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Investigate the Effect of Parameters Compressive on Behavior of Concrete-Filled Tubular Columns Under Fire

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ABSTRACT

Concrete-filled steel tubular columns have been extensively used in structures, owing to that they utilize the most favorable properties of both constituent materials, ductility, large energy-absorption capacity, and good structural fire behavior. Concrete inside the steel tube enhances the stability of the steel tube, and the steel tube, in turn, provides effective lateral confinement to the concrete. Furthermore, the fire resistance of (CFT) columns is higher than that of hollow steel tubular columns, external protection being not needed in most cases. During a fire, the steel tube acts as a radiation shield to the concrete core and a steam layer in the steel- concrete boundary appears. This paper presents to investigate the effect of the parameters compressive on behavior of concrete-filled tubular (CFT) columns under fire by numerical simulations using ABAQUS software. Three different diameters to thickness ration of 54, 32 and 20 are considered in this study with two concrete's compressive strengths of 44 and 60 MPa. The measured compressive axial capacity is compared to their corresponding theoretical values predicted by four different international codes and standards. The results indicate that the effect of diameter to thickness ratio on the compressive behavior of the sections is greater than the effect of the other factors. Also, the axial capacity calculated by most of these codes reduces as the diameter to thickness ratio increases as verified by experimental results.

Keywords: Concrete-filled tubular, Axial compressive capacity, Fire, ABAQUS, Parameters compressive

1. INTRODUCTION

Concrete and steel are materials that ane mainly used in buildings. The advantages of both materials are and having remarkable stability against fire – steel also is a material with high formation and resistance and low weight. Yet using only steel in building columns, especially tall building, is not economic. Also, tall buildings with steel columns usually have relatively great deformations and have low resistance fire. The collapse of the World Trade Center buildings NIST 2008, FEMA 2002 [1,2] and results of the Cardington full-scale eight-story steel-framed building fire tests in the UK Newman GM et al. have demonstrated that steel joints are vulnerable during both the heating and cooling phases of fire [3]. Joint behavior in fire is currently one of the most important topics of research on structural fire resistance; however, most of the present research studies have focused on the heating phase. The Elsawaf et al. [4] Sunder took detailed numerical simulations of the fire tests by Ding and Wang [5] to validate their numerical simulation model during the heating stage using a 3-D finite element model similar to that of Dai et al. [6]. Concrete and steel materials that widely used in constructions and the benefits of both materials are well known. Concrete materials with high hardness, low-cost (compared to other materials) and considerable resistance against fire and steel materials with high strength and ductility and low weight. The use of concrete- filled tubular (CFT) columns has increased in recent decades due to their excellent structural performance, which takes advantage of the combined effect of steel and concrete working together. In the fire situation, the degradation of the material properties gives rise to an extremely nonlinear behavior of these composite columns, which makes it difficult to predict their failure. Up until now, a large number of numerical models have been developed worldwide Zha, Renaud et al., Ding & Wang, Hong & Varma, Schaumann et al. [7-11], which have helped to gain insight into the fire behavior of this type of composite columns. In this work, a nonlinear three-dimensional finite element model for evaluating the fire resistance of axially loaded concrete-filled circular hollow section (CFCHS) columns is presented, which allows for a realistic representation of the fire behavior of these types of composite columns. Based on the results of a comprehensive sensitivity analysis, the values of the relevant parameters of the model are selected. The numerical model is validated by comparing its results with experimental fire tests of circular CFT columns available in the literature Chabot & Lie [12] as well as against the results of a series of fire tests carried out by the authors Romero et al. [13]. However, the use of steel in the construction filled, especially in high-rise structures, non-economic- the high structure with steel-columns usually have a relatively large lateral deformation and low resistance against fire. The use of concrete only in the columns of high-rise buildings, the more space it takes up on the lower floors and has a slightly higher weight and crisp and fragile due to the concrete, resulting structure has been lower ductility and loss of strength in seismic loads the structure will be created. Cleverly combining these two materials, an effective system and thus gives the character a distinct advantage of them. The system introduced by phrases such systems or dual supplies. A table for success in today's complex systems, columns, beams and slabs with opening on average taller buildings as well as bridges and beams used. Using the right combination of a concrete and steel columns Tool for cooperation in many structural systems are increased all over the world. Composite columns not only are many advantages in the manufacture of (especially speed and economy) But, also a significant improvement in the mechanical properties of steel-reinforced concrete structural members can only be compared to members. Concrete-filled steel structures (CFT) that includes steel section sections are filled with concrete is a composite section. So that the hardness and compressive strength of concrete core columns up and local Bucking of steel sections reduces the inside. In other words lateral and longitudinal cross-section of steel as reinforcement for concrete care causes the concrete core in stress. Bending moment and shear stable and concrete confinement and ultimately increase the fire resistance of structures to increase Sakino et al. [14]. Numerous laboratory studies on the effect of changing parameters on the behavior of the pressure of this type of education has been done. For example, Sakino and associates the effect of four parameters, the ratio of diameter to thickness, tensile strength steel chamber steel cross-sectional shape and core strength concrete on the behavior of the paid sections. O'shea and Bridge, as well as by the resistance ratio of diameter to thickness of the concrete core and the men looked for these sections. Am and Gardner [15], examined the behavior of columns filled with concrete with different concrete core strength and ultimately compared the results with regulations of AISC, 2010 [16] and ACI-318, 2011 [17]. The use of concrete filling offers a practical alternative for providing the required fire resistance in steel hollow structural section columns without the need of additional protection Kodur and Lie [18] and Twilt et al. [19]. This is due to the heat sink effect produced in the composite section because of the low thermal conductivity of concrete and the mechanical contribution of the concrete core, which helps to support the applied load and also prevents the inward local buckling of the steel. A kind of concrete-filled lattice rectangular steel tube (CFLRST) column was put forward. The numerical simulation was modeled to analyze the mechanical characteristic of CFLRST column Chengquan Wang et al. [20]. Hu et al. and his colleagues examined the be behavior of concrete-filled steel columns under axial impact load on the temperatures went up to 400°C [21].

