# COMPARISON OF AISC 360 – 16 AND EC4 FOR THE PREDICTION OF COMPOSITE COLUMN CAPACITY

Baraa J.M. AL-Eliwi, Ph.D. student
Civil Engineering Department, University of Gaziantep, 27310 Gaziantep, Turkey
Civil Engineering Department, University of Mosul, 41001 Mosul, Iraq
baraa.aleliwi@gmail.com

Talha Ekmekyapar, Ph.D
Civil Engineering Department, University of Gaziantep, 27310 Gaziantep, Turkey
ekmekyapar@gantep.edu.tr

Hussein A.M.S. Al-Juboori, M.Sc student
Civil Engineering Department, University of Gaziantep, 27310 Gaziantep, Turkey
hussainjuboori@gmail.com

**ABSTRACT:** Composite constructions are used widely in civil engineering structures. The steel and concrete act together to resist the loads. Composite columns are a significant application of composite construction, and the Concrete-Filled Steel Tube (CFST) columns are the most common type of composite columns. The CFST columns have been increasingly used all over the world due to their inherent advantages, and in particular because of their favorable behavior under seismic loads. The steel tube effectively confines the concrete core, providing a highly ductile response under compression and a high energy absorption capacity. This type of composite column has been used primarily in bridges, reservoirs, and tall buildings. Circular CFST column provides much more effective confinement to the core concrete than other types of column sections under axial load due to an enhancement of composite action between steel tube and core concrete. Many design specifications used to predict the capacity of CFST columns, the ANSI/AISC 360 – 16 and the Eurocode 4 (EC4). The ANSI/AISC 360 – 16 is the specification for steel structures in the United States; the Eurocode 4 is the European code for composite structure design, respectively. The objective of this study is to investigate the differences between the AISC 360-16 and the EC4 approaches of circular CFST columns under axial load and to evaluate how well they model the actual column behavior through a series of statistical comparisons. Also, the parameters which are used in design specification calculations steps will be assessed. The important parameters in calculations will also be specified to underline the best way in the design field.

**Key words:** Composite columns, CFST column, Axial capacity, ANSI/AISC 360 – 16, EC4.

## INTRODUCTION

Composite structures term is widely used in civil engineering structures where the steel and concrete formed together into an element. The aim is to achieve the best level of performance than would have been case had the two materials functioned separately.

Composite columns are very important part of composite structures; the term "composite column" refers to any compression member which a steel element acts compositely with the concrete element so that both elements resist compressive forces. There is a wide variety of column types of various cross – section, but the most commonly used are the concrete-encased composite columns, and the concrete filled steel tube columns, Figure 1 (Giakoumelis and Lam, 2004; Liang, 2014).

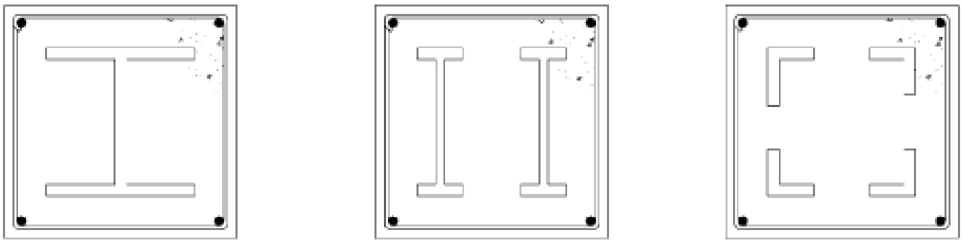

Figure 1a. Concrete-Encased Composite Columns

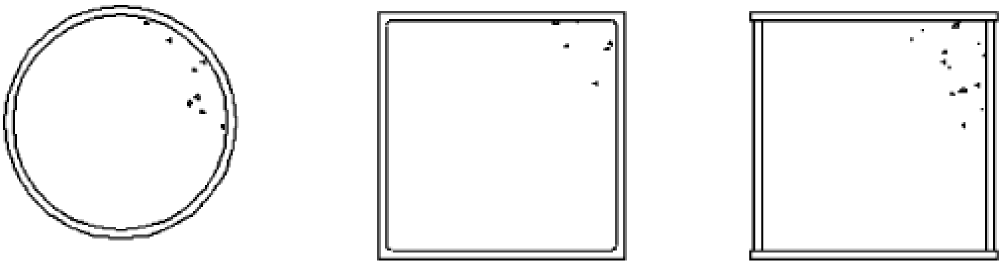

Figure 1b. Concrete-Filled Composite Columns

Figure 1. Composite Columns (Giakoumelis and Lam, 2004)

## CONCRETE – FILLED STEEL TUBE (CFST) COLUMNS

Concrete – Filled Steel Tube (CFST) Column offers features better than either pure steel or reinforced concrete column due to the interaction between the external steel tube and core concrete. The strength and ductility of CFST column are increased under compression due to the effective confinement of the steel tube to the core concrete. Also, the presence of the concrete prevents the inward buckling of the steel tube and enhance the local buckling response. The steel tube acts as the formwork, and this option gives a more economical and faster construction

(Ekmekyapar and Al-Eliwi, 2016; Han *et al.*, 2014; Li *et al.*, 2015). Figure 2 shows the typical cross-sections of CFST column.

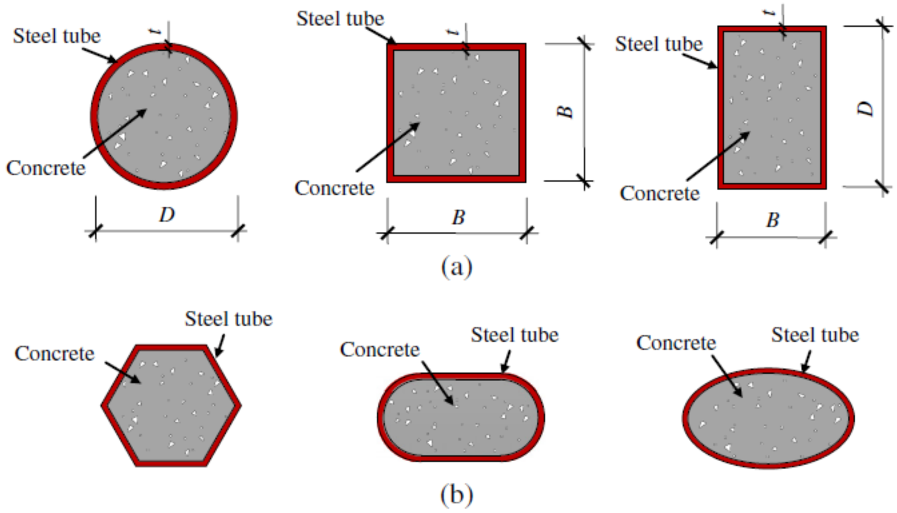


Figure 2. Typical cross – sections of CFST column (Han *et al.*, 2014)

