress versus ρ (volumetric ratio of CFRP sheets) (4), in terms of column size. Refer to Figure 11; by increasing the volumetric ratio of CFRP sheets, the axial stiffness of the confinement will be increased. For case 28MPa, Figure 11 (a), column with 600mm diameter has 52MPa strength in 0.005 volumetric ratios (4) and increases to 97MPa for volumetric ratio of 0.02. Figure 11(a) indicates that, when the column cross section is reduced, the concrete has higher strength in the same volumetric ratio. In other words, for thinner columns, increasing the volumetric ratio is more effective than thick columns. With same strength of concrete (28MPa), thinner column experiences higher axial stress in 0.005 volumetric ratio, 64MPa and in 0.02 volumetric ratio, it has 118MPa stress. In the lower and higher volumetric ratio, differences between 150mm diameter column and 600mm diameter column are 23% and 21% respectively.

In case of 40MPa concrete, for the column size of 600mm, in volumetric ratio of 0.005, axial strength has 68MPa and it goes up to 110MPa in 0.02 volumetric ratio. While, by decreasing column size, for 150mm diameter, stress in 0.005 and 0.02 volumetric ratio are 75MPa and 130MPa respectively.

Mesh Size Effect: There are three main reasons to raise stress singularities which cause to undesirable results on stress and strain as well. In case of circular RC short column, one of the reasons which depend to sharp and small edge is not considered in this study. There are two other reasons which are highly focused in this study: First, element high aspect ratio and second one depends to boundary condition. To enrich our understanding of the effect of element size in the finite element method, this study tries to estimate differences between stresses results, by applying different global mesh density. Hence, a mesh convergence study was done by applying different seeds number and element sizes. However, in order to obtain reasonable results, both concrete and CFRP were assigned the same mesh size to have same shared node between two different materials.

The element size for concrete and CFRP sheet differ in the range of 0.01, 0.03, 0.05 and 0.1mm. Figures 12 and 13 show details of the mesh which are considered in this study. Figures 14 (a) and (b) show the stress versus axial strain for the confined concrete which is predicted for different meshes under loading. The coarse mesh could not predict the exact behavior of the concrete. The results reveal that, the finer meshes give closer results in comparison to experimental. In the case of 150x450mm column with one layer CFRP, the coarser mesh of (0.1)- (50) elements gives undesirable overall behavior which after yield point (43KN) has slight slope until end. While, the smaller size meshes of (0.05, 0.03 and 0.01)-

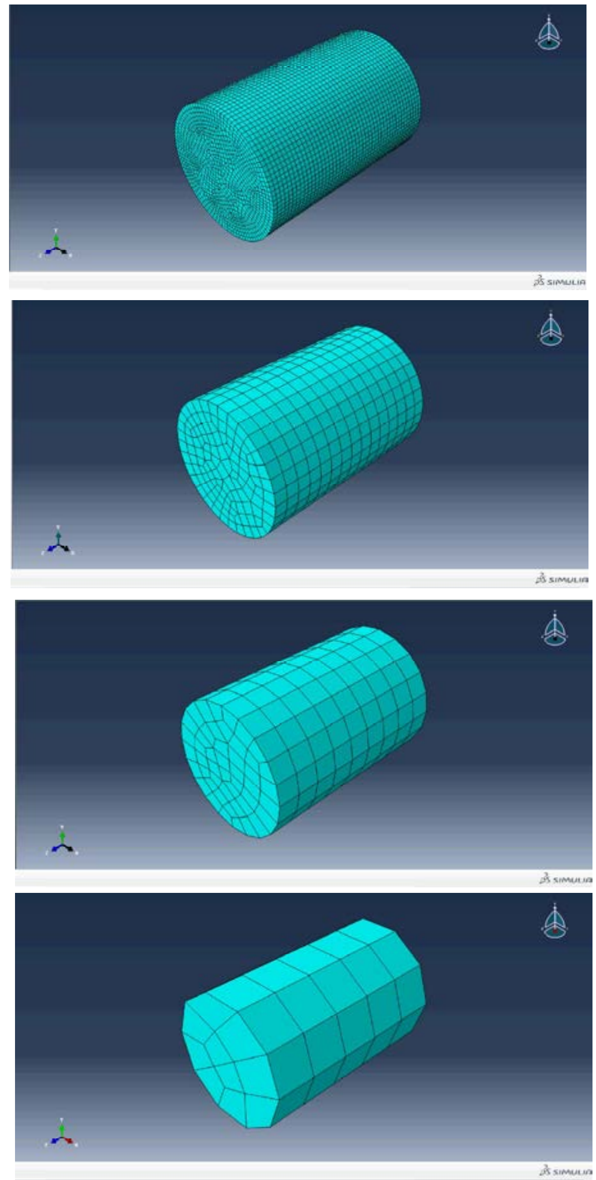


Fig. 12: Different mesh size 0.01, 0.03, 0.05 and 0.1 mm for column size for 450mm height and 150mm diameter

(171, 480 and 4275)element results in an real confinement behavior. For the stresses of 62, 58, 59 and 53 MPa, axial strain equal to 0.0095, 0.01, 0.01 and 0.0092 respectively Figure 14 (a). It seems the proposed model gives reasonable results for a model with (4275) elements. For the case of bigger column size 250x750mm, coarse mesh size 0.1 leads to have lower ductility behavior which has strain of 0.016 for 90KN stress. For 0.01 and 0.05 mesh sizes, the strain are 0.02 and closed to experimental result, while respect to axial stress, the finite element analysis shows higher stresses for both mesh sizes rather than