2. MATERIALS AND METHODS

In this paper, verification of modeling results with experimental results of Ding and Wang will be carried out [5]. In this experiment, the pillars of concrete-filled steel studs using reverse and flexible with end sheet steel beams connected that have been shown in Fig.1. In this research, the behavior of these sections against fire and tempera ture distribution by using the ratio of diameter to thickness of 20,32,54 and using concrete with compressive strength of 60 and 44MPa consider two types.

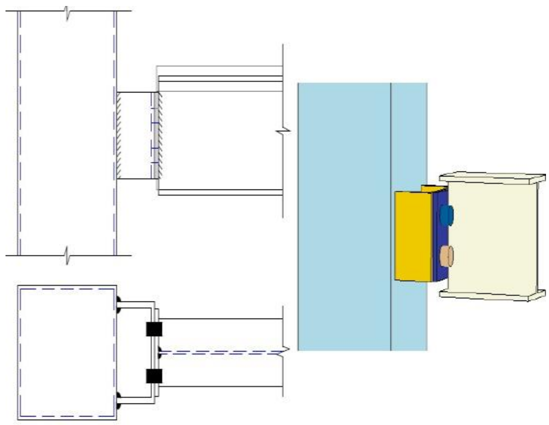

Figure 1. Reverse channel connection with flexible endplate

The most important purpose of collecting the results of experimental tests is to determine the structural function of junction temperature and is fire - resistant fitting and structures. In the first eight tests of 10 experiments, the beams under the same load and temperature rise, that steel beams behavior during warning in two other experiments with beams of maintaining loading conditions examined in the cooling phase. In all experiments, concrete-filled steel beam mounted on two steel columns are under standard temperature condition. Fig.2(a) is overview of testing Ding and Wang.

a

b

Figure 2. (a) Elevation view of schematic arrangement of test Ding and Wang. (b) The clamped scheme end of column of test Ding and Wang [5]

All tests were similar in size to the and are 178*102*19UB. In the seven tests of rectangular cross-section measuring 200mm in three tests circular with a diameter of 193.7mm and a diameter of 20mm for the connection of 8.8 screws are used. The upper flange beams with ceramic coating with a thickness of 15mm, using thermal source are heated. Like Fig.2(b), the end of columns are clamped against lateral movement, but they have free movement longitudinally. The beam loading in two points of beam are performed by separated jacks.

3.1. THE EFFECT OF TEMPERATURE INCREASE ON CONCRETE AND STEEL PROPERTIES

The impact of increased temperature on the characteristics of concrete and steel mechanical and thermal characteristics of steel and concrete are quite different, although with the temperature increases in both strength and stiffness reduced. Concrete and steel curve to room temperature (20 oC) for T20 are in Fig.3 and Fig.4 shows the effect of increasing temperature on stress-strain curve of steel.

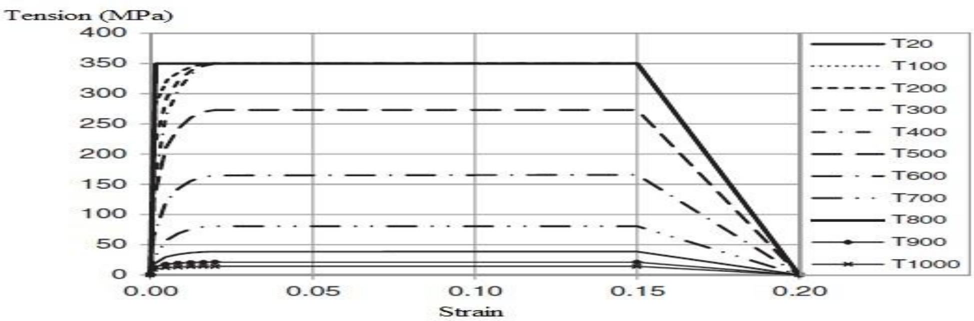

Figure 3. Stress-strain curve of steel affected by increasing the temperature

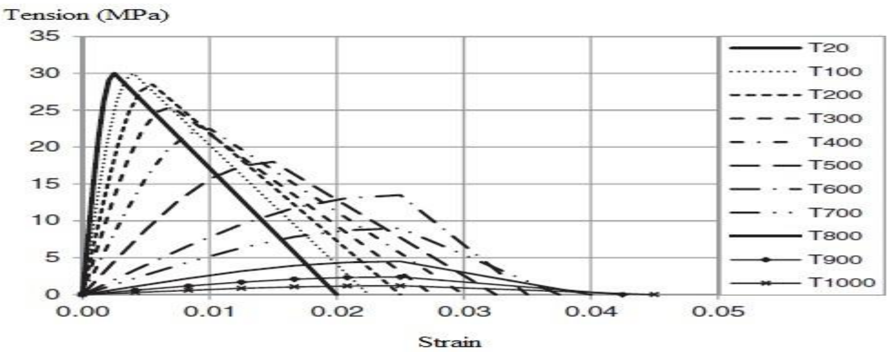

Figure 4. Stress-strain curve of concrete affected by increasing the temperature

For all sections in this article, yeild stress (Fy) of 350 N/mm2 and modulus of elasticity (Es) of 210000 N/mm2 and compressive strength and strain is equal to (fc) 30 N/mm2 and 0.0025 is considered. Increase heat stress- strain curve of steel and concrete on the basis of regulations BS EN 1993-1-2 [22] and concrete on basis of regulation BS EN 1994-1-2 [23] is drawn.