The increase in strength, stiffness, and ductility of CFST column are provided by the confinement of steel tube to concrete core. In the early stage of loading, Poisson's ratio of concrete is lower than that of steel tube, and no confinement at this stage. When the load is increased, the Poisson's ratio of concrete increased and reach that of steel tube, core concrete expands and interacts with a steel tube to develop the passive confinement. At greater load levels, the core concrete expands laterally more than steel tube, and hence a radial pressure is developed at the interface between concrete and steel. At this stage, confinement of the concrete core is achieved, and core concrete is stressed triaxially and the steel tube biaxially (de Oliveira *et al.*, 2009; Johansson, 2002; Shanmugam and Lakshmi, 2001).
The confinement index is a parameter has been adopted to specify the confinement capability of the CFST column roughly (Han *et al.*, 2014; Han *et al.*, 2005).

$$\xi = \frac{A_s f_y}{A_c f_c} \quad (1)$$

where $A_s$ and $A_c$ are the cross-sectional areas of the steel tube and core concrete, respectively, $f_c$ is the compressive strength of concrete, and $f_y$ is the steel yield strength.
The studies proved that the circular steel tube could provide more effective confinement to the core concrete than other types of steel tube sections. Large experimental studies focused on the performance of circular CFST column under axial load were carried out over the last decades. In addition to experimental works, several design specifications have been published to enhance the applications and design of the CFST columns.

## PAST RESEARCH ON CFST COLUMNS UNDER AXIAL LOADING

Many research on circular CFST columns under axial loading has been carried out. The main parameters effect on the circular CFST column are: section slenderness ratio (diameter – to – thickness (D/t) ratio), column slenderness ratio (length – to – diameter (L/D) ratio), and materials properties which presented by concrete compressive strength $f_c$, and steel yield strength $f_y$.

Schneider (1998) studied the behavior of short concrete-filled steel tube columns under axial load experimentally. Fourteen specimens were tested to investigate the effect of the tube shape and steel tube thickness on the capacity of the columns. It was concluded that circular steel tubes offer much more post-yield axial ductility than square and rectangular tube sections.

Giakoumelis and Lam (2004) studied the effect of the steel tube thickness, the bond strength between the steel and concrete, and the confinement on the behavior of circular CFST columns with various concrete strengths under axial loading and compared the results with the predictions of the design specifications. Han *et al.* (2005) studied experimentally the behavior of self-consolidating concrete filled steel tube stub columns under axial load. The main parameters varied in the study are section type, steel yielding strength, D/t ratio. The theoretical model was used to study the influence of parameters on the ultimate strength of CFST columns. And making comparisons between the experimental results and the existing codes.

de Oliveira *et al.* (2009) studied the effect of L/D ratio and concrete strength on the confinement factor. The columns length was short and long and concrete strength normal and high strength. The capacity decreased when L/D increased, the load capacity increased for high strength concrete but the confinement improved in normal concrete strength and compared the results with some design codes.

An *et al.* (2012) investigated the behavior of very slender CFST columns. The results showed that the very slender column reaches the ultimate capacity with no confinement exist and predict the ultimate strength by design specifications.

Abed *et al.* (2013) studied the effect of D/t ratio and concrete strength of short CFST columns. The results showed the D/t ratio had a greater effect than others. when, D/t ratio increased the stiffness and axial capacity of the columns decreased due to decrease in the confinement. Also, the results compared with the current codes.

Aslani et al. (2015) Investigated the suitability of the several codes to predict the axial load capacity of high strength concrete filled steel tube columns under the axial load. According to the statistical results, simplified relationships are developed to predict the section and ultimate buckling capacities of normal and high-strength short and slender rectangular and circular CFSTCs subjected to axial loading.

Ekmekyapar and Al-Eliwi (2016) examined the capacity and the confinement of CFST columns with three L/D ratios, two D/t ratios, three concrete compressive strength levels and two steel qualities. The results showed that the L/D ratio is very important parameter has direct impact column capacity, and D/t and confinement factor does not have a direct impact on the performance of CFST column.

## AIM OF THIS STUDY

Many design specifications have been proposed to predict the axial capacity of CFST columns; the common codes are AISC360-16 (2016) and EC4 (2004) where the AISC 360 – 16 is the specification for steel structures in the United States; the EC4 is the European code for composite structure design. The aim of this study is to confirm the applicability and prediction of AISC 360 – 16 and EC4 codes for circular CFST columns under axial loading and compare them.

## STRENGTH PREDICTION OF CIRCULAR CFST COLUMNS

The AISC 360 – 16 and EC4 codes depend on different functions to estimate the axial load capacity of CFST columns. These codes have some limitations on geometrical properties of the steel tube, and materials properties of steel and concrete and these limitations are different according to the code. Table 1 shows the limitations of these design specifications.

**Table 1. Limitations of Design Specifications**

| Parameter | AISC 360 – 16 | EC4 |
|---|---|---|
| $f_y$ (MPa) | $f_y \leq 525$ | $235 \leq f_y \leq 460$ |
| $f_c$ of NW (MPa) | $21 \leq f_c \leq 70$ | $20 \leq f_c \leq 60$ |
| D/t | $\leq 0.31\left(E_s/f_y\right)$ | $\leq 90\left(235/f_y\right)$ |
| Steel amount | ≥ 1% of gross area | $0.2 \leq \delta \leq 0.9$ |
| Slenderness | $KL/r \leq 200$ | $\lambda \leq 2$ |

Where $E_s$ refers the elastic modulus of the steel tube, $K$ is the effective length factor based on end boundary conditions of the column, $\lambda$ refers the relative slenderness and, $\delta$ is the steel contribution ratio defined in EC4:

$$\delta = \sqrt{\frac{A_s f_y}{N_{pl.Rd}}} \quad (2)$$

Elastic modulus of the concrete, $E_c$, is calculated in each specification as presented in Table 2.

