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State of Art of The Behavior of Concrete Filled Steel Tube Columns

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ملخص البحث :

تعتبر الأعمدة المعدنية المملوءة بالخرسانة أحد الأنواع الشائعة للقطاعات المركبة المختلفة التى تتميز بالأستجابة الفعالة لمقاومة الأحمال الأستاتيكية والديناميكية حيث أنها تستخدم فى العديد من المنشأت المعرضة لأحمال عالية كالكبارى وكذلك ناطحات السحاب والأنفاق وغيرها ونتيجة لهذه لهذه الأحمال فإن الإنبعاج هو أحد العوامل المؤثرة فى سلوك هذه الأعمدة، لذلك هذه الدراسة تهتم بدراسة االسلوك الحسابى لانهيار الأعمدة الأنبوبية المعدنية المملوءة بالخرسانة فى العديد من الأبحاث السابقة من خلال تعرضها للتحميل المركزى، وتوضيح مدى تأثير القيم المختلفة للسمك والارتفاعات لمقاومة النسبة الكلية والجزئية للانحناء ، حيث أن من المتغيرات التى تطرق على هذه الأعمدة من العوامل المختلفة التى تساعد على تغيير خواص هذه الأعمدة اجهاد الحديد المستخدم، مقاومة الخرسانة، قطر العمود، سمك الأنبوب المعدنى المستخدم وكذلك حالة التحميل المعرضة لها هذه الأعمدة .

ABSTRACT:

The concrete filled steel tube columns (CFST) were used for over many decades as a composite structural element due to its numerous structural benefits, including high strength, high ductility, fire resistance and considerable energy absorption capacities. Nowadays, the composite structures are considered as an advantageous system for carrying loads in different structure buildings. so, several design methods and many studies have been developed for studying the behavior of CFST columns under different loads. However, CFST columns can afford large axial loads especially when used in tall buildings, but shorter CFST columns may collapse by crushing of the concrete core or by the effect of local buckling. the study will be developed some previous studies for studying the behavior of CFST columns considering the different ratios between length to columns dimension, different column cross section shape, different compressive strength of concrete to yield strength of steel tube ratio and different steel tube thickness under concentric loading.

Keywords: Columns, Tube, Core, Concrete, Steel.

Introduction:

Concrete filled steel tube columns have been widely used in the last few years due to its high strength and high ductility performance that can be achieved by composite action. some of the previous studies of the last investigations on the behavior of concrete filled steel tube columns experimentally and analytically, these studies were interested in some of the problems concerned of structure elements, and main findings followed by the conclusions and recommendations. At the end of this topic, the plan of the present study is clarified.

Concrete Filled Steel Tube Columns studies

In 1999, J. Brauns [1] carried out a study on the behavior of Circular concrete filled steel tube columns with longitudinal reinforcement for analyzing the stress state in case of composite action. Figure (1) showed the circular CFST column with longitudinal reinforcement. This study showed the effect of different geometric parameters on the analysis of reinforced CFST columns such as; dimeter of steel hollow section, steel tube thickness, reinforcement ratio of concrete section, longitudinal reinforcement area of cross section.

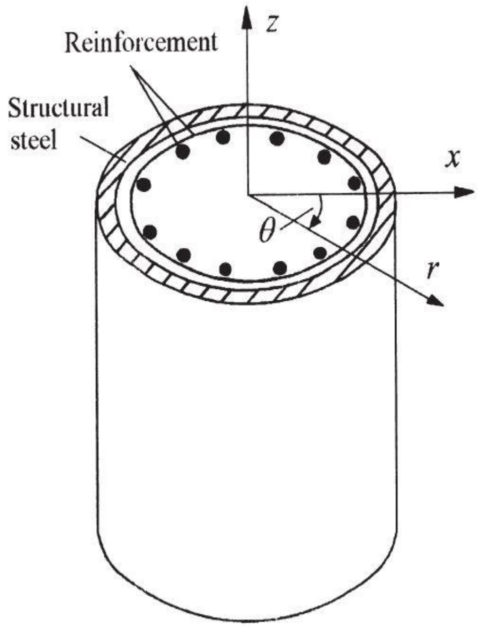

Figure (1) Circular CFST column with longitudinal reinforcement by **J. Brauns 1999.**

The stress state of CFST columns was determined considering the effect of modulus of elasticity and poisson’s ratio on the stress in the concrete. The study noticed that the effect of confinement occurred at high stress level when the steel acted in tension and the concrete acted in compression. It was concluded that in order to improve the composite action of CFST columns and to prevent the failure due to small thickness of steel tube, large eccentricities and fire, compatible strength of concrete core and steel should be used.

