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New Numerical Study for Strengthened short columns with different jackets techniques

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Abstract

Today, the use of fibreshotcrete for strengthening the concrete structures in large scale is increasing due to its advantage. The properties and the factors effect on it, has been discussed. This work presents a theoretical investigation concerning the efficiency of different strengthening systems for the reinforced concrete columns. In this work, the experimental results for six columns (20x20x100) had the same cross section of dimensions and main longitudinal reinforcement distribution and cross sections for all columns. These Columns had four deformed longitudinal steel with 10 mm diameter were tested under compression loading will study, C0 column without strengthening, columns C6, and C7 were strengthened with Strips of CFRP were 2 mm and 4 mm thickness respectively, these were placed onto the column surface in the lateral direction with epoxy resin. Others three columns had four deformed longitudinal steel bars 10 mm diameter. Column C1 strengthened with fibreshotcrete jacket layer 3cm thickness, C2 similar C1 except additional stirrups in lateral direction 8 mm diameters each 200 mm with reinforcement and C5 column 26*26 cm cross section with no strengthening. Columns were tested under compression loading and The deformations were measured by linear variable differential transducers LVDT's, two transducers in both sides to measure the longitudinal deformations (LO) and three in the lateral direction to measure the lateral deformations: the first (EQ1) was near the end of the column, the second (EQ2) was in the middle and the third (EQ3) was in the middle between the fist and the second had the same cross section of dimensions and main longitudinal reinforcement distribution and cross sections. I produced a new formula in the three dimensional for numerical modeling to compare between strengthening columns.

Keywords: strengthen; numerical modeling; fibershotcrete (FSpB).

1-Introduction

The strengthening of concrete structures by externally bonded plates of carbon fiber reinforced plastics (CFRP) and fibreshotcrete are gaining ground due to its advantages over the strengthening with steel. A great number of structures requires repairing and strengthening. The repair and redesign techniques must therefore be investigated to obtain a deeper understanding; both theoretically and experimentally. For studying the subject

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of this paper, the difficulties lie in the selection of the parameters, which are mainly responsible for the overall behavior and failure. Thus, the aim is to define a model which is developed with respect to a successful reduction of the physical problem. The main characteristics of the composite materials appear in the interactive compound of the individual components. Whereupon, it is impossible to know exactly the in homogeneity in each constituent. Models for the description of failure can be developed based on micromechanics and macro mechanic analysis.

The study of these effects requires highly sophisticated models; developed in the field of material scientists. Here, a great importance attached to use measurable, mechanical values in the respective material models. The distinction between the properties of these materials is governed by the physical properties of the phases and the phase interface geometry. Considering composites consisting of phases with three- dimensional internal geometries embedded in the second phase, the material is denoted as particulate composite.

2-Discrete Reinforcement Modeling-Rebar element

The discrete reinforcement modeling is used to characterize composites with large, distinct reinforcements. The reinforcement can be introduced by:

- Rebar
- Discrete line elements
- Discrete surface elements

In three dimensions, the element's isoperimetric coordinates are denoted by r,s,t and the are isoperimetric coordinate along the orientation of reinforcement. The additional intake of the reinforcement into the matrix continuum. is not accompanied by additional degrees of freedom. Consequently, bond slip cannot be simulated and this element can only represent a homogeneous displacement field. Furthermore, it is assumed that the plane of reinforcement is perpendicular to the element faces. The conceptual illustratration is shown in Figure (1)

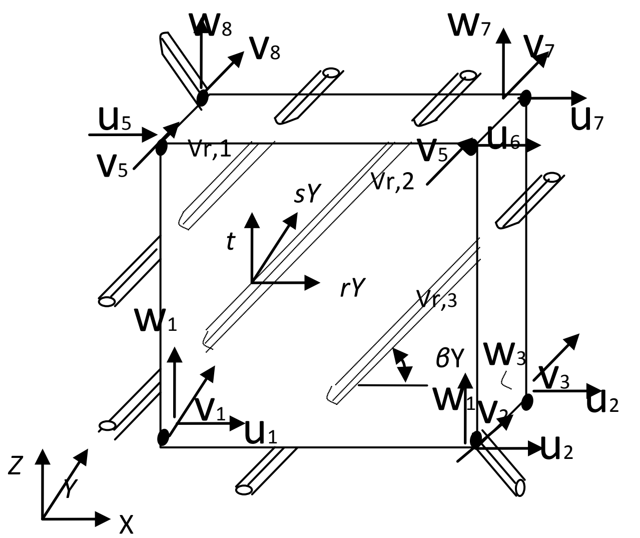


Fig 1 Three dimensional solid with embedded, skew rebar

The element stiffness matrix K^e represented by equation (1)

$$K^e = \int_{Ve} B_m^T D_m B_m \, .dV + \int_{Vr} B_m^T D_r B_m \, .dV \ldots\ldots\ldots \quad (1)$$

where

Bm = strain displacement matrix for the (3D) parent element

Dm = elasticity matrix of the matrix

Ve = element volume

Dr = elasticity matrix of the rebar with respect to local coordinates

In the above equation, (1) it can be seen that the strain –displacement matrix Bm of the rebar is expressed by the same Shape Function as for the matrix portion.