3.2. DESCRIPTION OF USED SECTION

First, we to introduce the structural model and the introduction of bing Ding and Wang used in numerical simulations.Fig.5 shows the structural model and Fig.6 details a reverse channel connection with a flexible end plate in an ABAQUS [24] simulation software is shown.

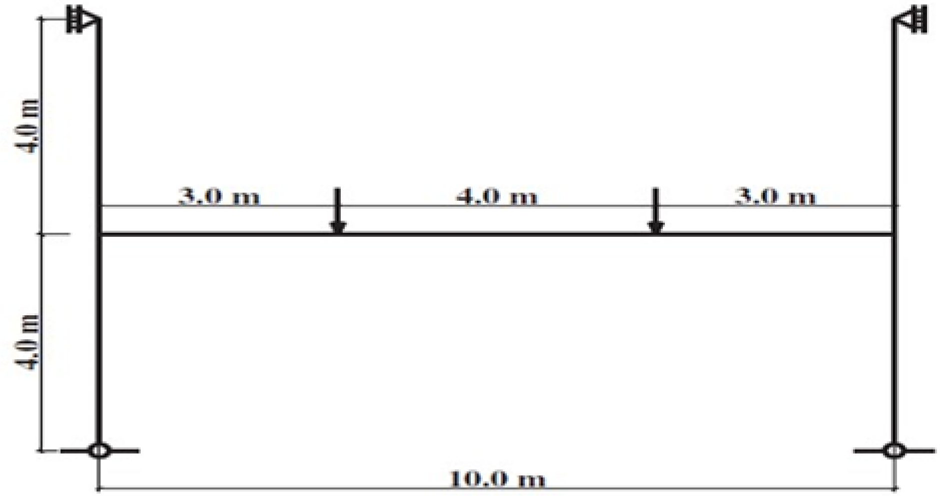

Figure 5. Dimensions and boundary condition of structure assembly

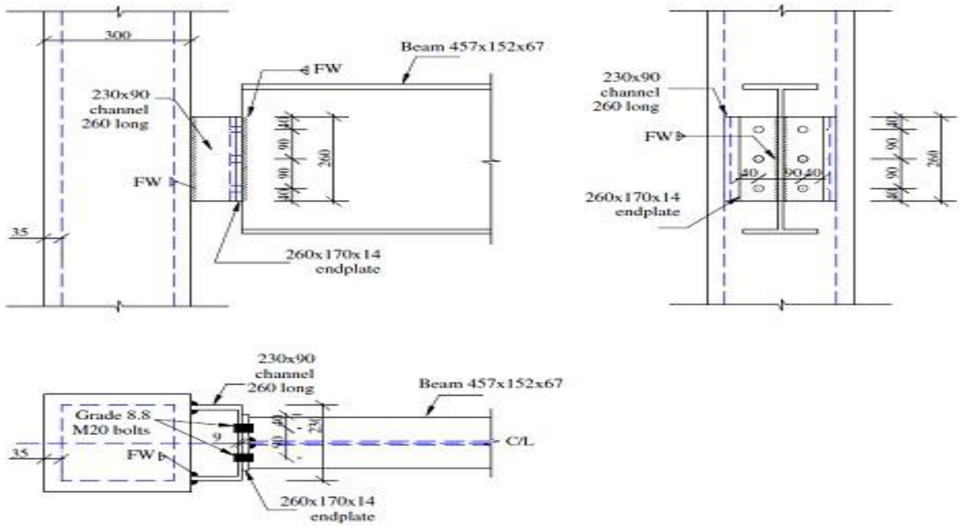

Figure 6. Basic geometrical details of flexible end plate connection to reverse channel

3.3. A NUMERICAL SIMULATION SOFTWARE ABAQUS

At first, the connection of concrete-filled steel columns to the steel beam will be modelled by using a reverse channel in Abacus software like Fig.7. The plastic analysis includes three main parts: stress-strain curve, yield criteria and stiffening law. For modelling the behavior of materials, Von-Misez yield criteria and isotropic stiffening law have been applied. In this model, the issues relevant to geometric nonlinear analysis were also considered and a great deformation method has been used. The analysis method was Newton-Raphson software and due to contact elements between steel and concrete and regarding friction of contact surfaces, asymmetric Newton-Raphson method were utilized. Concrete core is defined by a 6-sided, 8-node element with three transitive degrees of freedom in each node and by C3D8R model. Materials are of concrete type with capability of fraction in three orthogonal directions under the effect of tension and failure affected by compressive stresses and plastic deformations too. Steel wall is described by C3D8I element which as well as C3D8R model, is defined with eight nodes and three degrees of freedom in each node and it has suitable agreement to other used elements in model. In addition, friction and slip between steel and concrete core are modelled by surface to surface contact element. This element is able to transfer compression in the normal direction and shear in direct tangent to the surface. Moreover, to investigate the behavior of column after buckling and passing from critical point such that it shows a reduction in bearing capacity without divergence in solving the problem, arc length method has been used for nonlinear equations.