**Table 2. Elastic Modulus of the Concrete**

| **Specification** | $E_c$ **(MPa)** | **Details** |
|---|---|---|
| AISC 360-16 | $0.043 w_c^{1.5}\sqrt{f_c}$ | $w_c$: Concrete density ($1500 \le w_c \le 2500\ kg/m^3$ ). |
| EC4 | $22000\ ((f_c+8)/10)^{0.3}$ | |

**AISC 360 – 16**

The nominal strength of composite sections shall be determined by the plastic stress distribution method, where the steel tube reaches the yield stress $f_y$ when the core concrete strength about $0.95 f_c$. The CFST sections are classified as compact, noncompact or slender. This classification accordance to the cross-section slenderness (D/t) ratio. The section is compact if the D/t ratio does not exceed $\lambda_p = 0.15E/f_y$, noncompact if the D/t ratio exceed $\lambda_p$ but does not exceed $\lambda_r = 0.19E/f_y$, and slender if the D/t ratio exceeds $\lambda_r$. For all cases, the maximum D/t ratio does not exceed $0.31E/f_y$.
The nominal compressive strength of doubly symmetric axially loaded CFST shall be determined for the limit state of flexural buckling based on member slenderness as follows:

$$P_{AISC} = P_{no}\left[0.658^{\frac{P_{no}}{P_e}}\right] \qquad \frac{P_{no}}{P_e} \le 2.25 \qquad (3)$$

$$P_{AISC} = 0.877 P_e \qquad \frac{P_{no}}{P_e} > 2.25 \qquad (4)$$

Where, $P_{no}$ is the nominal strength of the composite section and $P_e$ is the Euler critical load, which is calculated using effective stiffness $(EI)_e$:

$$(EI)_e = E_s I_s + C_3 E_c I_c \qquad (5)$$

$$P_e = \frac{\pi^2 (EI)_e}{(KL)^2} \qquad (6)$$

$K = 1$

$C_3$ is the coefficient of effective rigidity of the CFST column:

$$C_3 = 0.45 + 3\left(\frac{A_s}{A_s + A_c}\right) \le 0.9 \qquad (7)$$

For compact section, the nominal axial capacity is calculated as:

$$P_{no} = P_p \qquad (8)$$

$$P_p = A_s f_y + C_2 A_c f_c \quad (9)$$

Where, $P_p$ is the plastic strength of the section, $C_2 = 0.95$, a circular section.
AISC 360 – 16 adopts the confinement effect of circular section by the coefficient of $C_2$ of 0.95, which gives an 11% constant improvement due to confinement.

For non – compact section; the nominal axial capacity is evaluated as:

$$P_{no} = P_p - \frac{P_p - P_y}{(\lambda_r - \lambda_p)^2} (\lambda - \lambda_p)^2 \quad (10)$$

$$P_y = A_s f_y + 0.7 A_c f_c \quad (11)$$

Where, $P_y$ is the yield strength of the composite section.

For slender section, the nominal axial capacity is given by:

$$P_{no} = A_s f_{cr} + 0.7 A_c f_c \quad (12)$$

$$f_{cr} = \frac{0.72 f_y}{\left(\left(\frac{D}{t}\right) \frac{f_y}{E_s}\right)^{0.2}} \quad (13)$$

$f_{cr}$ is the critical local buckling stress of the filled circular section.

**EC4**

EC4 code adopts simplified method to predict the capacity of CFST columns. This code gives details to estimate the confinement effect, and the confinement effect is considered if the relative slenderness ($\bar{\lambda}$) is lower than 0.5. The plastic resistance of the CFST section ($N_{pl.Rd}$) is calculated by adding the resistance of the steel and concrete. The plastic compressive capacity of circular CFST column as:

$$N_{EC4} = \eta_a A_s f_y + A_c f_c \left(1 + \eta_c \frac{t}{D} \frac{f_y}{f_c}\right) \quad (14)$$

Where, $\eta_a$ is the steel reduction factor, where the yield stress decreased due to the hoop stress. And $\eta_c$ is the concrete enhancement factor, where, the concrete strength increased under triaxial stress state.
when eccentricity is smaller than 10% of the outer diameter of the steel tube D, the steel reduction and the concrete enhancement factors are evaluated as follows:

$$\eta_a = 0.25(3 + 2\bar{\lambda}) \leq 1.0 \quad (15)$$

$$\eta_c = 4.9 - 18.5\bar{\lambda} + 17\bar{\lambda}^2 \geq 0 \quad (16)$$

$\bar{\lambda}$: the relative slenderness ratio; the confinement effect is considered, if the value of $\bar{\lambda}$ does not exceed 0.5.

$$\bar{\lambda} = \sqrt{\frac{N_{pl.Rd}}{N_{cr}}} \leq 0.5 \quad (17)$$

Where, $N_{pl.Rd}$ is the plastic resistance of column, and $N_{cr}$ is the Euler critical load:

$$N_{pl.Rd} = A_s f_y + A_c f_c$$
(18)

$$N_{cr} = \frac{\pi^2 (EI)_e}{(KL)^2} \quad (19)$$

Where, $(EI)_e$ is the effective stiffness of the member which is given by:

$$(EI)_e = E_s I_s + K_e E_c I_c \quad (20)$$

Where, $E_s$; $E_c$ are the elastic modulus of steel and concrete, respectively. Table 2 defines the modulus of elasticity of concrete. $I_s$; $I_c$ are the moment of inertia of steel tube section and concrete section, respectively. Finally, $K_e$ is a correction factor equal to 0.6.
EC4 considered the effect of imperfections that might be caused second order moments by multiplying the column plastic resistance by a reduction factor $\chi$:

$$\chi = \frac{1}{\phi + \left(\phi^2 - \bar{\lambda}^2\right)^{0.5}} \leq 1.0 \quad (21)$$

The reduction factor $\chi$ is calculated using European column curves and the parameter $\phi$ is calculated as:

$$\phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 2\right) + \bar{\lambda}^2\right] \quad (22)$$

Where, $\alpha$ is an imperfection factor, equal to 0.21 for circular CFST columns.

## PARAMETRIC STUDY OF CIRCULAR CFST COLUMNS

This study aims to investigate the appropriateness of AISC 360 – 16 and EC4 of practice for predicting the capacity of circular CFST columns under axial loading, where the data will be within and behind the limitations of these codes and analyze the results, where the variation of geometrical and material properties covered in this study. A total of 81 specimens, where various structural parameters were varied to investigate their combined effect: concrete compressive strength $f_c$ taken as 20, 60, and 100 MPa to cover normal and high strength concrete, steel tube yield strength $f_y$ taken as 235, 435, and 600 MPa to cover mild and high tensile strength steel, D/t ratio taken as 20, 60, and 100, and L/D ratio taken as 3, 6, and 9 to cover short and long columns.