By using the eight points Gauss numerical integration (n=8) in the r, s, and z direction, the following matrix [H] contain the interpolation function hij=1,…….,8 and is defined as :

$$[H]=\begin{pmatrix} h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4 & 0 & 0 & h_5 & 0 & 0 & h_6 & 0 & 0 & h_7 & 0 & 0 & h_8 & 0 & 0 \\ 0 & h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4 & 0 & 0 & h_5 & 0 & 0 & h_6 & 0 & 0 & h_7 & 0 & 0 & h_8 & 0 \\ 0 & 0 & h_1 & 0 & 0 & h_2 & 0 & 0 & h_3 & 0 & 0 & h_4 & 0 & 0 & h_5 & 0 & 0 & h_6 & 0 & 0 & h_7 & 0 & 0 & h_8 \end{pmatrix}$$

The strains in both domains of the element and rebar, are referenced to the local coordinate (x,y,z), whereas the displacements are expressed in terms of natural coordinate systems (r,s,t) derivatives and the (x,y,z) derivatives is of the form

$$\partial / \partial r = J \, \partial / \partial x \quad [4]$$

where J is jacobian operator

The elements of strain-displacement transformation matrix Bm are affected by the Jacobean operator as

$$[B_m] = [L_m] \, [H]$$

where Lm is the differential operator representing small deformation under conditions of stress

$$[L_m]=\begin{pmatrix} \partial/\partial x & 0 & 0 \\ 0 & \partial/\partial y & 0 \\ 0 & 0 & \partial/\partial z \\ \partial/\partial x & \partial/\partial y & 0 \\ \partial/\partial z & 0 & \partial/\partial x \\ 0 & \partial/\partial z & \partial/\partial y \end{pmatrix}$$

For a smeared modeling of the reinforcement, the numerical integration of the element stiffness matrix equals the terms as shown in equation (2)

$$K^e = \sum_{i=1}^{GPm} B_{m,i}^T D_{m,i} B_{m,i} .\det J.\alpha_i + \sum_{i=1}^{G\,\mathrm{Pr}} B_{m,i}^T T_{\beta,i}^T D_{r,i} T_{\beta,i} B_{m,i} V_r \quad ..(2)\ [3]$$

Where

Gpm = number of Gauss points associated to the matrix portion

detJ = Jacobean determinant

α α i = weight of Gauss point

GPr = number of Gauss points associated to the rebar

Tβ = transformation matrix from the local to the natural axis

Vr = rebar volume within an element

The skew reinforcement orientation is merely taken into account by the incorporation of transformation matrix Tβ.

Considering a discrete modeling of reinforcement, the numerical integration of element stiffness matrix reads.

$$K^e = \sum_{i=1}^{GPm} B_{m,i}^T D_{m,i} B_{m,i} . \det J . \alpha_i + \sum_{j=1}^{nr} \sum_{i=1}^{G\Pr} B_{m,i}^T T_{\beta,i}^T D_{r,i} T_{\beta,i} B_{m,i} . l_{r,i} . A_{r,i} \quad (3)$$

where

nr = number of rebars

lr,i = length of the it rebar

Ar,i = cross-sectional area of the i-the rebar

From equation (3) it is obvious, that the length lr,i of each rebar has to be estimated. Thereby, the intersection points of rebars with the element faces are detected. Accordingly, the user has to map these points back to global coordinates, or to give the isoperimetric coordinates back as input to the FE- computation (Elwi and Hrudey(1989)[1], Barzegar and Maddipudi (1984))[2].