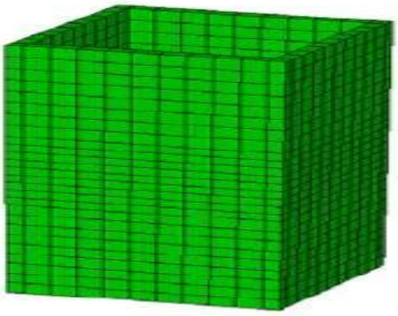

Figure 7. Finite element model of steel-walled steel sections fill with concrete

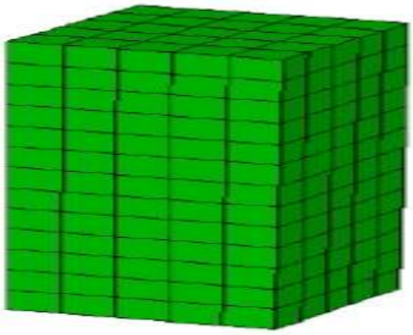

Figure 8. Finite element model of concrete core of concrete-filled steel sections

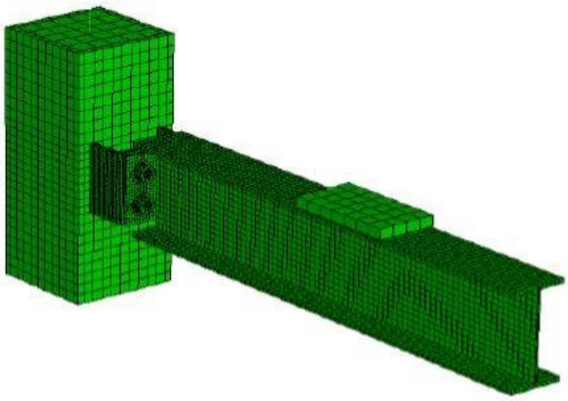

Figure 9. Finite element model of reverse connection studs

Also, in Fig.9 element model of reverse channel connection with a flexible end plate is shown. For simulation by ABAQUS, the steel will be modeled based on real stress-strain relationship that is obtained from equations 1 and 2.

$$\sigma_{true} = \sigma_{nom}\left(1+\varepsilon_{nom}\right) \quad (1)$$

$$\varepsilon_{true} = \ln\left(1+\varepsilon_{nom}\right) \quad (2)$$

In which, ε_{nom} and σ_{nom} are respectively nominal strain and stress of section. The real values of stress and strain of steel have been shown in Table 1.

Table 1. Real values of steel strain-stress

Plastic strain	Real stress (MPa)
0.000	300
0.025	350
0.100	375
0.200	394
0.350	400

For modeling concrete in plastic area and investigating its destruction, concrete plastic damage model has been used. The values of stress-strain and destructing concrete plastic in tension and compression have been presented in Tables 2 and 3.

Table 2. Values of stress, strain and destruction of concrete plastic in tension

Destruction in stretch parameter	Cracking strain	Tensile strength (MPa)
0.00	0.000000	5.3
0.25	0.000176	5.31
0.99	0.001539	0.58

Table 3. Values of stress, strain and destruction of concrete plastic in compression

Destruction in stretch parameter	Cracking strain	Compression strength (MPa)
0.000	0.00000	17.5
0.112	0.00038	25.7
0.429	0.00189	34.9
0.466	0.00218	35
0.701	0.00456	38

3. RESULTS AND DISCUSSION

3.1. FINITE ELEMENT MODEL VERIFICATION

As can be seen in Fig.10 and Fig.11 results from the finite element model for the reverse channel connections the axial force caused by increasing temperature in the bottom beam flange beams, as well as the deflection in the mid-span beam with high compliance Ding and Wang experimental results.

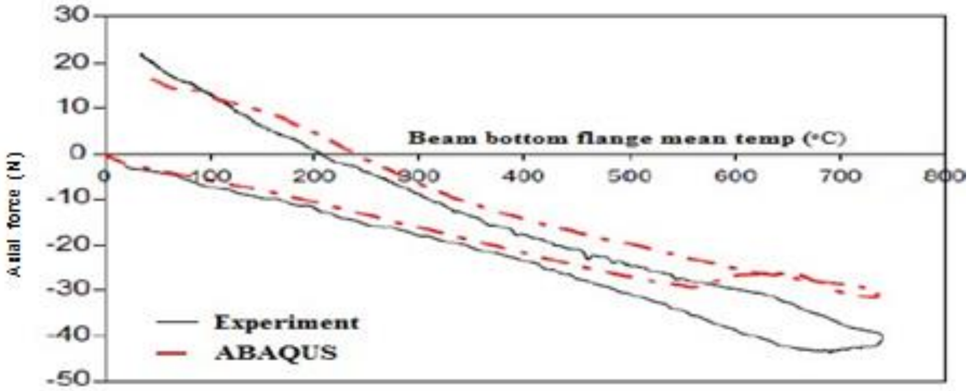

Figure 10. Comparison axial force in the beam of finite element models with test results Ding and Wang to the reverse channel connections

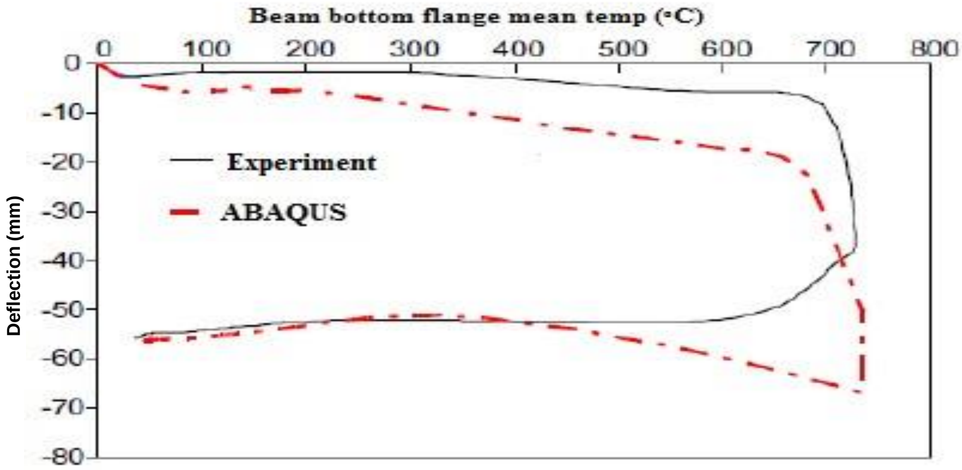

Figure 11. Comparison the results mid-span deflection in the beam of finite element models with test results Ding and Wang to the reverse channel connections