In definition of short and long CFST columns the AISC 360 – 16 and EC4 codes are completely different, therefore, the term "short column" and "long column" are classified according to L/D ratio, where the "short column" is defined as specimen with L/D ratio less than or equal 4, while, "long column" is defined as specimen with L/D ratio more than 4 (Han *et al.*, 2014; Le Hoang and Fehling, 2017; Li *et al.*, 2015). The modulus of elasticity of steel tube is 200 GPa, and modulus of elasticity of concrete is determined according to the corresponding codes.

**The effect of parameters on axial capacity of CFST columns**

To study the behavior of the CFST columns, there are materials and geometrical parameters are effect on the axial capacity of column, (1) concrete compressive strength $f_c$, (2) steel tube yield strength $f_y$, (3) diameter – to – thickness D/t ratio, and (4) length – to – diameter L/D ratio.

To investigate which parameter has more effect on the axial capacity of the CFST column, the results of analysis of variance by using Minitab software showed that the D/t ratio and concrete compressive strength have the more effects than other parameters and the maximum interaction is between D/t ratio and $f_y$ for both AISC 360 – 16 and EC4.

The results show that the CFST column of (D/t = 20, L/D = 3, $f_c$ = 100 MPa, and $f_y$ = 600 MPa) gives the maximum axial capacity of 7.501 MN, and 9.063 MN for both AISC 360 – 16 and EC4 respectively by difference about 20.8% where the EC4 takes the confinement effect on its consideration. While the CFST column of (D/t = 100, L/D = 9, $f_c$ = 20 MPa, and $f_y$ = 235 MPa) gives the minimum axial capacity of 1.034 MN, and 1.117 MN for both AISC 360 – 16 and EC4 respectively by difference about 8%.

Figure 4 and Figure 5 present the interaction plots for both AISC 360 – 16 and EC4. Use an interaction plots to show how the relationship between one parameter and the mean of the axial capacity depends on the value of the second parameter.