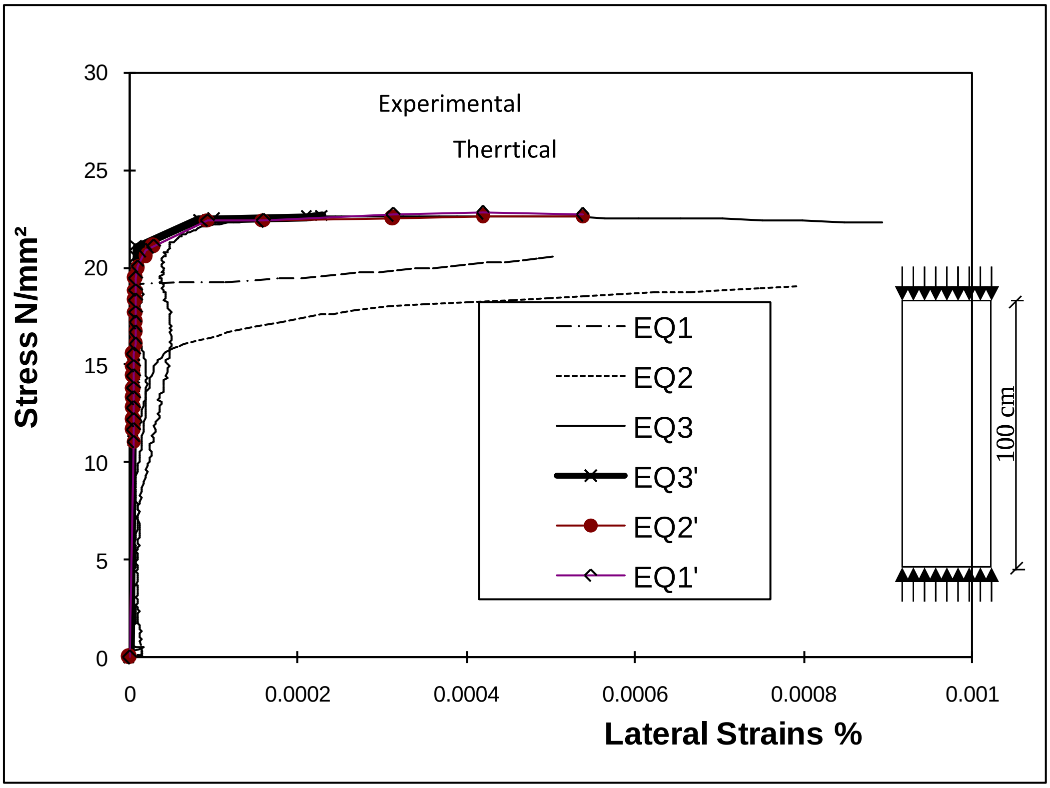
With the knowledge of the intersection points, the location of the integration points associated to the rebars can be determined. Consequently, the element stiffness matrix in equation (3)can be evaluated.

3- MODELLING OF CONCRETE

Advanced methods for the design of concrete structures have placed increasing emphasis on the stress-strain behavior of concrete subjected to triaxial-axial stresses Under such state of stress concrete exhibits not only a different stress-strain behavior but also varying strength characteristics The considered material constitutive relations are those for orthotropic one These relations are modified when failure is detected to represent the gradual decay of strength due to the onset of failure The failure includes either crushing and for cracking reduced the elasticity modules of concrete by half precentage.of elastic modules.

4- Comparison theoretical and experimental program

Axial stress-axial strain and axial stress-lateral strain curves for columns are shown in Fig. 2 to Fig. 7.



