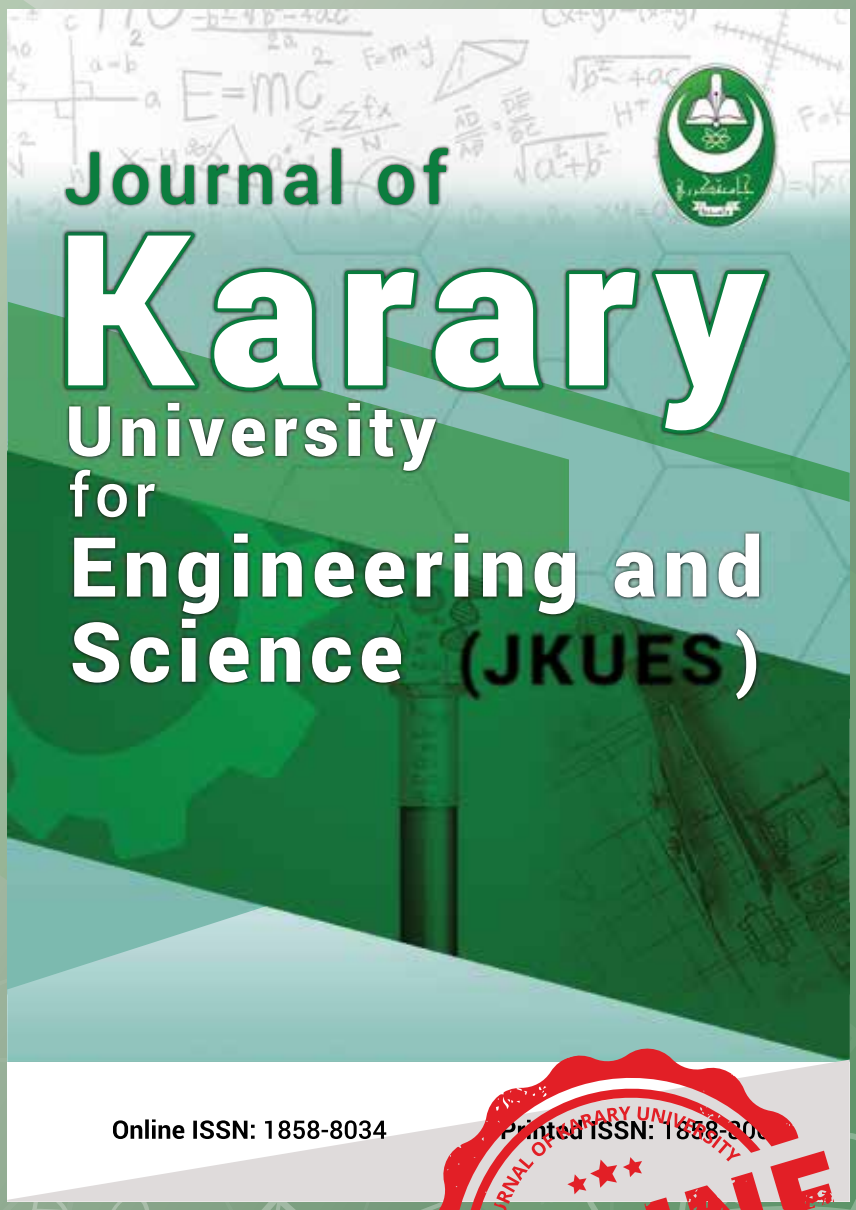
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Structural Behaviour of Concrete-Filled Steel Tubular Stub Columns-Comparative Study

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Abstract

This paper presented details of a research to investigate the structural behaviour of Concrete-Filled Steel Tubular (CFST) stub columns through axial load strength. Three series distinguished were chosen depending of the steel X-sectional area of the tubes for each series of different shape are compared: circular, rectangular and square steel sections considering the parameters of the different types of concrete infill, i.e. normal strength concrete (NSC) or high strength concrete (HSC). It is found from these comparisons that all the codes (Eurocode part 4 (EC4), AISC-360-10 and BS5400-5) predicted conservative column strengths compared to the test results and published theoretical method with an average ratio (0.75 for EC4,0.656 for AISC-360-10 and 0.6 for BS5400-5). the main advantages of the ABAQUS software program are it gave closer predictions to the published experimental study results with an average ratio 0.96, simplicity and the savings in test time. circular CFST stub columns strength was higher than square CFST stub columns when compare rectangular and square in same series the column have higher area of concrete have higher strength.