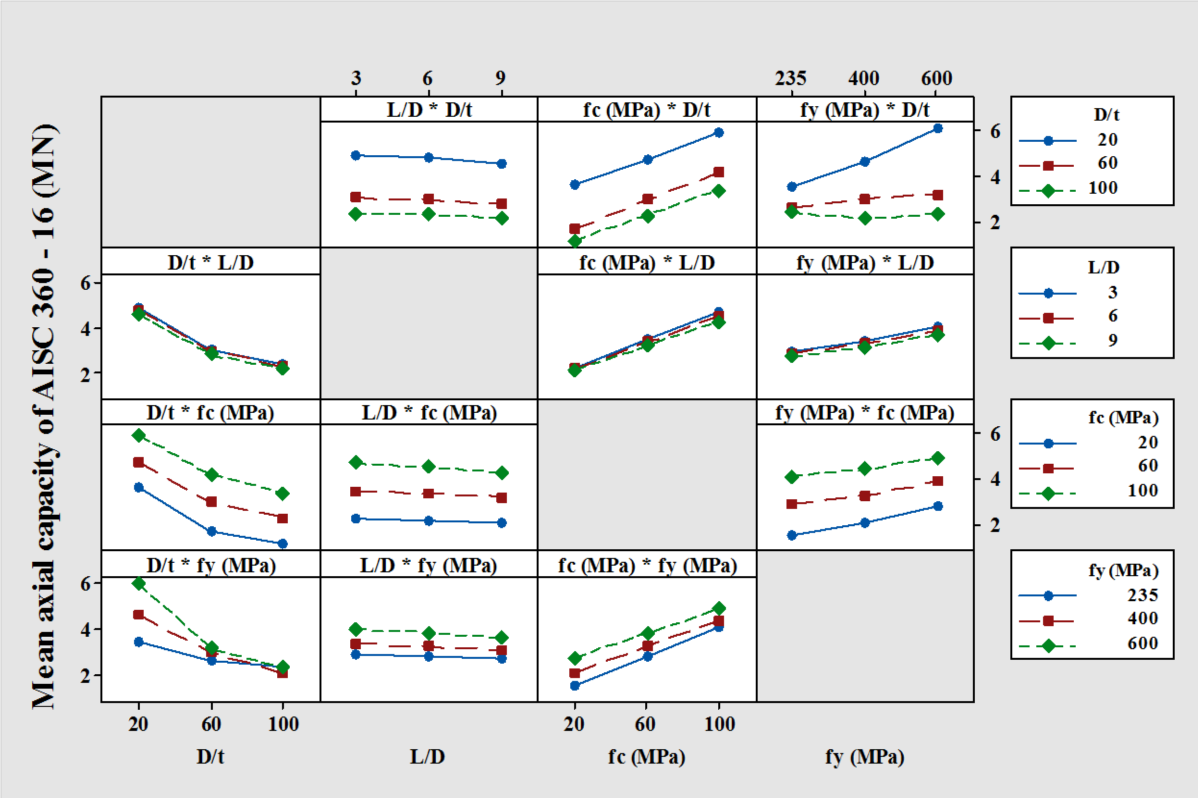


Figure 4. Interaction Plot of AISC 360 – 16 Design Code

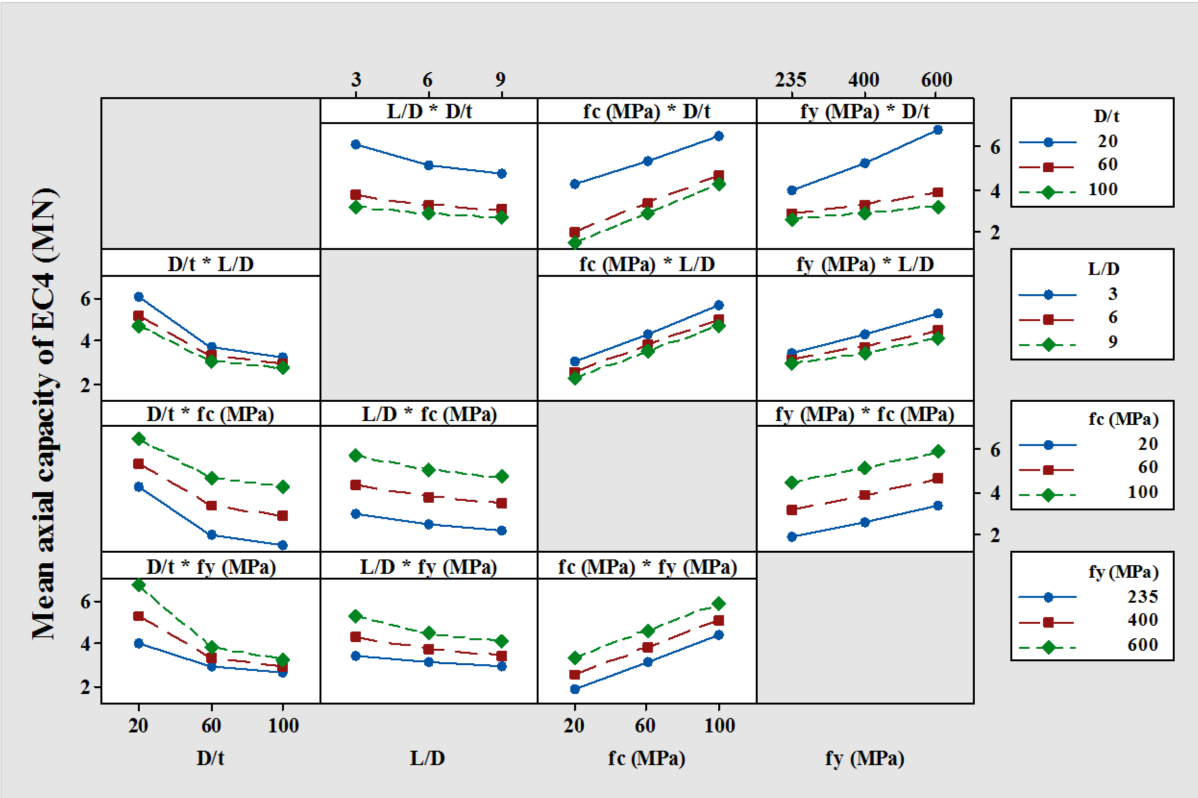


Figure 5. Interaction Plot of EC4 Design Code

### *Effect of concrete compressive strength $f_c$*

The effect of concrete compressive strength $f_c$ is shown in Figure 6 for both AISC 360 – 16 and EC4, where the axial capacity increase when $f_c$ increases.

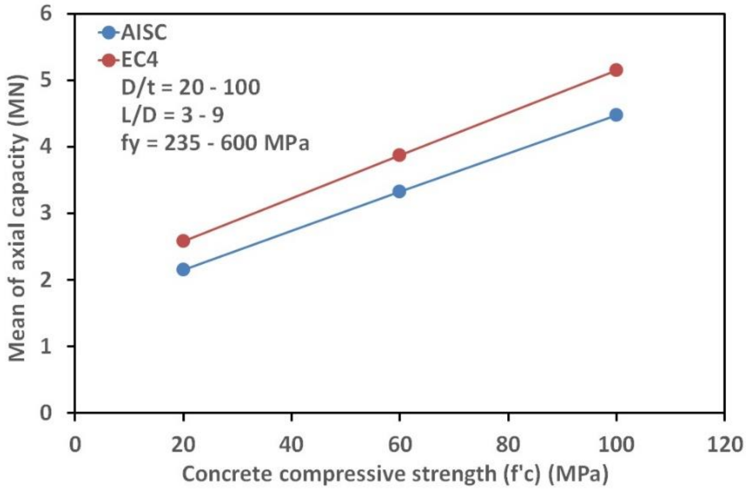


Figure 6. Effect of $f_c$ on Axial Capacity of CFST Columns

This increasing in axial capacity of the CFST columns is due to the effects of confining tube in increasing the infill concrete compressive strength $f_c$. As shown in Figures 4 and 5, the maximum axial capacity gives when $f_c$ = 100 MPa with D/t = 20 compared with others parameters.

### *Effect of steel yield strength $f_y$*

Figure 7 shows the influence of $f_y$, for both AISC 360 – 16 and EC4 the axial capacity of the CFST column increase when increase in $f_y$ increases. Figures 4 and 5 present the maximum axial capacity gives when $f_y$ = 600 MPa with D/t = 20 compared with others parameters.

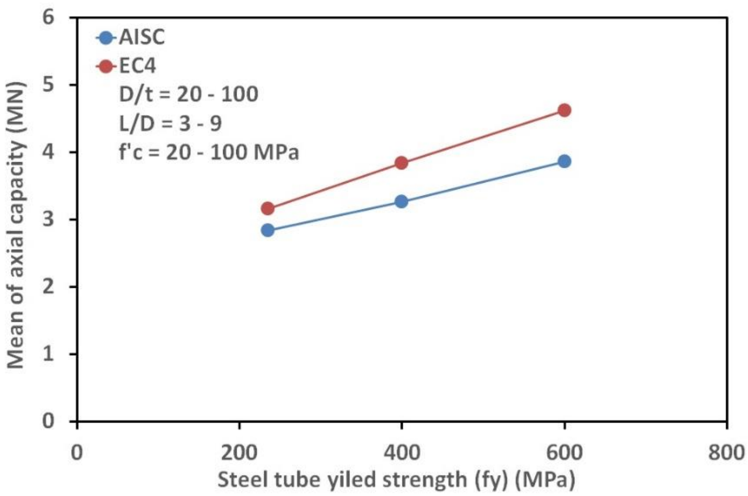


Figure 7. Effect of $f_y$ on Axial Capacity of CFST Columns

***Effect of diameter – to – thickness D/t ratio***

D/t ratio also defines as cross-section slenderness ratio also this ratio effect on local buckling of the CFST columns, however, the for AISC 360 – 16 the local buckling accounted according to the classification of cross-section as compact, noncompact and slender. While the EC4 the local buckling occurs when this ratio passed the maximum value. Furthermore, this parameter effect on the confinement as shown in Equation 1. For both AISC 360 – 16 and EC4 the axial capacity of the CFST column decrease when D/t increases due to the reduction in confinement provided by small thickness. Figure 8 shows the influence of D/t ratios on the axial capacity of the CFST columns. However, the D/t = 20 gives the maximum effect with compared with other values (D/t = 60, 100).