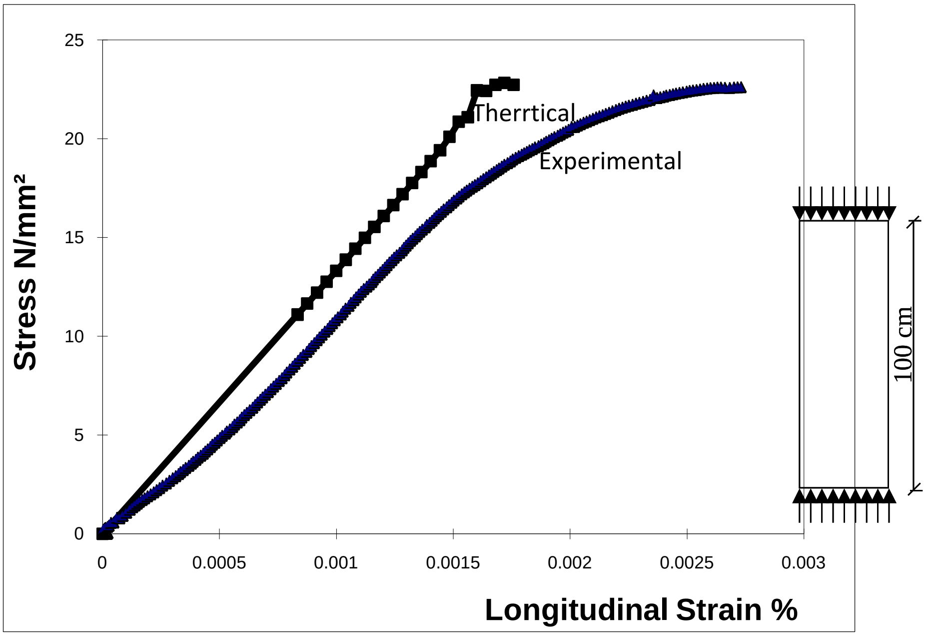
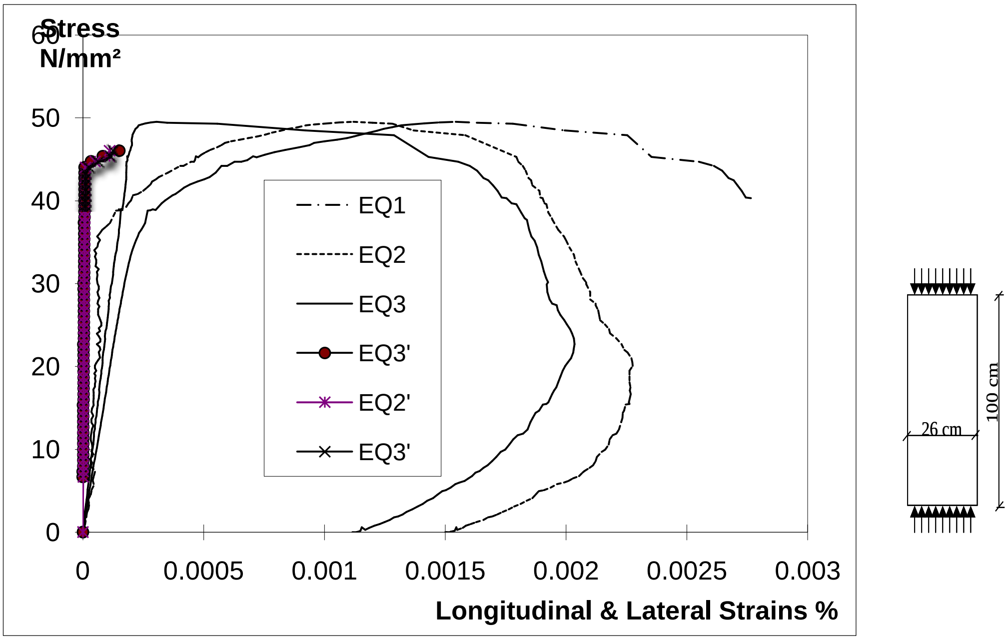


Fig. 2 Behaviour of column specimen C0 without strengthening under axial load[5]



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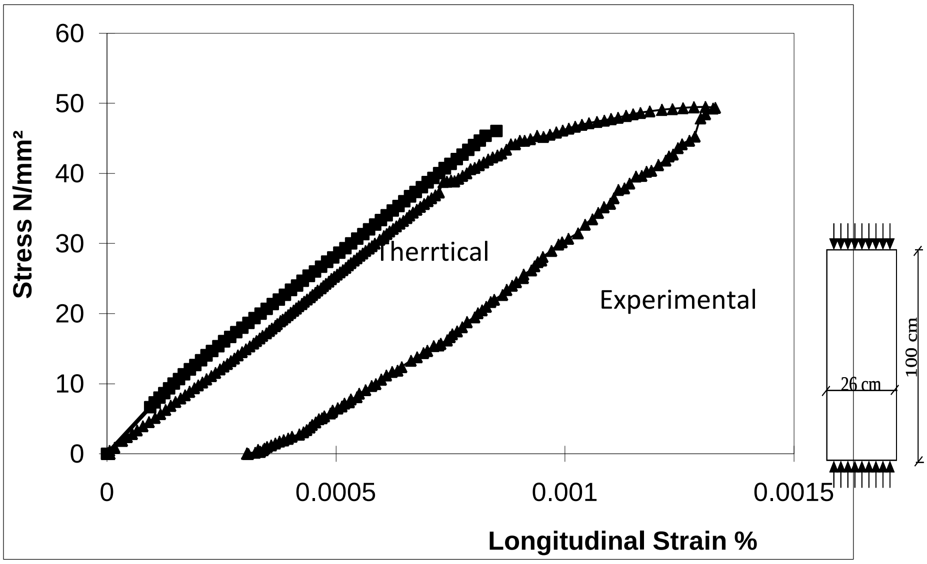
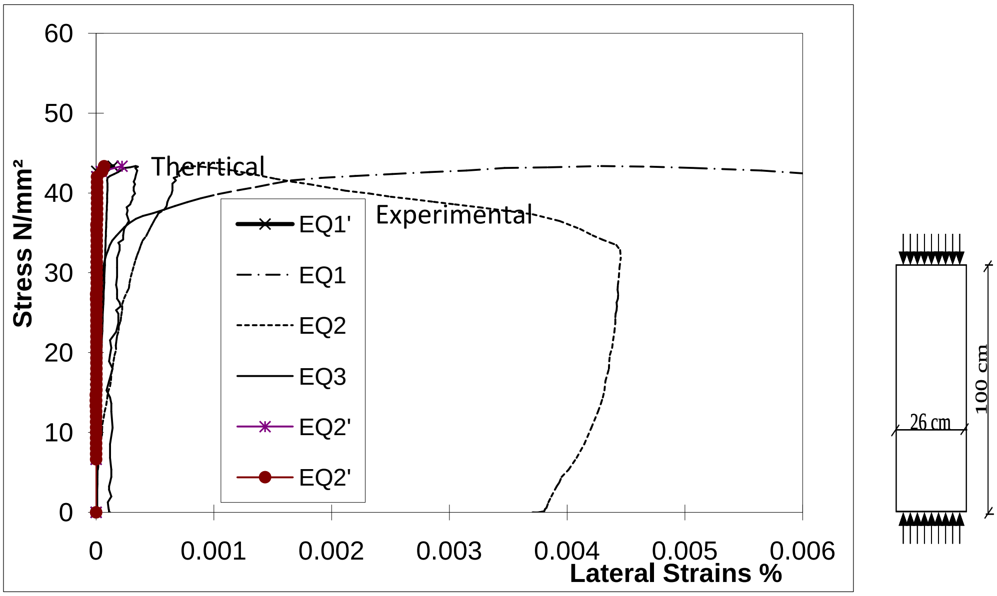