In 2002, B. Lakshmi and N. E. Shanmugam [2] prepared a semi-analytical method for studying the behavior of concrete filled steel tube columns subjected to uniaxial or biaxial loading. They used different cross section of CFST column, circular, rectangular, and square cross section. The study showed the comparison between the ultimate strength which calculated by the proposed method and with the experimental results of CFST columns that were tested by the other researchers. The study was found that the moment capacity of columns decreased when the applied axial load increased, and for the eccentrically loaded CFST columns the moment capacity was found to be dropped appreciably with the increase of the eccentricity. Finally, it was noticed that the proposed analytical method could expect the strength of concrete filled steel tube in an effective manner and accurately, and the method could, therefore, to be used for analysis of short CFST columns which loaded to uniaxial and biaxial loading.

In 2004, Kenji Sakicno et.al [3] carried out an experimental study on 114 specimens of concrete filled steel tube short columns for studying their behavior under concentric loading. Different cross sections were used with different parameters such as; steel yield strength, concrete core strength, ratio of cross section dimension to thickness. Figure (2) and Figure (3) showed the Specimens test setup and the size samples of CFST columns, respectively.

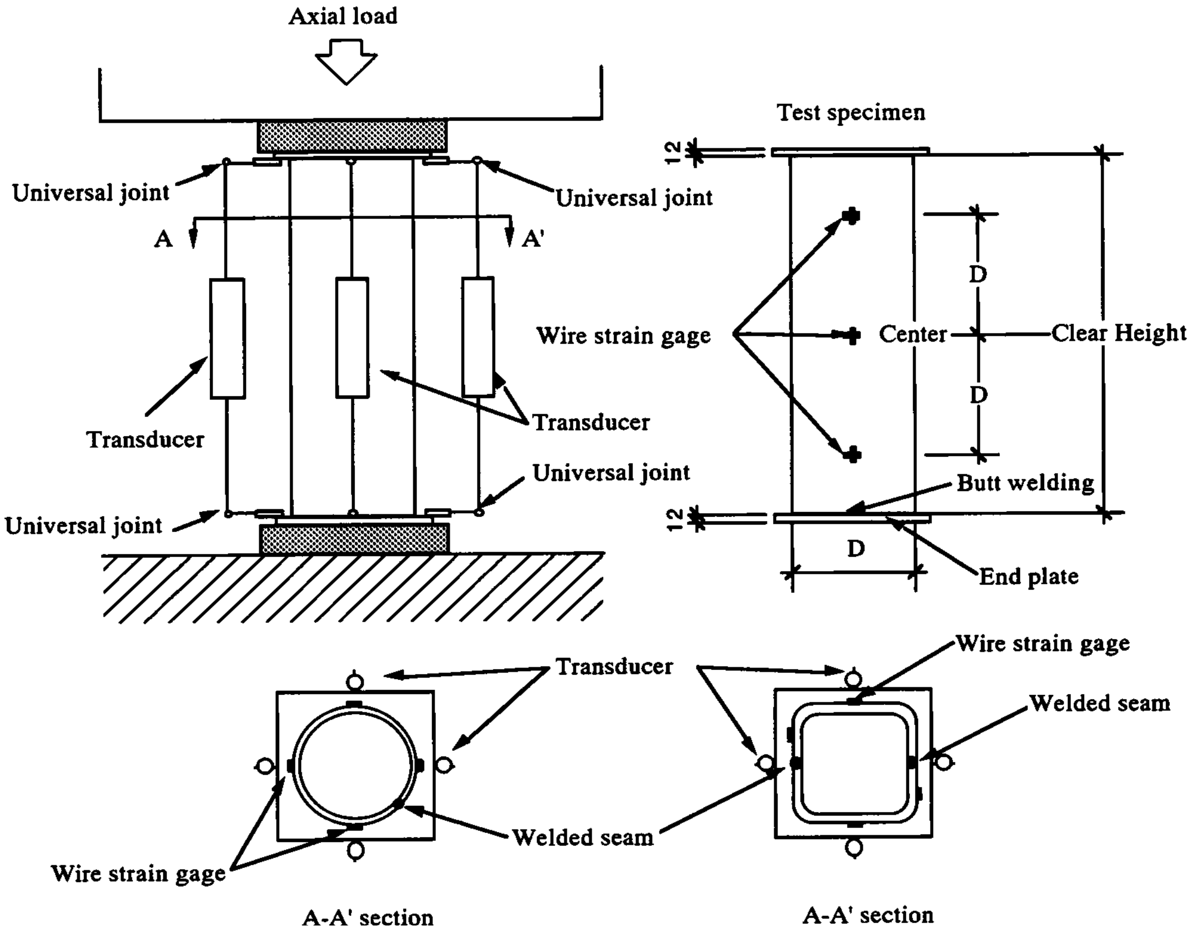

Figure (2) Specimen's test setup by **Kenji Sakicno et.al 2004.**

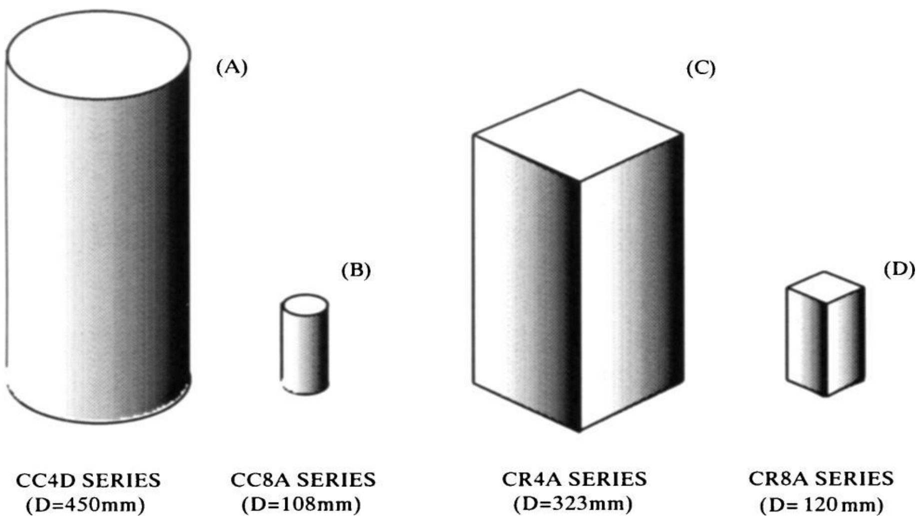

Figure (3) Size Samples of CFST columns by **Kenji Sakicno et.al 2004.**

They noticed from the experimental results that the difference between the axial load and the ultimate strength of CFST columns can be evaluated as a linear function of the steel tube yield strength. The reduction factor of the capacity which occurred by the local buckling of the square tube was empirically carried out depended on the experimental results of hollow square section of steel tube columns, and then this factor was modified to the square CFST columns by considering the confining effect of concrete core on the steel tube local buckling. Finally, the study formulated a stress-strain relation model for the square section of the steel tube.

In 2006, Muhammad Naseem Baig et.al [4] conducted an experimental study on the behavior of concrete filled steel tube short columns under axial load. The 28 specimens (16 were filled with concrete and 12 were retained hollow) were tested with different parameters such as; cross section, ratio of column length-to-diameter, ratio of dimeter-to-thickness, internal bracing of deformed bars. Figure (4) showed the geometry of braced and unbraced columns. They compared the test results with the theoretical results of previous studies.