3.2. THE EFFECT OF THE INCREASED RATIO OF DIAMETER TO THICKNESS

In this section, values of 20, 32, and 54 diameters to thickness ratio then increased the compressive strength of 44MPa to 60MPa results will be compared with each other. As can be seen in Fig.12 with a reduced diameter to thickness ratio, the amount of allowable stress, ductility and strain hardening region increase. The increased contact of the tension can be due to increase contact area surrounding the steel wall is in the front of a load.

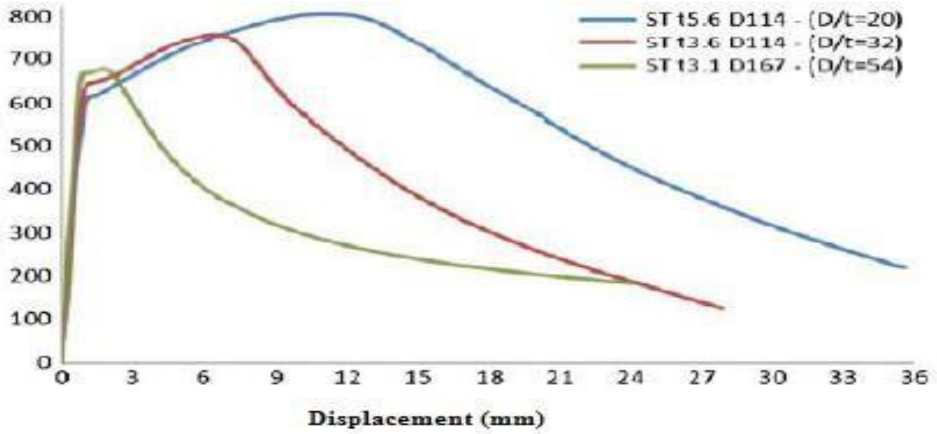

Figure 12. The impact of increased ratio of diameter to thickness

In Fig.13 to 18, the effect of increasing the compressive strength of concrete core on the loading capacity column.

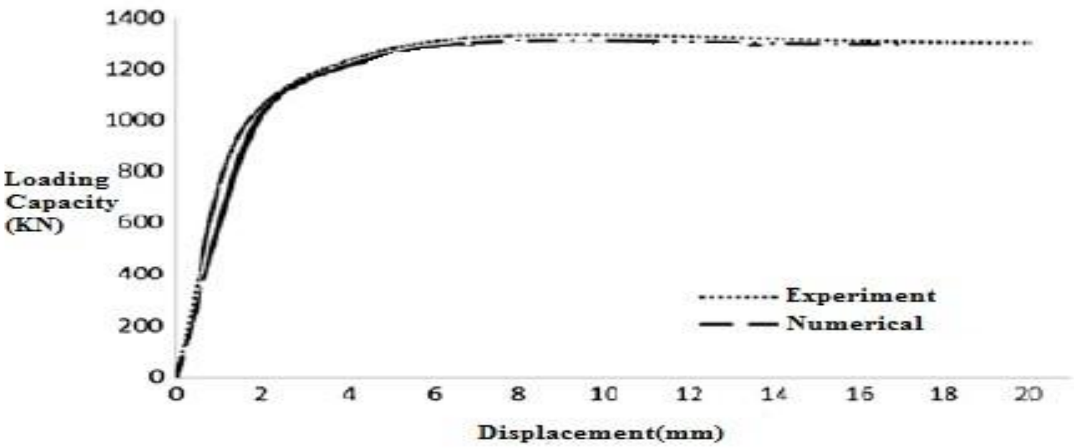

Figure 13. Loading capacity section with ratio of diameter to thickness 20 and compressive strength of 44MPa

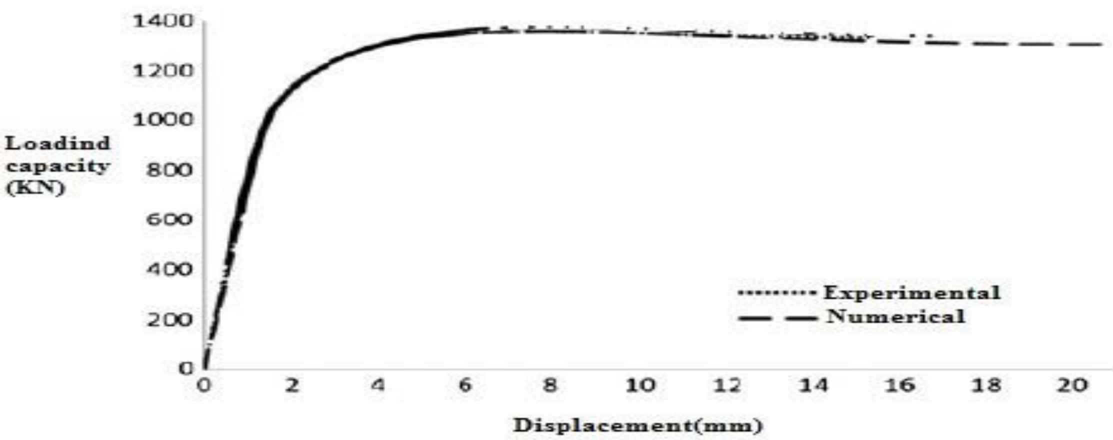

Figure 14. Loading capacity section with ratio of diameter to thickness 20 and compressive strength of 60MPa