Fig. 3 Behaviour of column specimen C3 FSpB under axial load[5]



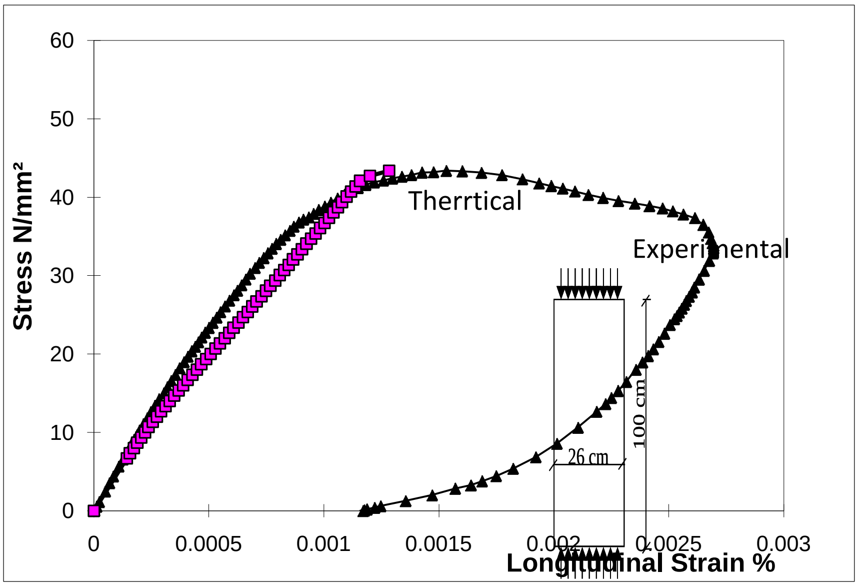
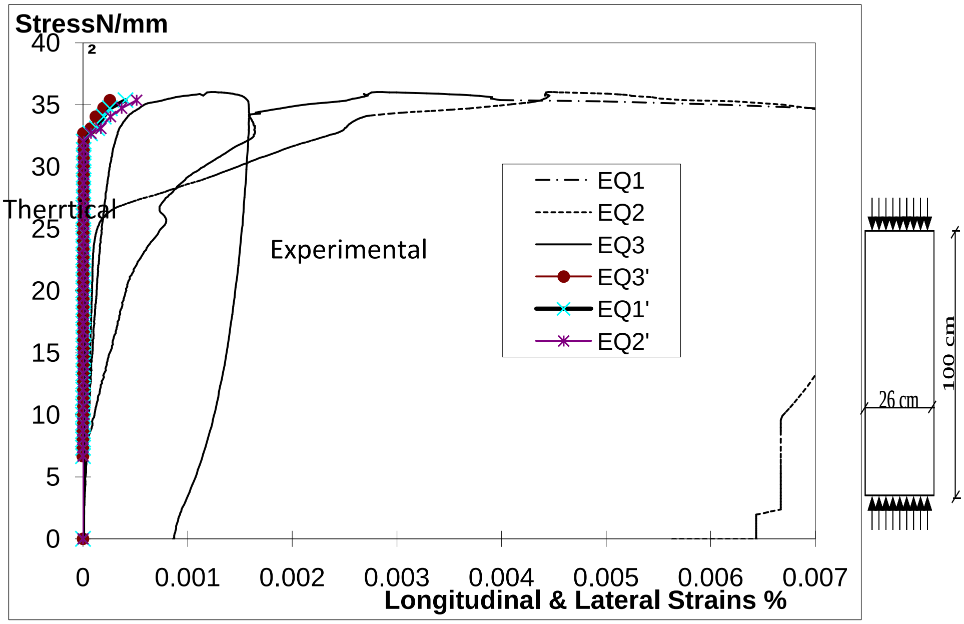