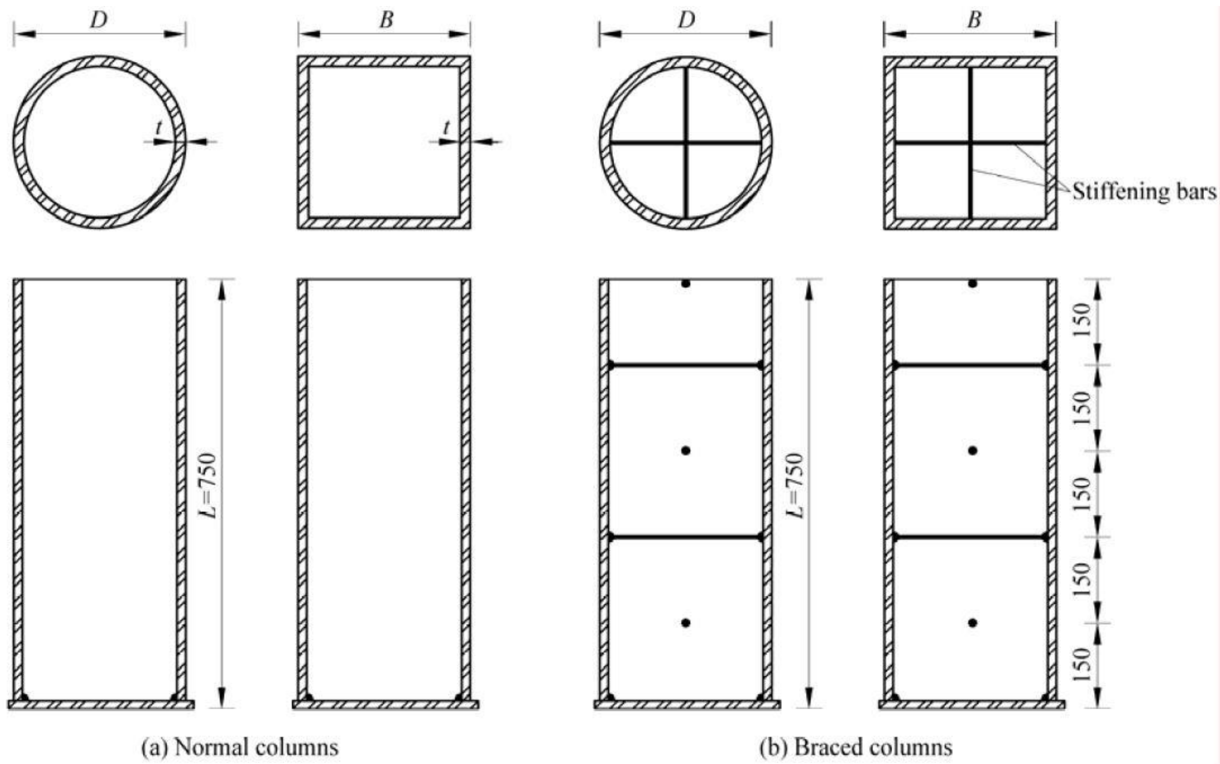

Figure (4) Geometry of braced and unbraced columns by **Muhammad Naseem Baig et.al 2006.**

The study showed that the circular columns strength increased more than in box square columns, and observed that the local buckling occurred in square columns both filled with concrete and hollow. Finally, the study recommended that experiments should be conducted on double skinned columns DCFST with different geometries.

In 2008, George D. Hatzigeorgiou [5] presented a numerical study for the behavior of circular CFST short columns and verified the results against an experimental result. Two new methods for calculating the load capacity of CFST columns were applied. The first one was by surveying the composite action especially for evaluating the bearing capacity load, while the second method was presented a modification of an existent building code recommendations such as; the polynomial expansion of the axial force- flexural moment interaction curve. The study proposed from the comparisons between the analytical method, experimental results, and codes that the proposed relations method could calculate the load capacity of CFST columns accurately and in a simple way.

In 2011, Fa- xing Ding et.al [6] carried out an elasto-plastic analysis on circular concrete filled steel tube stub columns under concentric loading by using continuum mechanics, and the analysis was performed by a FORTRAN program. They used different parametric analysis to examine the effects of material strength, ratio of steel section on the triaxial stress-strain development and the load pattern of circular CFST columns. The study showed that the ductility and the concrete core axial stress were increased due to the confining by steel tube, but the steel tube axial stress was decreased due to this confinement effect because the stresses transmitted from the steel tube to the concrete core. The slenderness ratio and the yield strength of steel tube could improve the confinement effect, ductility, and loading capacity of CFST columns, while with the increasing of the concrete strength, the ductility and confinement effect decreased, on the other hand the loading capacity increased. Finally, it was noticed that the elasto-plastic method developed a good prediction for the circular CFST stub column bearing capacity under concentric loading.