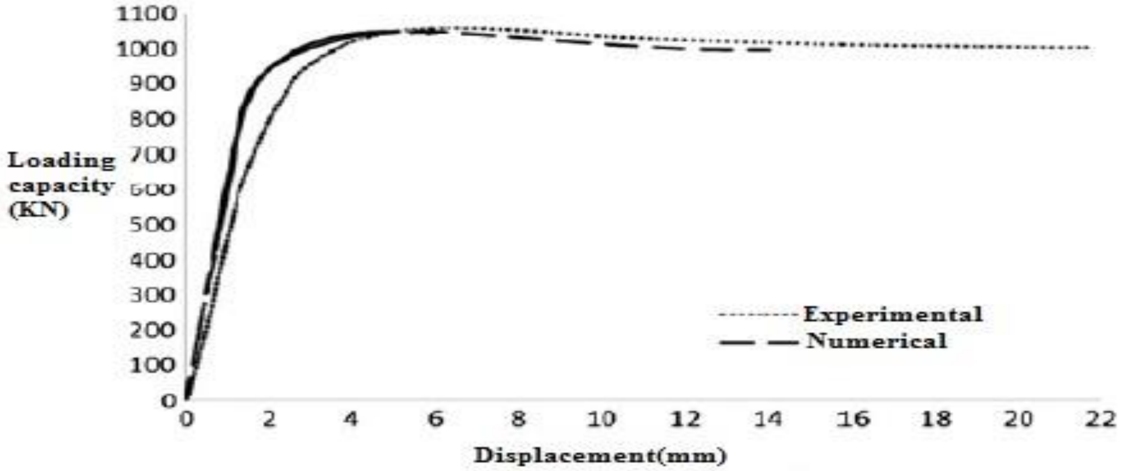

Figure 15. Loading capacity section with ratio of diameter to thickness 32 and compressive strength of 44MPa

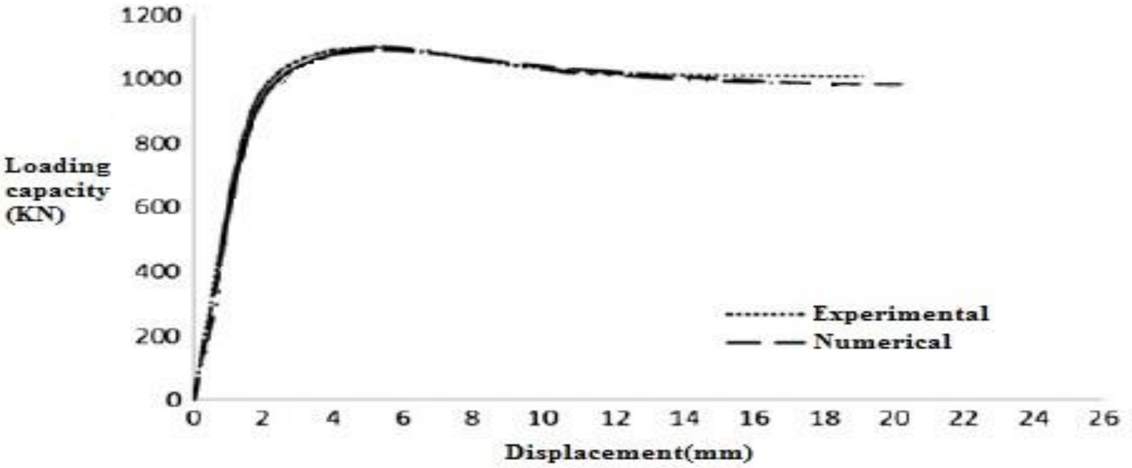

Figure 16. Loading capacity section with ratio of diameter to thickness 32 and compressive strength of 60MPa

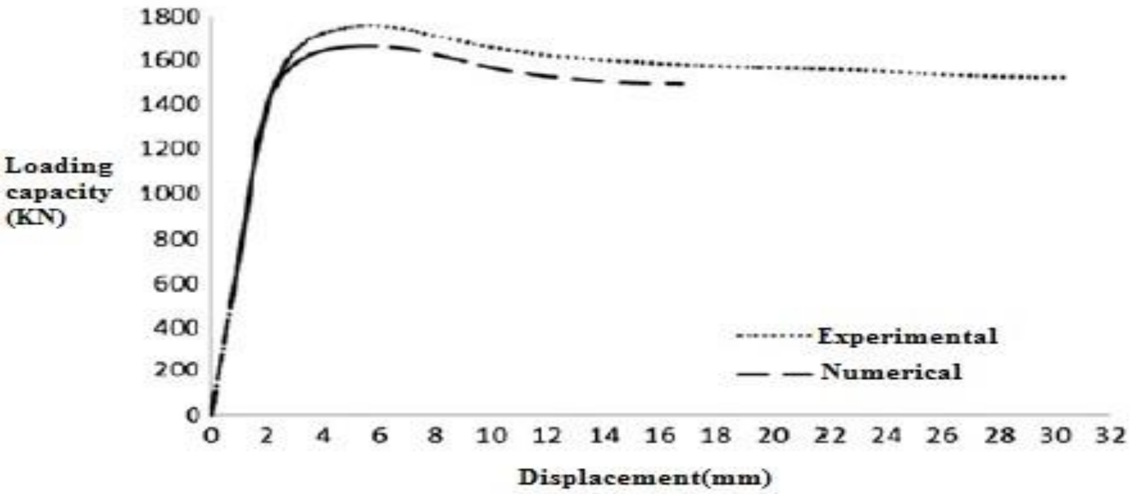

Figure 17. Loading capacity section with ratio of diameter to thickness 54 and compressive strength of 44MPa