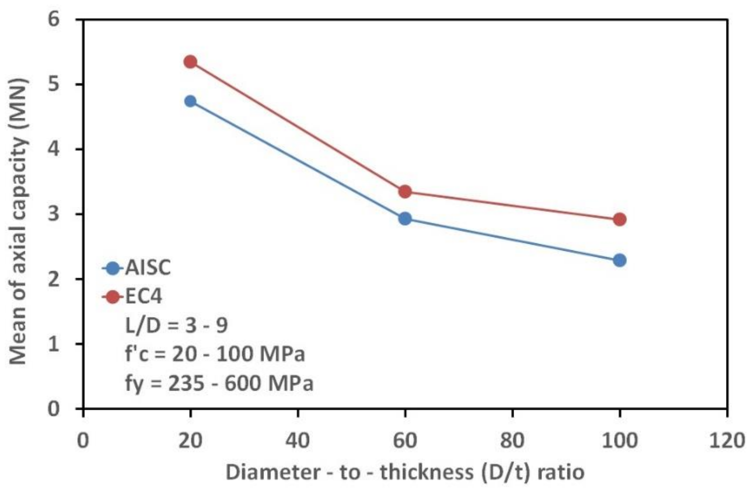


Figure 8. Mean Effect Plot of D/t Ratio

### *Effect of length – to – diameter L/D ratio*

The L/D ratio affects the axial capacity and the confinement effect of the CFST columns, where, both decrease when L/D ratio increased (de Oliveira *et al.*, 2009; Ekmekyapar and Al-Eliwi, 2016). Figure 9 shows the mean effect of L/D ratio on the axial capacity of the CFST columns for both AISC 360 – 16 and EC4. Where the axial capacity of short columns (L/D = 3) greater than long columns (L/D =6 and 9). Also from Figures 4 and 5 the L/D = 3 with D/t ratio = 20 gives the maximum axial capacity in compared with other parameters.

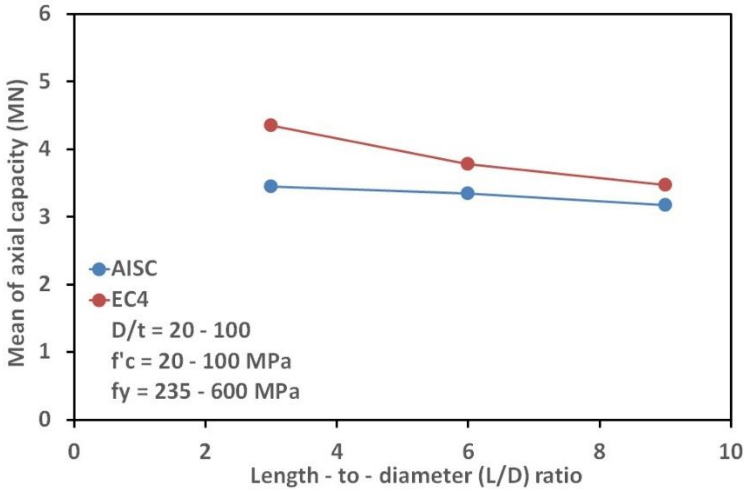


Figure 9. Mean Effect Plot of L/D Ratio

### *The strength index (SI) and the confinement index ($\xi$)*

For the design of the CFST columns, most codes recognize the effect of the "composite action" especially for members with the circular cross – section. Therefore, the strength of the composite member is enhanced. Strength index *SI* and the confinement index $\xi$ are very useful measures for composite action and confinement assessments in CFST columns. where $\xi$ is defined in equation 1 and *SI* is defined as follows and (Ekmekyapar and Al-Eliwi, 2016; Han *et al.*, 2014; Portolés *et al.*, 2011; Yang *et al.*, 2008; Yu *et al.*, 2008):

$$SI = \frac{P_u}{P_{uo}} \quad (23)$$

Where, $P_u$ is the axial capacity of a CFST column predicted by AISC 360 – 16 and EC4 codes. And $P_{uo}$ is the sectional capacity or sqush load:

$$P_{uo} = A_s f_y + 0.85 A_c f_c \quad (24)$$

The following Figures 10 to 13 show the effect of parameters of the parametric study on the strength index. For AISC 360 – 16 *SI* ranges from 0.747 to 1.088 and for EC4 ranges from 0.937 to 1.403 by increasing in mean about 18%, this in difference is due to the EC4 code take the confinement effect in its consideration. Figures 10 and 11 show that *SI* for normal strength concrete ($f_c$ = 20 MPa) greater than high strength concrete (60 and 100 MPa) and for mild steel strength ($f_y$ = 235 MPa) gretaer than higher strength steel strength (400 and 600 MPa) because the squash load of the CFST column depends on cross – section and the materials properties $f_c$ and $f_y$.

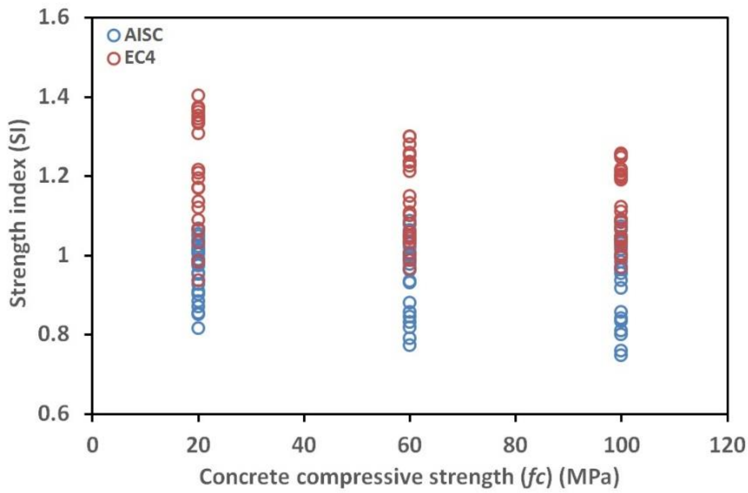


Figure 10. Effect of $f_c$ on the Strength Index *SI*

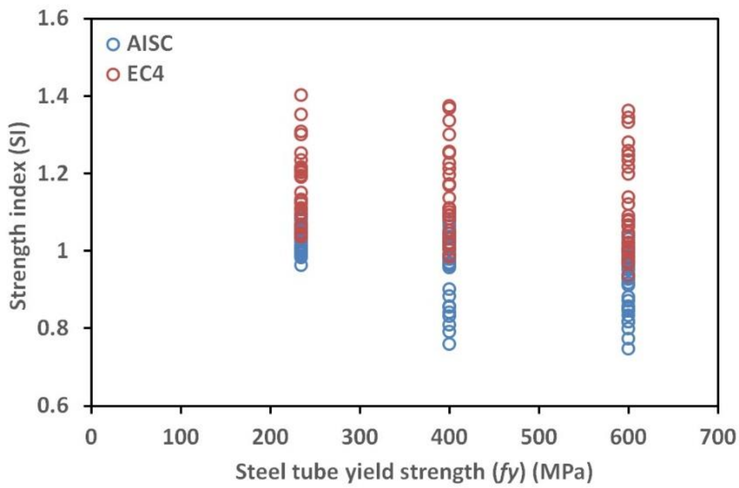


Figure 11. Effect of $f_y$ on the Strength Index *SI*

Figure 12 shows the effect of D/t ratio on the strength index for both AISC 360 – 16 and EC4 codes. The strength index decreased when the D/t ratio increases this means the thicker tube provides confinement more than, the thinner tube. The column's ductility decreases as the concrete compressive strength increases for higher D/t ratios, but for smaller D/t ratios the opposite is true (Abed *et al.*, 2013).