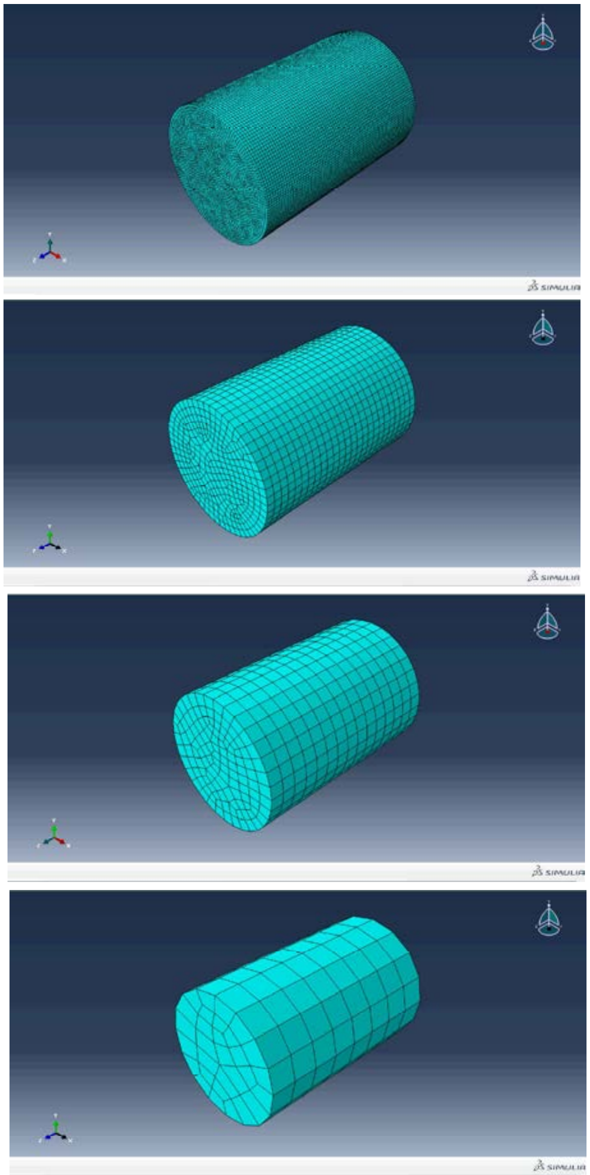
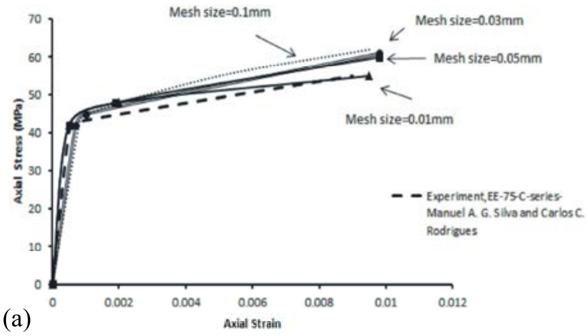


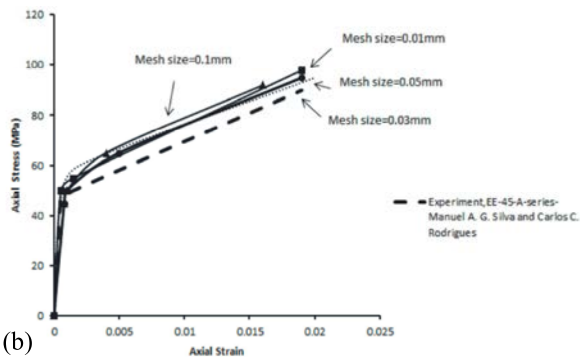
Fig. 13: Different mesh size 0.01, 0.03, 0.05 and 0.1 mm for column size for 750mm height and 250mm diameter

experiment. Mesh size of 0.03 does not satisfy the general behavior of the concrete in comparison by experimental especially in yield point. The mesh size should be small enough to have fewer errors, but large enough in which the software be able to run within a reasonable time. In general, finer mesh leads to more accurate results.

Summary and Concluding Remarks: The results showed that, the confinement with CFRP has significant effect to increase the ductility of RC short column and ultimate strength as well. Indeed, the ultimate strength and



(a)



(b)

Fig. 14: Comparison of different size of element used in finite element analysis with experimental results [6]

stress-strain curve predicted by NLFEA is in good agreement with the previous researches. When the confinement is enough to control concrete expansion, the stress-strain behavior is such that, both ultimate strain and stress occur in one position. This is known as perfect confinement effect. By increasing number of CFRP sheets, there is significant increase in terms of ultimate strain and stress as well. Inspection of the results reveals that confinement effectiveness decreases when the column size is increased. In addition, the influence of increasing number of CFRP layers on the ductility is significant and by increasing number of layers from 1 to 5, ductility also increases. Mesh size has a considerable effect on finite element analysis accuracy. Also, when the volumetric ratio is constant, the lower concrete strength has a better performance respect to confinement behavior. Finally, the confined RC short columns with 1 to 5 layers of CFRP showed an increase in stress up to failure.

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