# STUDY ON UNIFIED BEARING CAPACITY OF RECTANGULAR CONCRETE-FILLED STEEL TUBULAR COLUMN SUBJECTED TO AXIAL COMPRESSION

Feng Yu[1,*], Shuanhai He[2] and Ditao Niu[3]

[1]*Associate professor, School of Civil Engineering, Anhui University of Technology, China*
[2]*Institute of highway, Chang'an University, China*
[3]*College of Civil Engineering, Xi'an University of Architecture and Technology, China*
**(Corresponding author: E-mail: yufeng2007@126.com)*

*Received: 11 July 2011; Revised: 26 August 2011; Accepted: 23 September 2011*

**ABSTRACT:** This paper summarizes the calculating methods of the bearing capacity of rectangular concrete-filled steel tubular columns(CFT) subjected to axial compression, and then points out the deficiency of the existing calculation methods of the bearing capacity. Based on the analysis of the experimental data, the concept of the effective confinement of rectangular CFT columns are introduced. The effects of the cross-sectional aspect ratios, the strength of in-filled concrete, the thickness of steel tube, the equivalent confining coefficient and the longitudinal stiffener on the bearing capacity are carefully considered, and the unified model of the bearing capacity of rectangular CFT columns are presented. The model may be applicable to calculate the bearing capacity of the normal strength concrete filled steel tubular column, the high-strength concrete-filled steel tubular column, the concrete filled thin-walled steel tubular column and concrete-filled stiffened thin-walled steel tubular column. The predictions of the model agree well with large experimental results. Comparisons are also made with predicted column bearing capacity using the existing design codes.

**Keywords:** Concrete-filled steel tube, Bearing capacity, Effective confinement, Short column, Axial compression

## 1. INTRODUCTION

Concrete-filled steel tube is a new structure, which has developed on the basis of steel reinforced concrete structure and spiral hoop reinforced concrete structure. The earliest concrete filled steel tube structure was used as the pier of English Severn railway bridge built in 1879, at that time, the purpose of pouring concrete into the tube is to prevent the errosion of steel tube and carry axial compression. Subsequently, due to the high axial load capacity, good ductility, large engergy absorption of concrete filled steel tubes, it has been widely used in structural columns of multi-storey and tall buildings, bridges, barriers and so on(ACI318[1], CECS28:90[2], EC4[3], DL/T5085-1999[4]). The increment in structural properties of CFT columns is mainly determined by the composite action between the steel tube and core concrete. The core concrete confined by steel tube behaves in a triaxial stress state and also prevents the wall of steel tube from inward buckling.

According to the cross-sectional shapes, concrete filled steel tubular column may be divided into circular and rectangular CFT column. The behavior of rectangular CFT column differ from that of its circular counterpart, this is mainly because that the confinement action of circular steel tube to concrete is greater than its rectangular counterpart, and that the local buckling is more likely to occur for rectangular CFT column. Therefore, circular CFT columns have been widely used in civil engineering (Han[5], Zhong[6]). While rectangular CFT columns are not widely used, the main reason is that the study on the mechanical behavior of rectangular CFT is not systematic and perfect, and the related unified design codes are also lack for different kinds of rectangular CFT columns.

The determination of the bearing capacity is the key to study the performance of rectangular CFT columns. Scholars have done a lot of experimental study and theoretical analysis on the bearing capacity of rectangular CFT column, the plentiful and substantial achievements have been obtained, and the related design specifications and technical regulations are also established. But great difference also exists in the design specifications and technical regulations of different countries(ACI318[1], EC4[3], ASCCS[7], AIJ[8]), and even if the different standards in the same country such as China (DL/T5085-1999[4], JCJ01-89[9], CECS159-2004[10], GJB4142-2000[11], DBJ13-51-2003[12]). The existing calculating models have higher calculating precision only for rectangular CFT columns with normal concrete strength, but it will produce great errors by using the existing models to predict the bearing capacity of other types rectangular CFT columns such as high-strength concrete-filled steel tubular column, concrete filled thin-walled steel tubular column and concrete-filled stiffened thin-walled steel tubular column. Based on the analysis of many experimental data, this paper presents a unified bearing capacity for different types of rectangular CFT columns. The effects of the cross-sectional aspect ratios, the strength of in-filled concrete, the thickness of steel tube, the equivalent confinement coefficient and the longitudinal stiffener on the bearing capacity are carefully considered. The predictions of the proposed model agree well with large experimental data.