Key words-*CFST; stub columns; NSC; HSC*

I. Introduction

CFST columns are increasingly being used because of their many advantages, including high strength, speed of construction, light weight, stiffness, damping properties, and economy than conventional steel or concrete columns of the same size [1] . CFST columns consist of circular, square or rectangular hollow sections lled with concrete [2], [3]. Fig.1 show examples of typical CFST column sections.The primary aim of this paper was twofold rst, to provide pervious experimental test information for the calibration of different codes (Eurocode 4, AISC-360-10 and BS 5400-5) for CFST stub columns and secondly to assess the accuracy of modeled used ABAQUS software program.

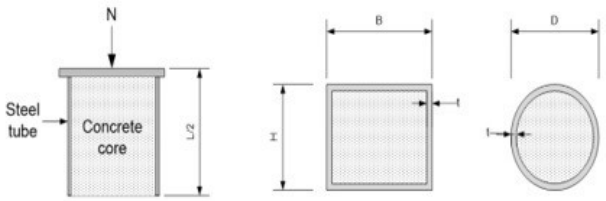


Fig. 1. Examples of typical CFST column sections [4].

Fig. 1 Examples of typical CFST column sections [4]. In 2020 , Ding et al [5] examined the behaviour of concrete-lled square double-skin steel tubular stub columns under axial loading presents a numerical, experimental, and theoretical study on the behaviour of concrete-lled square double-skin steel tubular (CFDST) stub columns under axial compressive loading. Firstly, three-dimensional solid model of CFDST stub columns was established by ABAQUS nite element software and veried through the existing experimental results. Then a full-scale model was established to investigate the inuence of various parameters on ultimate bearing capacity and internal and external compressive stress of concrete. By considering the connement coecient, the practical calculation formula for the bearing capacity of CFDST stub columns was proposed. Comparison of FE and experimental loadstrain curve is shown in Fig.2.

II. Aims and Objectives

The primary aim of this paper was twofold rst, to provide pervious experimental test information for the calibration of different codes (Eurocode 4, AISC-360-10 and BS 5400-5) for concrete-filled steel tubular stub columns and secondly to assess the accuracy of modeled used ABAQUS software program.

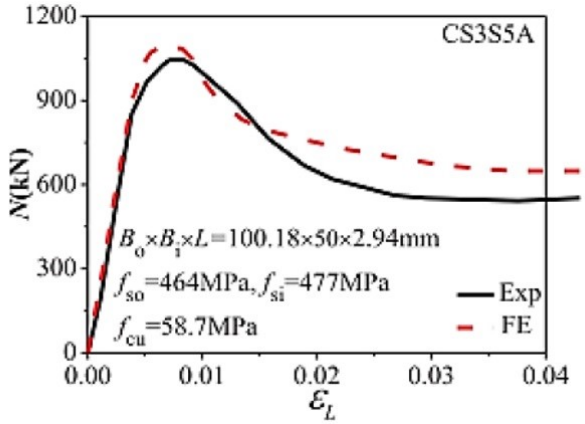


Fig. 2. Comparison of FE and experimental loadstrain curves [5].

The specific objectives of the paper are:

- To investigate and compare, through FE modeling by ABAQUS software, structural behavior of CFST stub columns.
- To examine the axial load carrying capacities of the different type of CFST stub columns.

TABLE I
COMPARISON RESULTS OF TEST PREDICTIONS WITH INDEXES STRENGTH [4].

series	Name	N_{tst} (kN)	N_{sr} (kN)	N_{sr}
1	C108,2-30	694.2	492.88	0.71
1	C101,6.2-30	582.7	396.23	0.68
2	C168,3.2,8-30	1282.5	1026	0.8
2	C168,3.2,8-90*	2375.7	2256.9	0.95
2	C159.3-30	1185.7	690.4	0.81
2	C159.3-90*	2021.7	2021.7	1
2	S125.125.3-30	824.5	824.5	1
3	S125.125.4-30	1159.2	938.9	0.81
3	R150.100.4-30	912	912	1
3	R150.100.4-90*	1188.5	1687.6	1.42
3	R200.120.3-30	1042	1187.8	1.14
3	R200.120.3-90*	2091.3	2509.5	1.2

N_{test} the ultimate strength from pub lished experimental tests
N_{SI} the ultimate strength from pub lished the oretical method
$N_{SI} = A_s * f_y + A_c * f_c$ [4]
high strength concrete -filled stee1tubular stub columns

- To correlate the FE models results with the pervious experimental results and the results obtained by codes of practice, and thoroughly investigate their complex structural behavior in terms of axial load capacity when use different type of concrete NSC and HSC.