In 2016, A.L. Krishman et. al [7] carried out a theoretical study on concrete filled steel tube columns to improve their design efficiency. The study considered the CFST columns with precursory compressed concrete core to calculate the bearing capacity from the equation; R = Rb +α $\sqrt{\Delta_f \sigma_{br_0}}$, where α ≈ 1; coefficient attached on the synthesis of concrete mix, Δ_f= 0.44$\sqrt{R_b}$; correction factor which considered that the strength increased of the primary concrete and σ_{br_0} ; was the steel holder initial lateral pressure. They developed that the authoritative calculation restrained of CFST columns bearing capacity depended on the use of nonlinear deformation model. the triaxial stress- strain state and holder of steel tube were considered. Finally, they noticed that the calculations have been studied agreeable for traditional design and precursory transverse compressed CFST columns.

In 2017, Simon Schnabl and Igor Planinc [8] prepared a mathematical study and verified against an experimental data for studying the buckling of concrete filled steel tube columns and the compliant interface between the concrete and the steel tube was considered. Six circular CFST columns were studied and used to estimate the critical buckling loads. Figure (5) represented the material properties and cross section of CFST columns.

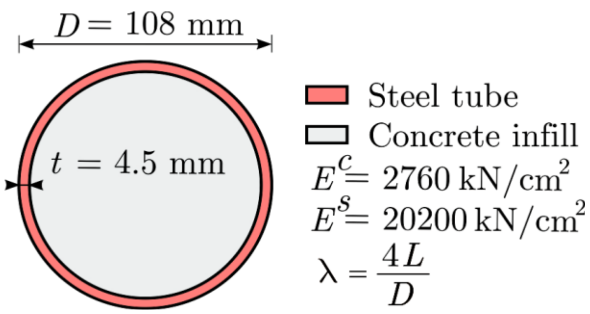

Figure (5) Material properties and cross section of CFST columns by **Simon Schnabl and Igor Planinc 2017.**

The study developed that the compliant interface was the exact solution for the buckling loads of CFST columns. They noticed that the critical buckling loads were decreased significantly when the finite compliant interface was found. Finally, the study showed that the loads of the critical buckling were also affected very much by the sort of boundary condition of CFST columns.

In 2017, Yahia R. Abbas [9] Verified against an experimental test using the software program ABAQUS to the circular CFST columns to study the failure loads. The specimens of CFST columns were meshed in an accurate method to obtain accurate results that can be computed in the lower possible time. As shown in Figure 2.19, the models were meshed by generating 24 elements along the outer circumferential, the concrete core was meshed in slices to restrain the non-uniform element shapes from running to obviate possible invalidity, and the cross section was having 144 elements, while the normal direction was having (6) times the number of elements in the lateral direction.

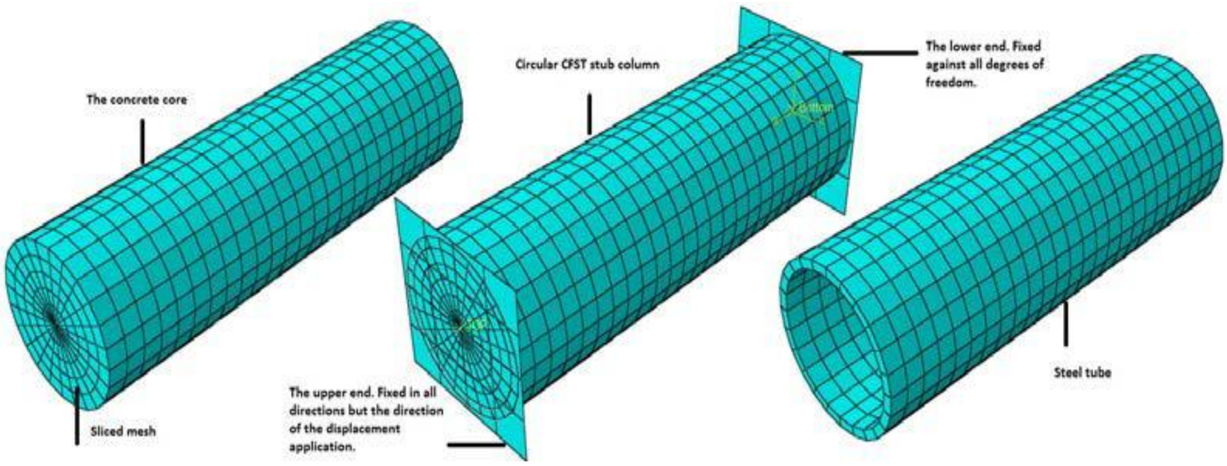

Figure (6) FE model of CFST columns by **Yahia R. Abbas 2017.**

He noticed by comparing the results of FE model that specimens reserved and obtained an accurate result with experimental tests, comparisons showed that the ultimate load obtained by the finite element analysis and the experimental study have been conducted in a good agreement.