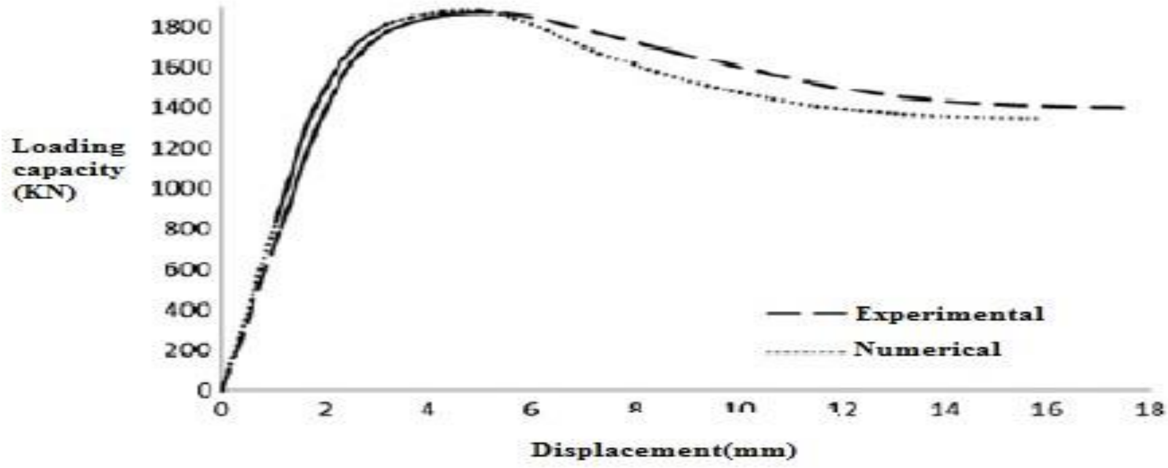

Figure 18. Loading capacity section with ratio of diameter to thickness 54 and compressive strength of 60MPa

As can be seen with the increase of ratio diameter to thickness accuracy of finite element models dropped in comparison with the experimental results. Except in ratio diameter to thickness of 54, in other case by increasing the ratio, the amount of cross-bearing capacity is reduced; moreover, the shift of the axial load except the third increase this ratio increase. Also in figure 19 we determine the effect of increasing diameter to thickness ratio coincides with the change in the compressive strength of concrete core to the degree of tension.

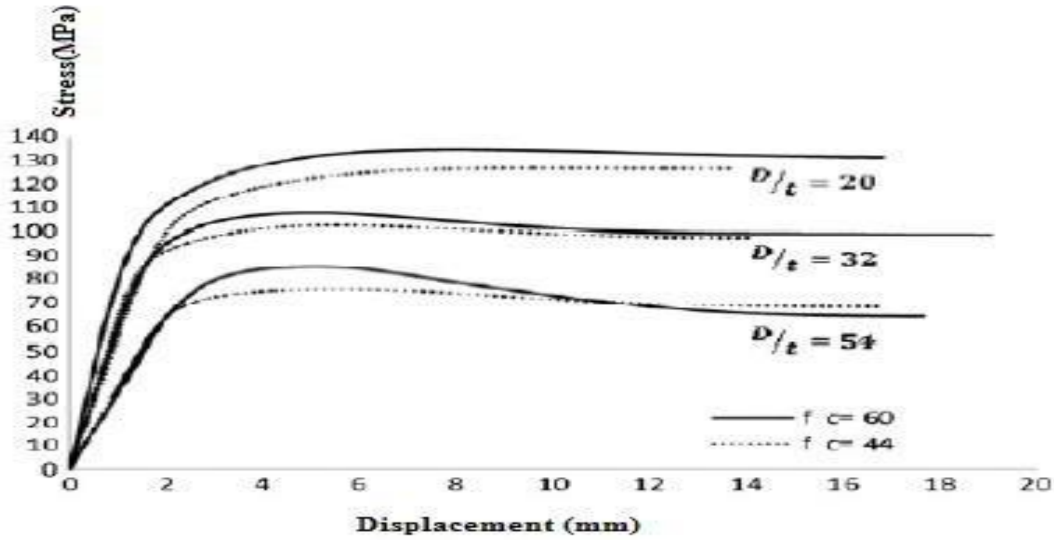

Figure 19. The effect of increasing ratio of diameter to thickness while increasing the compressive strength of concrete core on section amount stress

As can be seen by increasing the diameter to thickness ratio, the amount of stress on the cross-section decreased shift amount increase, It also increase the compressive strength of concrete core with increase the stress on the cross.

3.3. THE EFFECT OF SLENDERNESS FACTOR ON THE NUMERICAL RESULTS

In figures 20 to 23 compared the effect of increasing the slenderness factor of under remaining duration section. As can be seen with increasing slenderness factor, the remaining amount duration of the fire is reduced. While most of the sections circular section in each case the remaining duration of the square.