In 2017, Hernandez et al. [4] investigated the Experimental study of cross-section shape and infill influence on CFST stub columns subjected to axial load. In this paper, the results of an experimental campaign on 12 concrete-filled steel tubular (CFST) stub columns subjected to concentric load are presented. Different shape of columns circular, rectangular and square with equivalent steel area has been considered. With respect to the materials properties, all the tubes were thin-walled, and two types of concrete strengths were involved in this study: NSC and HSC. Three aspects were analysed to draw conclusions about the most efficient combination of geometries: ultimate load, strength index. As regards to the shape effect, the configuration with circular steel tubes provides to be the most efficient, contrarily to the rectangular/square sections, which presents the poorest ultimate load and indexes values. Comparison results of test predictions with indexes strength is shown in TABLE I.

III. THEORETICAL AND MODELLING FRAME WORK

A. Design Codes of CFST

in this section, the following design guides will be reviewed:

1) BS EN 1994-1-1 Euro code 4 (CEN, 2005) [6]:

$$N_{(PL.Rd)} = A_a * F_{yd} + 0.85 * A_c * F_{cd} + A_s * F_{sd} \quad (1)$$

$N_{(PL.Rd)}$=Design value of the plastic resista nce of the composite section to compressive normal force

2) American Institute of Steel Construction (AISC) Specification (AISC, 2010) [7]:

$$P_{(no)} = F_y A_s + F_{(ysr)} A_{(ysr)} + 0.85 f_c A_c \quad (2)$$

3) BS 5400-Part 5: Code of practice for design of composite bridges [8]:

$$N_u = 0.91 * A_s * f_y + 0.45 * A_c * f_{(cc)} \quad (3)$$

TABLE II
SYMBOLS

Symbols	meaning
N_{plRd}	Desing value of the plasic resistance of the composite section to compressive normal force.
A_a	is the cross-sectional area of the structural steelsection
f_{yd}	is the design valu of the yield strength of the structural steel.
A_c	is the cross-see tional area of the concrete.
f_{ad}	is the design valu of the compressive cylinger strength of the concrete.
A_s	is the cross-see tional area of the reinforcement.
F_{sd}	designyield strength of reinforced steel.
P_{no}	Nominal compressve strength of zero length,doudly symm etric.
f_v	Nominal value of the yield strength of structural steel.
A_s	is the cross-see tional area of reinforcement.
F_{ysr}	specified minimum yield stress of reinforcing bars
f_c	specifiedcompressive strength of concrete.
Nu	Squash load of acolumn
f_v	is the nominal yield strength of structural steel
f_{cc}	is an enhanced charac teristic strength of triaxixally contained .
A_{ysr}	is the Cross-sectional area ofreinforcing bars.

B. Modelling Using ABAQUS Program

In recent few decades, finite element (FE) technique is becoming increasingly popular for modelling CFST columns thanks to the existence of many commercially available software, such as ABAQUS, ANSYS and many commercial nite element analysis programs are available. The general-purpose finite element program ABAQUS CAE 2019 was used in the present study to build a FE model for CFST stub columns. Abaqus is discussed in this section, it is obvious that material nonlinearity is dened at the stage of dening material properties and force nonlinearity at load conditions. Kinematic nonlinearity, such as contact conditions, is dened at the stage of dening displacement boundary conditions [9], [10], [11]. Surface-to-surface contact is usually used for the interaction simulation of the steel tube and concrete. A contact surface pair comprised of the inner surface of the steel tube and the outer surface of concrete core can be defined. Hard contact in the normal direction can be specified for the interface, which allows the separation of the interface in tension and no penetration of that in compression. The tangent contact can be simulated by the Coulomb friction model. For CFST stub columns, there is little or no slip between the steel tube and concrete since they are loaded simultaneously. For this reason, the columns behaviour is not sensitive to the selection of friction coefficient between steel and concrete [12]. Friction coefficients of 0.25, 0.3 and 0.6 were used by researcher Schneider [13], Lam et al. [12] and Han et al. [14], respectively.