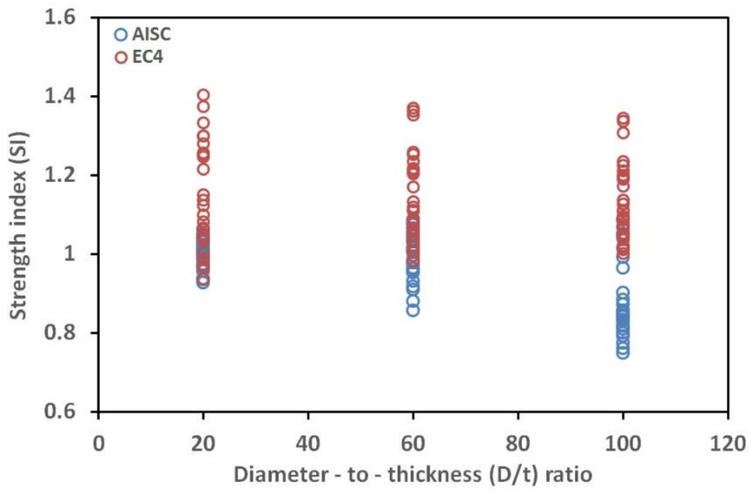


Figure 12. Effect of D/t Ratio on the Strength Index *SI*

As shown in Figure 9, the L/D ratio has a direct impact on the axial capacity of the CFST column. The short columns have an axial capacity greater than long columns for both AISC 360 – 16 and EC4. This also clear in Figure 13 where the short columns have strength index more than unity particularly for EC4 due to the effect of the L/D ratio on the confinement index, where the confinement decrease when L/D ratio increases. For a column with small L/D ratio, the failure is recognized by material yielding while for high L/D ratio the failure is characterized by global instability with small deformation before the facing the confinement (de Oliveira *et al.*, 2009).

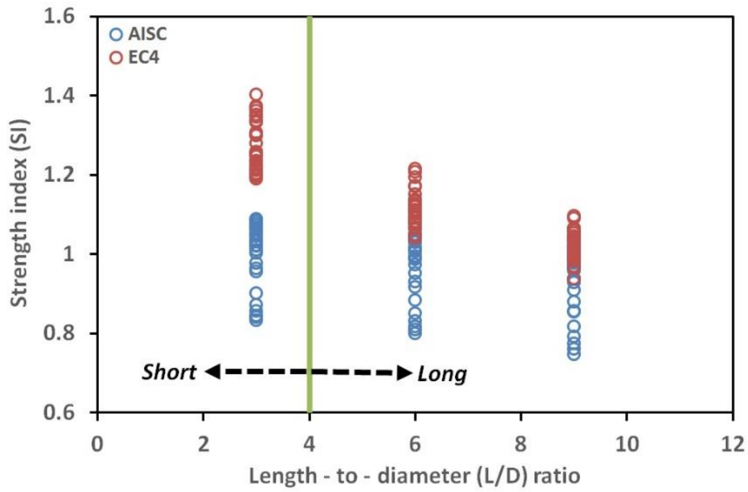


Figure 13. Effect of L/D ratio on the Strength Index *SI*

The confinement index $\xi$ is a function of D/t ratio, as well as the material properties $f_c$ and $f_y$, for this parametric study the confinement index ranges from 0.097 to 7.037. Figures 14 – 16 show the relation between the D/t ratios and the confinement index $\xi$ with different values of $f_c$ and $f_y$. It is observed that the samples of D/t ratios = 20 with $f_c$ = 20 MPa and $f_y$ = 600 MPa are more affected on the confinement index.

