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Mahjoob Osman
Mohammed Awad
Mahgoub Elhaj
Ibrahim Gamaleldain

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

Mahjoob Osman*, Mohammed Awad*, Mahgoub Elhaj Mahgoub Kambal*, Ibrahim Gamaleldain*
*Department of Civil Engineering, Engineering College, Karary University, Khartoum, Sudan
Email: ibrahimgamalb@gmail.com

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 filled with concrete [2], [3]. Fig.1 show examples of typical CFST column sections.

The primary aim of this paper was twofold rst, to provide previous 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-filled square double-skin steel tubular stub columns under axial loading presents a numerical, experimental, and theoretical study on the behaviour of concrete-filled 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 finite element software and verified through the existing experimental results. Then a full-scale model was established to investigate the influence of various parameters on ultimate bearing capacity and internal and external compressive stress of concrete. By considering the confinement coefficient, 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.
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 FRAMEWORK

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]:

\[ N_{pl,Rd} = A_n \cdot F_{yd} + 0.85 \cdot A_c \cdot F_{cd} + A_s \cdot F_{sd} \]  

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

\[ P_{(n0)} = F_y A_s + F_{(ysr)} A_{(ysr)} + 0.85f_c A_c \]  

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

\[ N_u = 0.91 \cdot A_s \cdot f_y + 0.45 \cdot A_c \cdot f_{(cc)} \]  

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 finite 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 as contact condition, 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
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 part 4, 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.

<table>
<thead>
<tr>
<th>Series</th>
<th>Name</th>
<th>N_{exp} (kN)</th>
<th>N_{predicted} (kN)</th>
<th>N_{AISC} (kN)</th>
<th>N_{BS5400} (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C108.2-30</td>
<td>453.05</td>
<td>339.78</td>
<td>329.83</td>
<td>650</td>
</tr>
<tr>
<td>1</td>
<td>C101.6-2-30</td>
<td>362.93</td>
<td>272.19</td>
<td>257.66</td>
<td>550</td>
</tr>
<tr>
<td>2</td>
<td>C186.3.2-8-30</td>
<td>933.03</td>
<td>699.77</td>
<td>645.94</td>
<td>1280</td>
</tr>
<tr>
<td>2</td>
<td>C186.3.2-8-90*</td>
<td>1398.34</td>
<td>1495.01</td>
<td>1206.38</td>
<td>2350</td>
</tr>
<tr>
<td>2</td>
<td>C159.3-30</td>
<td>873.1</td>
<td>654.83</td>
<td>616.07</td>
<td>11000</td>
</tr>
<tr>
<td>2</td>
<td>C159.3-90*</td>
<td>1286.74</td>
<td>1358.05</td>
<td>1112.48</td>
<td>2000</td>
</tr>
<tr>
<td>2</td>
<td>S125.125.3-30</td>
<td>68.82</td>
<td>572.78</td>
<td>557.54</td>
<td>800</td>
</tr>
<tr>
<td>2</td>
<td>S125.125.4-30</td>
<td>806.18</td>
<td>661.1</td>
<td>669.29</td>
<td>1000</td>
</tr>
<tr>
<td>3</td>
<td>R150.100.4-30</td>
<td>793.68</td>
<td>649.13</td>
<td>660.85</td>
<td>850</td>
</tr>
<tr>
<td>3</td>
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<td>1159.47</td>
<td>1148.85</td>
<td>1013.57</td>
<td>1150</td>
</tr>
<tr>
<td>3</td>
<td>R200.120.3-30</td>
<td>960.93</td>
<td>811.92</td>
<td>770.51</td>
<td>1040</td>
</tr>
<tr>
<td>3</td>
<td>R200.120.3-90*</td>
<td>1580.12</td>
<td>1657.78</td>
<td>1367.59</td>
<td>2090</td>
</tr>
</tbody>
</table>

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 1306413689 was higher than rectangular concrete-filled steel tubular stub column (S125.125.4-30) with area of concrete 13689.

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


Mahjoob Osman is an associate professor of structural engineering in Civil Engineering Department, Faculty of Engineering, Khartoum University, Khartoum, Sudan.

Mohammed Awad is an assistant professor of structural engineering in Civil Engineering Department, Faculty of Engineering, Karary University, Khartoum, Sudan. He received his B.Sc. and M.Sc. degrees in structural engineering from Karary University and his Ph.D. degree in Steel Structural from Northeast Forestry University, Harbin, China. His current research interests include design of concrete, steel and masonry structures, design of bridges, and computer aided analysis and design.

Mahgoub Elhaj Mahgoub Kambal is an assistant professor of structural engineering in Civil Engineering Department, Faculty of Engineering, Karary University, Khartoum, Sudan. He received his B.Sc. and M.Sc. degrees in structural engineering from Karary University and his Ph.D. degree in Steel Structural from Northeast Forestry University, Harbin, China. His current research interests include design of concrete, steel and masonry structures, and computer aided analysis and design.

Ibrahim Gamaleldain is an assistant professor of structural engineering in Civil Engineering Department, Al-Nasr Technical College, Khartoum, Sudan. He received his B.Sc., M.Sc. and Ph.D. degrees in structural engineering from Karary University. His current research interests include design of concrete, steel, and computer aided analysis and design.

Ibrahim Gamaleldain is an assistant professor of structural engineering in Civil Engineering Department, Al-Nasr Technical College, Khartoum, Sudan. He received his B.Sc., M.Sc. and Ph.D. degrees in structural engineering from Karary University. His current research interests include design of concrete, steel, and computer aided analysis and design.