Fig. 4 Behaviour of column specimen C4 FSpB+ stirrups under axial load[5]



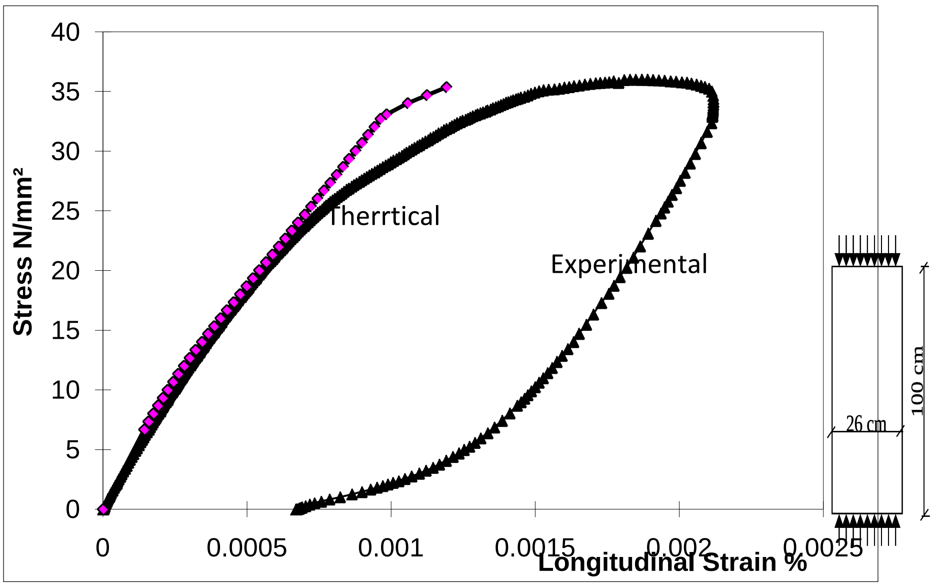
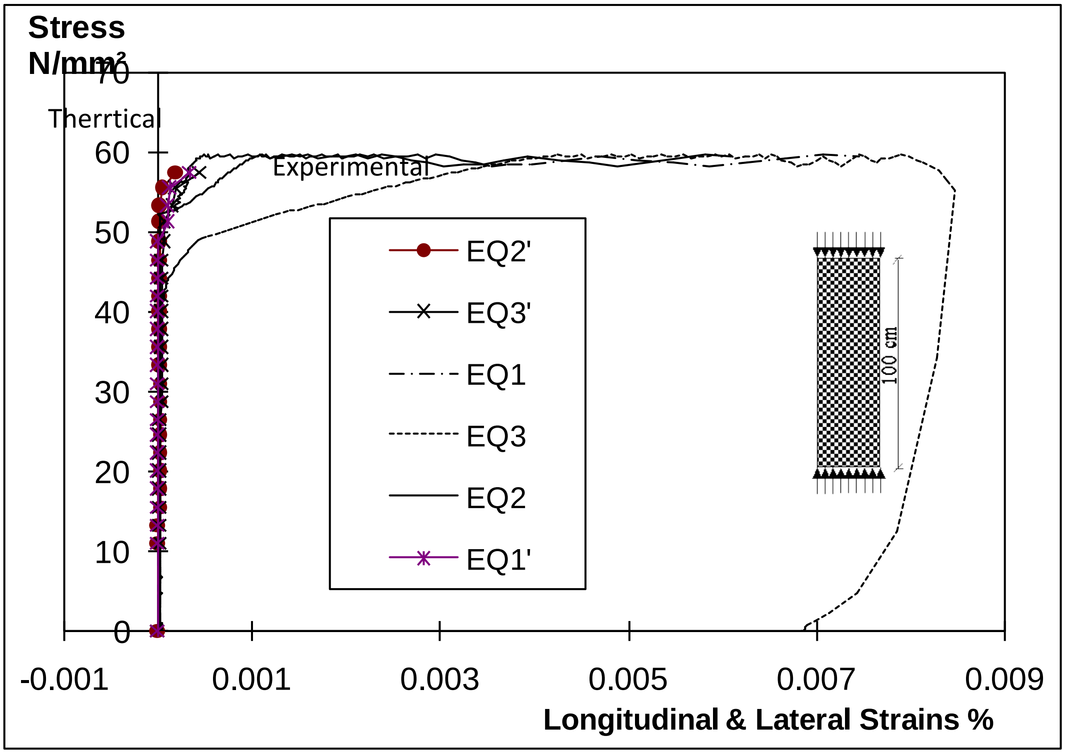