To capture the failure point in the column using ABAQUS software the loads and parameters you need to determine in

TABLE III
COLUMNS STRENGTH FROM PREDICTED DESIGN CODE AND ABAQUS.

seriea	Name	N (kN)	N (kN)	N (kN)	N (kN)
1	C108.2-30	453.05	339.78	329.83	650
1	C101,6.2-30	362.93	272.19	257.66	550
2	C186,3.2.8-30	933.03	699.77	645.04	1280
2	C186,3.2.8-90*	1398.34	1495.01	1206.38	2350
2	C159.3-30	873.1	654.83	616.07	11000
2	C159.3-90*	1286.74	1358.05	1112.48	2000
2	S125.125.3-30	68.82	572.78	557.54	800
3	S125.125.4-30	806.18	661.1	669.29	1000
3	R150.100.4-30	793.68	649.13	660.85	850
3	R150.100.4-90*	1159.47	1148.85	1013.57	1150
3	R200.120.3-30	960.93	811.92	770.51	1040
3	R200.120.3-90*	1580.12	1657.78	1367.59	2090

module Step and Field Output should be defined and then after successful run of the model the curve of load failure in Job module should be drew.

when the model run successfully go to Result then from the left part of ABAQUS screen find XY data, chose (stress strain load)

after that the loads could be drawn specially the failure load because after failure load no more load affect in the model or from other accept after that the load finished and cut in your model. see Fig.3.

IV. RESULTS

Published experimental results strengths and published theoretical method strengths [4] were compared with the predicted columns, strengths using the design codes (Eurocode part4, AISC-360-10 and BS5400-5) and the numerical results were obtained from 3D nonlinear finite element analysis using ABAQUS finite element program. See Fig.3 samples of results of CFST stub columns using ABAQUS. Table II shows Columns Strength from predicted Design Code and ABAQUS. Table III shows Comparison of the Columns, Strengths ratio between Published Experimental Results with Design Codes and Abaqus Software.

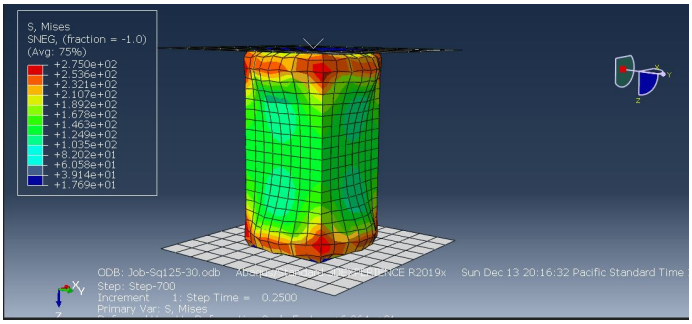


Fig. 3. Samples of results of CFST stub columns

V. DISCUSSION

The strength of concrete-filled steel tubular stub columns through axial load for the same steel area of the steel and different cross-section shape depending on area of concrete filled sections when area of concrete is large the strength of the section was increased, circular concrete-filled steel tubular stub columns strength were higher than square concrete-filled steel tubular stub columns in series 2 and square concrete-filled steel tubular stub column (S125.125.4-30) with area of concrete 13689 was higher than rectangular concrete-filled steel tubular stub column (R150.100.4-30) with area of concrete 13064 and less than (R200.120.4-30) with area of concrete 14161 in series 3. In general compression between pervious experimental study and predicted design codes found that predicted design codes are more conservative with an average ratio (0.75for EC4,0.656 for AISC-360-10 and 0.6 for BS5400-5). The average from ABAQUS software program is equal the average from published theoretical method but the standard division from ABAQUS software program is the lower than the standard division from published theoretical method. The values of columns strength ratio using ABAQUS software in TableIII, found that it is closer than predicted Design Code with average ratio 96% which is closer predictions to the published experimental study results than design codes.

TABLE IV
COMPARISON OF THE COLUMNS, STRENGTHS BETWEEN PUBLISHED EXPERIMENTAL RESULTS WITH DESIGN CODES AND ABAQUS SOFTWARE

Series	Name	$\frac{N_{TH}}{N_{exp}}$	$\frac{N_{EU}}{N_{exp}}$	$\frac{N_{AISC}}{N_{exp}}$	$\frac{N_{Rs5400}}{N_{exp}}$	$\frac{N_{Abq}}{N_{exp}}$
1	C108.2-30	0.71	0.65	0.49	0.48	0.93
1	C101.6.2-30	0.68	0.62	0.47	0.44	0.94
2	C168,3.2.8-30	0.8	0.73	0.55	0.5	0.99
2	C168,3.2.8-90*	0.95	0.59	0.63	0.51	0.98
2	C159.3-30	0.81	0.74	0.55	0.52	0.92
2	C159.3-90*	1	0.64	0.67	0.55	0.98
2	S125.125.3-30	1	0.83	0.69	0.67	0.97
3	S125.125.4-30	0.81	0.7	0.57	0.58	0.96
3	R150.100.4-30	1	0.87	0.71	0.72	0.93
3	R150.100.4-90*	1.42	0.98	0.97	0.85	0.96
3	R200.120.3-30	1.14	0.92	0.78	74	0.99
3	R200.120.3-90*	1.2	0.76	0.79	0.65	0.99
Avc. For columns		0.96	0.75	0.656	0.6	0.96
Standard Division		0.22	0.124	0.144	0.126	0.041