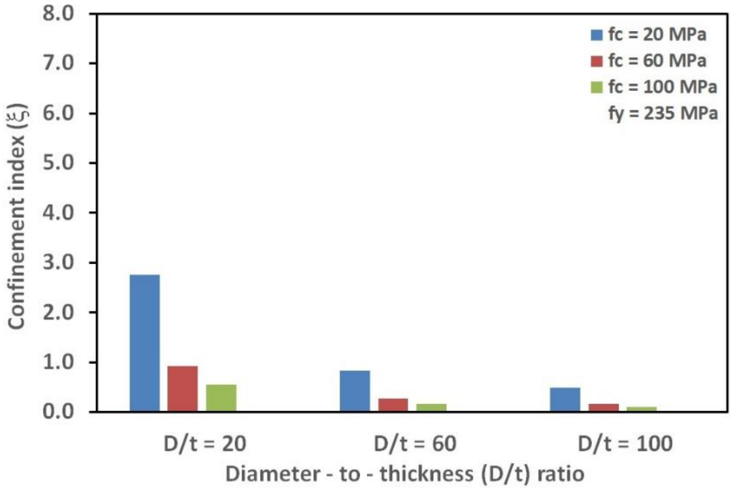


Figure 14. D/t Ratio Versus the Confinement Index $\xi$, $f_y$ = 235 MPa

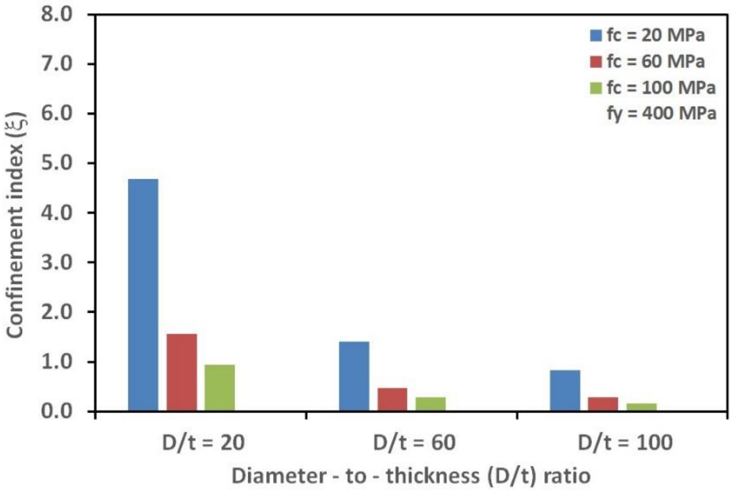


Figure 15. D/t Ratio Versus the Confinement Index $\xi$, $f_y$ = 400 MPa

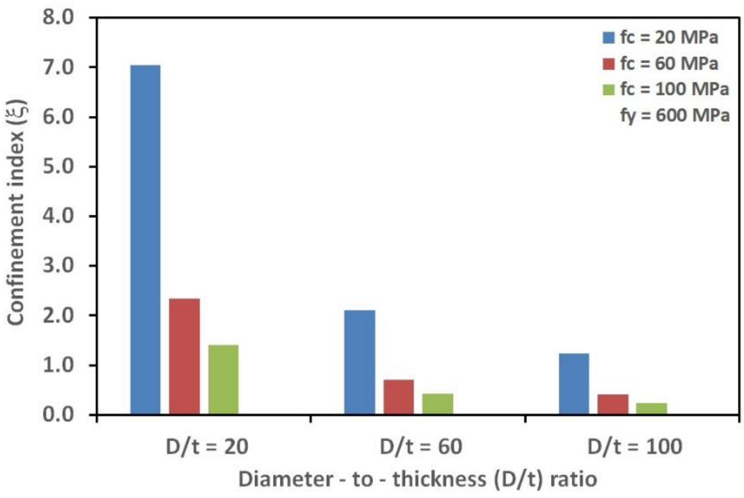


Figure 16. D/t Ratio Versus the Confinement Index $\xi$, $f_y$ = 600 MPa

As a summary of this parametric study, Table 3 shows the difference in predictions between AISC 360 – 16 and EC4, where, the percentage of the difference of the axial capacity for total columns specimens is 16.53%, this difference due to the confinement effect and the variation between the limitations of codes for materials and geometrical properties, when classify the columns specimens according to length, the difference is 26.24% this exactly due due to the confinement where EC4 takes in its consideration the confinement effect for short column while for long columns the difference decreased to 11.39% because no confinement effect for long column in EC4 calculations.

Also for the same reasons the same result is clear to observe for strength index calculations for short and long columns where the difference is 27.83% and 12.95% respectively. For normal strength concrete (NSC) and high-strength concrete (HSC), also the variation is clear for prediction of axial capacity between two codes, generally, the confinement is more effective when the infilled concrete is NSC due to its higher deformation capacity in comparison with the HSC (de Oliveira *et al.*, 2009), this result is obvious in mean of $SI_{EC4}$ between NSC and HSC due to confinement effect while it is slight difference in $SI_{AISC}$ because no big effect of confinement in this code.

The same conclusion observed when comparisons between the mean of the confinement index $\xi$ between NSC and HSC. While there is no effect of length on the mean of $\xi$ because the equation 1 do not take the length in calculations. conversely for steel tube strength, where, the mild steel strength (MSS) ($f_y \leq 460$ MPa) gives lower confinement than high tensile steel strength (HSS) ($f_y > 460$ MPa).

**Table 3. Summary of the Results**

| | Mean of $P_{AISC}$ (MN) | Mean of $P_{EC4}$ (MN) | $P_{EC4}/P_{AISC}$ (%) | Mean of $SI_{AISC}$ | Mean of $SI_{EC4}$ | $SI_{EC4}/SI_{AISC}$ (%) | Mean of $\xi$ |
|---|---|---|---|---|---|---|---|
| Total columns | 3.321 | 3.870 | 16.53 | 0.964 | 1.139 | 18.09 | 1.213 |
| Short columns | 3.447 | 4.351 | 26.24 | 0.999 | 1.276 | 27.83 | 1.213 |
| Long columns | 3.258 | 3.630 | 11.39 | 0.947 | 1.070 | 12.95 | 1.213 |
| NSC | 2.211 | 3.010 | 36.09 | 0.994 | 1.354 | 36.20 | 2.374 |
| HSC | 4.064 | 5.022 | 23.56 | 1.001 | 1.238 | 23.67 | 0.633 |
| MSS | 3.051 | 3.498 | 14.639 | 0.993 | 1.151 | 15.94 | 0.936 |
| HSS | 3.861 | 4.615 | 19.518 | 0.908 | 1.115 | 22.79 | 1.768 |

## CONCLUSIONS

The present study is an attempt to compare between the prediction of AISC 360 – 16 and EC4 of composite columns, with the rapid growth of research and application of concrete-filled steel tube in the world, the circular concrete-filled steel tube column under axial loading is considered as a parametric study. On the basis of this study, the following conclusions can be drawn:

The variation of geometrical and material properties of specimens suggested covering the practical cases in this field.
These specimens were within and behind the limitations of the AISC 360 – 16 and EC4 codes.
The AISC 360 – 16 and EC4 codes depend on different functions to estimate the axial load capacity of CFST columns. Therefore, there is the difference in results between them.
The EC4 takes the confinement effect within its consideration that represents by the term $\left(1+\eta_c \frac{t}{D}\frac{f_y}{f_c}\right)$ as shown in equation 14, while for AISC 360 – 16 is constant as shown in equation 9.
The parameters of geometrical and material properties of specimens are the effect on the predictions of both codes with different percentages.
The analysis of variance showed that the D/t ratios and $f_c$ have the more effective parameters than others and the maximum interaction occurred for D/t ratio and $f_y$.
The CFST column of (D/t = 20, L/D = 3, $f_c$= 100 MPa, and $f_y$ = 600 MPa) gives the maximum axial capacity for AISC 360 – 16 and EC4 respectively by difference about 20.8% where the EC4 takes the confinement effect on its consideration.

While the CFST column of (D/t = 100, L/D = 9, $f_c$ = 20 MPa, and $f_y$ = 235 MPa) gives the minimum axial capacity for AISC 360 – 16 and EC4 respectively by difference about 8%.
The axial capacity increased when $f_c$ and $f_y$ increase, while decreased when D/t ratio and L/D ratio increase.
Strength index *SI* and confinement index $\xi$ are very useful measures for composite action and confinement assessments in CFST columns. *SI* for NSC and short column is greater than HSC and long column, while the HSS gives confinement index more than MSS.

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