Fig. 5 Behaviour of column specimen C5 26x26 cm under axial load



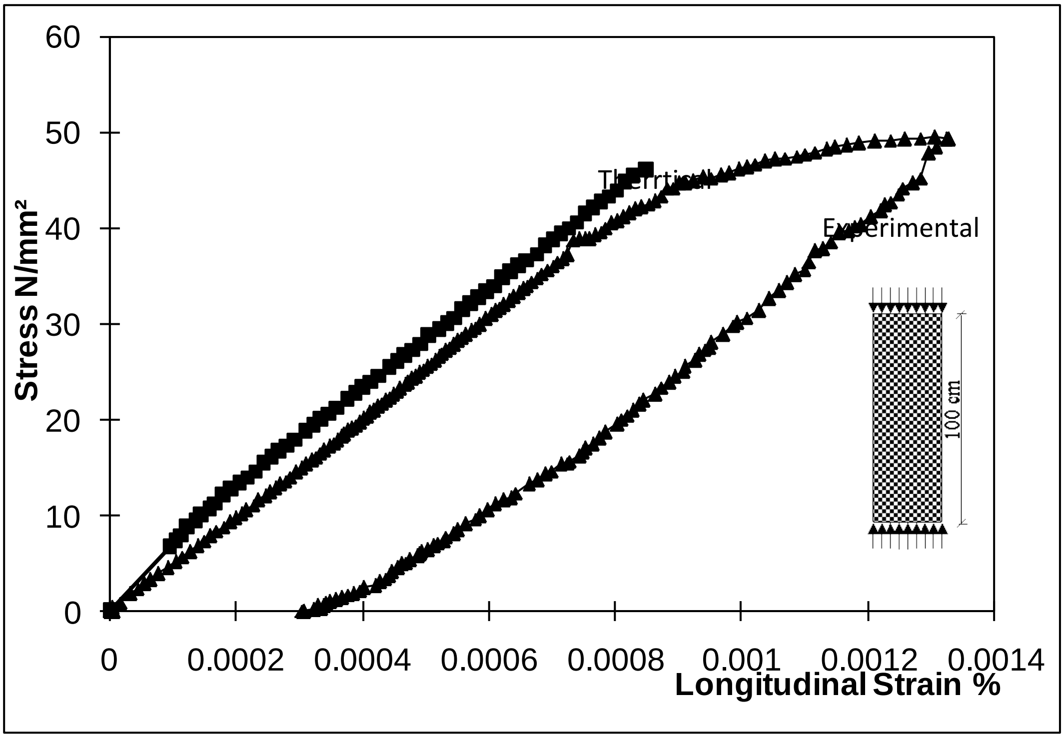
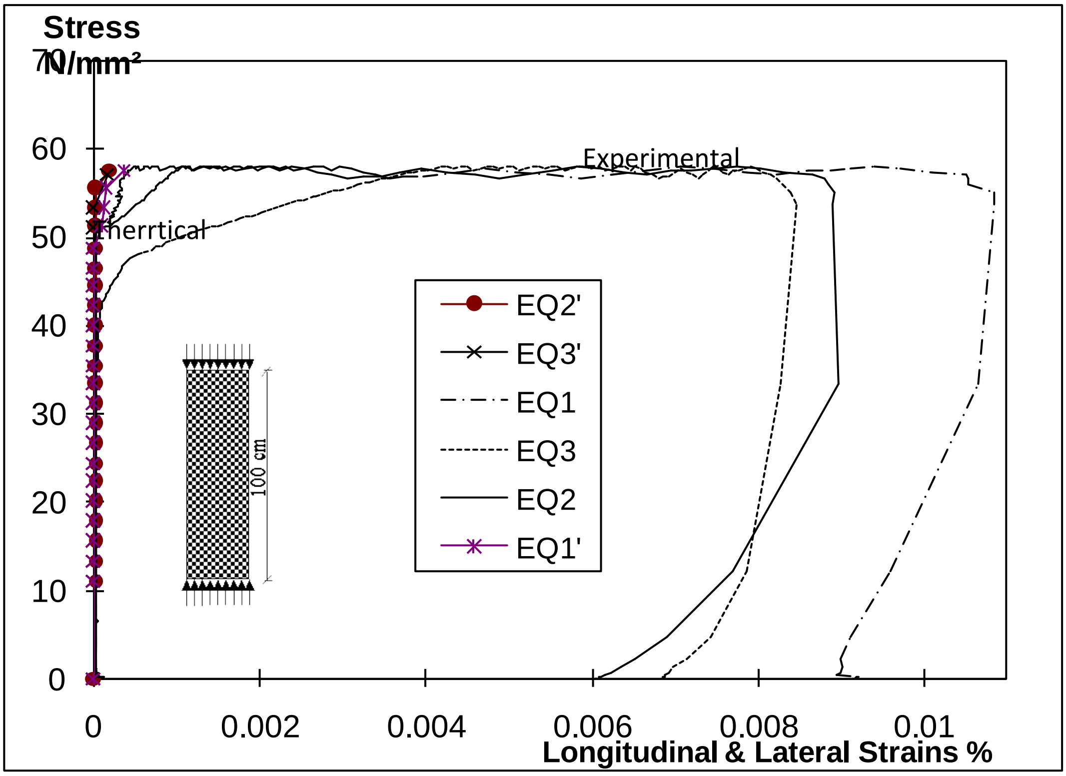