VI. CONCLUSIONS

This paper presenting details of research project to investigate the structural behaviour of concrete-filled steel tubular stub columns through axial load strength, The main findings of the comparison are as follows:

- All the codes (Eurocode part 4, AISC-360-10 and BS5400-5) predicted conservative column strengths compared to the test results and published theoretical methods.
- ABAQUS Software Program simplicity and the savings in test time.
- The strength of CFST stub columns through axial load for the same steel area of the steel and different cross-section shape depending on area of concrete filled sections when area of concrete is large the strength of the section was increased.

For the future study we recommended that the study of the structural behavior of concrete-filled steel tubular for short columns and slender columns. The study of the structural behaviors using previous experimental work, codes ABAQUS software program with reinforcement-stiffened concrete-filled steel tubular columns. The study of the structural behavior of concrete-filled steel tubular for short columns and slender columns using different type of X-Section (L-shaped cross-sections, T-shaped cross-sections, and +-shaped cross-sections).

REFERENCES

[1] D. Sousa, Jr, J. Batista, and R. B. Caldas, "Numerical analysis of composite steel-concrete columns of arbitrary cross section," *Journal of Structural Engineering*, vol. 131, no. 11, p. 17211730.

[2] W. Zhang and B. M. Shahrooz, "Comparison between aci and aisc for concrete-filled tubular columns," *Journal of structural engineering*, vol. 125, no. 11, p. 12131223.

[3] M. E. M. Kambal, M. Awad, and M. M. Ali, "Nonlinear finite element modelling and parametric study of prestressed steel box girder," *Journal of Karary University for Engineering and Science*, 2021.

[4] D. HernndezFigueirido, "08.47: Experimental study of crosssection shape and infill influence on cfst stub columns subjected to axial load," *ce/papers*, p. 1 23.

[5] F.-x. Ding, W.-j. Wang, D.-r. Lu, and X.-m. Liu, "Study on the behavior of concrete-filled square double-skin steel tubular stub columns under axial loading," in *Structures*, vol. 23, pp. 665–676, Elsevier, 2020.

[6] E. C. Standardization, "Design of composite steel and concrete structures. part 1-1: General rules and rules for buildings," *Eurocode*, vol. 4.

[7] A. Committee, *Specification for structural steel buildings (ANSI/AISC 360-10*. American Institute of Steel Construction, Chicago-Illinois.

[8] A. No, "Steel, concrete and composite bridges," 2004.

[9] Z. Tao, Z.-B. Wang, and Q. Yu, "Finite element modelling of concrete-filled steel stub columns under axial compression," *Journal of constructional steel research*, vol. 89, pp. 121–131, 2013.

[10] M. E. M. Kambal and Y. Jia, "Theoretical and experimental study on flexural behavior of prestressed steel plate girders," *Journal of constructional steel research*, vol. 142, pp. 5–16, 2018.

[11] M. Attaelmanan, M. E. M. Kambal, and M. I. Mansour, "A study the effect of using ceramic waste powder as partial replacement for cement on concrete properties," *Journal of Karary University for Engineering and Science*, 2021.

[12] D. Lam, X. Dai, L. Han, Q. Ren, and W. Li, "Behaviour of inclined, tapered and sts square cfst stub columns subjected to axial load," *Thin-Walled Structures*, vol. 54, pp. 94–105, 2012.

[13] D. Lam, X. Dai, L. Han, Q. Ren, and W. Li, "Behaviour of inclined, tapered and sts square cfst stub columns subjected to axial load," *Thin-Walled Structures*, vol. 54, pp. 94–105, 2012.

[14] L.-H. Han, G.-H. Yao, and Z. Tao, "Performance of concrete-filled thin-walled steel tubes under pure torsion," *Thin-Walled Structures*, vol. 45, no. 1, pp. 24–36, 2007.



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