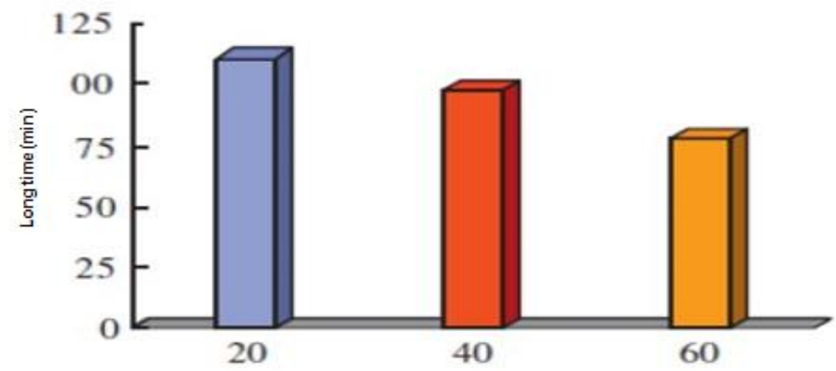

Figure 20. The effect of increased slenderness factor for a circular section 300×5mm

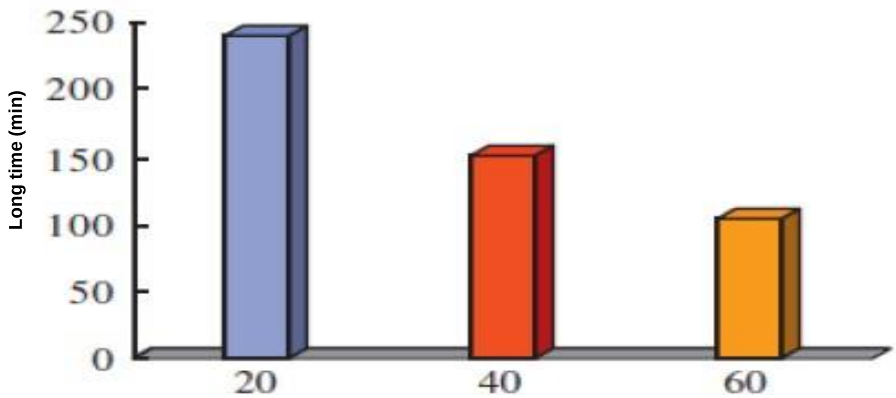

Figure 21. The effect of increased slenderness factor for a circular section 900×5mm

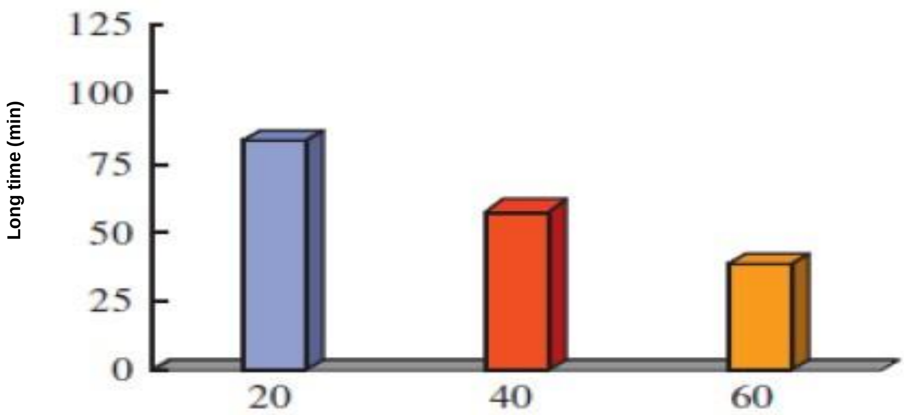

Figure 22. The effect of increased slenderness factor for a square section 300×5mm

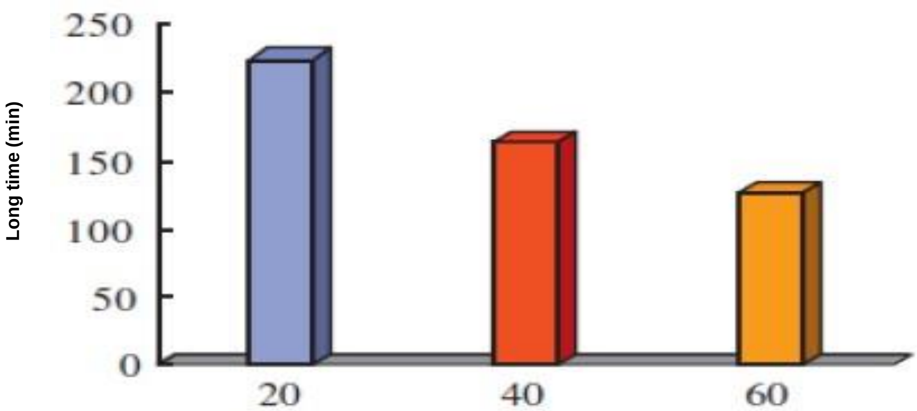

Figure 23. The effect of increased slenderness factor for a square section 900×5mm

4. CONCLUSION

Increasing the compressive strength increased cross-section loading capacity, although the will have minimal impact in increasing difficulty. Reduced ductility of columns concrete with increase the compressive strength of concrete core when the increase of ratio diameter to thickness. With increasing slenderness factor, the amount of remaining duration of the fire is reduced. The failure of the study can be reversed by increasing the thickness of the bottom sheet delayed of course the increase size end thicknesses, must be provided to meet the regulations. Use of connections with flexible endplate in phase of getting cold increases the possibility of failure, although the probability of this failure can be reduced by increasing the thickness of reverse channel web and use of ductile steel. Failure in reverse channel and endplate can be postponed by increasing their thickness. Of course, increasing dimensions and thickness should be subject to fulfill the conditions of codes. In connections with extensive, flexible and extensive flexible endplate affected simultaneously by tension and bending moment in screws, failure happens and in connections with balanced and flexible balanced endplate, failure occurs in the web of channel in screw region and also in the corner of channel web near to flanges usually happens.

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AUTHORS CONTRIBUTION

This work was carried out in collaboration among all authors.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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