Fig. 6 Behaviour of column specimen C6 CFRP 2 mm under axial load



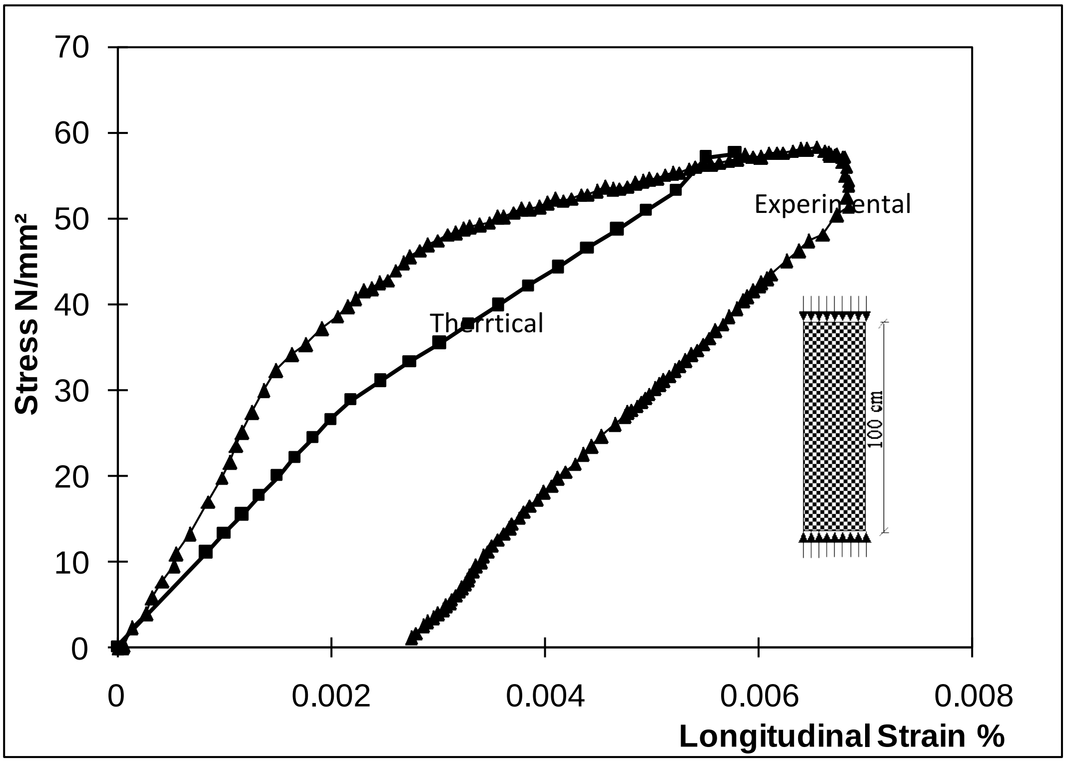


Fig. 7 Behaviour of column specimen C7 CFRP 4 mm under axial load

5-CONCLUSION

The production of new formula in the three dimensional for numerical modeling gives good results comparing to the experimental work. With comparing the results of strengthening reinforced concrete columns with FSpB and CFRP were investigated and , and from the above figures, modeling gives results closer to with the experimental work in cracking loads, ultimate loads, displacements, deflections, the longitudinal and lateral strains are similar. The following results were obtained:

1- For RC columns strengthened with FSpB and having jackets with longitudinal steel reinforcement and stirrups have high loading capacity than those strengthened without reinforced jackets.

2- Using the steel fibers in the fibershotcrete strengthening layer gives some improvements in the ductility and subsequently in the load carrying capacity compare by the concrete without fibers[5].

Also, the ductility of reinforced concrete column by using FSpB was obtained:

1- Using the CFRP strengthening layer gives some improvements to the ductility and subsequently in the load carrying.

2- The strength improvement by CFRP strengthening method can be evaluated as additional truss action to the steel hoop reinforcement.

The influence of fibershotcrete on the structural performance of reinforced concrete columns retrofitted with fibers was investigated: [5].

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