In 2017, Dionisios N. Serras et.al [10] proposed a study for determining the response of circular concrete filled steel tube columns under monotonic loading. They created the columns by using three-dimensional nonlinear finite element models on ATENA analysis program see figure (7), and verified the results with the experimental tests which were available. They used 192 circular CFST specimens for studying the effect of the different parameters of columns to determine their response to monotonic lateral loads like the ratio of diameter to thickness, steel tube yield stress, concrete core compressive strength and levels of axial loads. The specimens were having concrete core strength ranged from 20 to 50 Mpa and the steel yield stress from 235 to 460 Mpa, they were subjected three different axial load levels 0, 20, 40 % of the capacity loads.

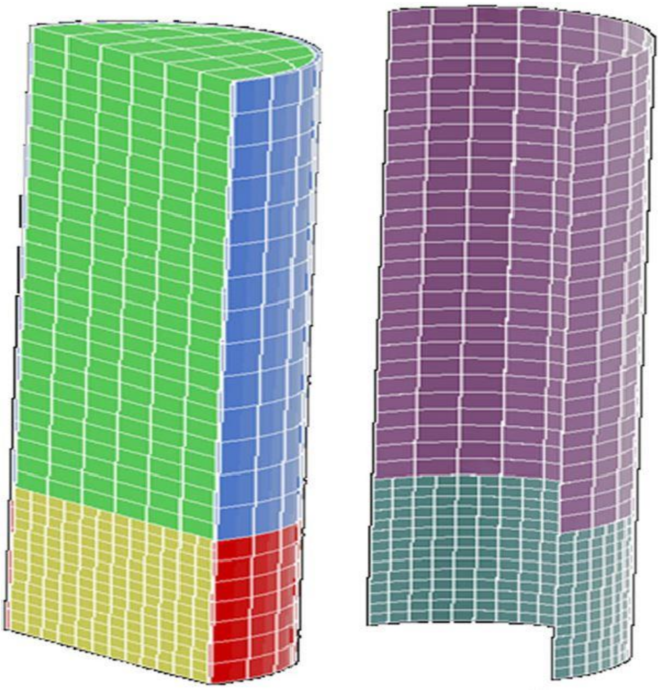

Figure (7) Concrete core and steel tube of CFST columns by **Dionisios N. Serras et.al 2017.**

The authors found by comparisons that the finite element analysis can be simulated effectively to the behavior of circular concrete filled steel tube columns which subjected to monotonic loading, and it was also shown that the empirical expressions can simulate the lateral force, lateral displacement in an effective manner. And finally depicted that the repayment of CFST columns to monotonic loading is various from their repayment to cyclic loading, so it was recommended the monotonic load method not the cyclic load method when a static inelastic analysis is required.

In 2018, Anatoly L. Krishan et.al [11] proposed a study to evaluate the strength resistance of short concrete filled steel tubular columns under central loading, concrete strength formulas have been reviewed to determine the lateral pressure and strength of columns, a theoretically study had been proposed to obtain the formulas and the calculations by using a computer program, the coefficient of error vector which estimated in this comparison has high accuracy. The formulas which have been verified were used to calculate the volumetrically loading of concrete strength, axial stress in steel, axial strain in concrete, steel holder confinement to the lateral pressure on the concrete, and the scale factor coefficient which used to determine the strength of centrally loaded columns according to geometry of CSTC and design parameters.

Conclusions:

The main conclusions of the study are presented as follow:

1- The use of large tube thickness of CFST columns improve the composite action to prevent the failure compared to the small thickness of the steel tube and have a large ultimate axial strength.
2- The reduction factor of the capacity of CFST columns which occurred by the local buckling of the square tube was empirically carried out depended on the experimental results of hollow square section of steel tube columns.
3- The circular CFST columns strength increased more than in box square columns, and observed that the local buckling occurred in square columns both filled with concrete and hollow.
4- The slenderness ratio and the yield strength of steel tube could improve the confinement effect, ductility, and loading capacity of CFST columns, while with the increasing of the concrete strength, the ductility and confinement effect decreased.
5- The finite element analysis can be simulated effectively to the behavior of circular concrete filled steel tube columns which subjected to axial Concentric loading.

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