## 2. LITERATURE REVIEW

Many studies have been carried out to investigate the behavior of rectangular CFT columns subjected to axial compression, it is well known that the bearing capacity and ductility can be certainly increased by the confinement of rectangular steel tube, The earliest study on the bearing capacity of rectangular CFT columns were widely carried out(Han[5], Zhong[6], Furlon[13], Yu and Niu[14], Uy.[15], Cai[16]), the calculating models of the bearing capacity of CFT columns mainly include the following types:

EC4[3] is the most recently completed international standard in composite construction. EC4 covers concrete-filled and partially filled steel tubes and concrete-filled steel tube with or without reinforcement. EC4 considers the confinement effects for circular sections when relative slenderness has value less than 0.5. EC4 uses the limit state concepts to acquire the aim of serviceability and safety by applying partial safety factors to load and material properties. It is the only code that treats the effects of long-term loading separately. Based on the superposition method of steel tube and core concrete, the ultimate axial bearing capacity of a rectangular column is that

$$N = A_s f_y + A_c f_{co}^{'} \tag{1}$$

Where, $A_s$ is the section area of steel tube, $f_y$ is the tensile yield strength of steel tube, $A_c$ is the section area of core concrete, $f_{co}^{'}$ is the compressive strength of unconfined concrete column.

The ACI and Australian Standards (AS) use the same equation for calculating the bearing capacity. The confinement of steel tube to concrete are not well considered in both codes. The limiting thickness of steel tube to prevent local buckling is almost the same for both codes and is calculated in succeeding paragraphs. The equation of the bearing capacity is given by

$$N = A_s f_y + 0.85 A_c f_{co}^{'} \tag{2}$$

Han[5] considered the effect of rectangular steel tube on the bearing capacity, taking the confinement effect coefficient as main parameter, the bearing capacity is determined by

$$N = f_{sc} A_{sc} \tag{3}$$

Where, $A_{sc}$ is the section area of CFT columns, $f_{sc}$ is the compound strength of CFT columns subjected to axial compression, whose expression is that

$$f_{sc} = \left(1.212 + B\xi + C\xi^2\right) f_{co}^{'} \tag{4}$$

Where, $B = 0.138 f_y / 215 + 0.765$ , $C = -0.072 f_c / 15 + 0.0216$ , $\xi$ is the confinement effect coefficient，the expression is that

$$\xi = \frac{A_s f_y}{A_c f_{co}^{'}} \tag{5}$$

Also, the section should follow these limits: side/edge of steel columns should be greater than or equal to 20mm and thickness of the steel should be greater than or equal to 4mm.

In the code of AISC[17], the equivalent substitution principle is adopted, which converts the concrete strength to steel strength, the equation of concrete filled rectangular steel tube is that

$$N = A_s F_{cr} \tag{6}$$

Where, $A_s$ is the section area of the steel tube, the expression of $F_{cr}$ is that

$$F_{cr} = \begin{cases} \left(0.658^{\lambda_c^2}\right) F_{my} & \lambda_c \le 1.5 \\ \left(0.877/\lambda_c^2\right) F_{my} & \lambda_c > 1.5 \end{cases} \tag{7}$$

Where, $F_{my} = f_y + 0.85 f_{co}^{'} \left(A_c / A_s\right)$, $\lambda_c = \frac{\sqrt{F_{my} / E_s}}{i_s \pi}$, $E_s$ is the elastic modulus of steel tube, $i_s$ is the radius of gyration of steel tube.

Considering the effect of concrete strength, Yu[18] proposed the bearing capacity of concrete filled square steel tube is that

$$N = A_s f_y + A_c f_c (1 + \phi) \tag{8}$$

Where, $\phi$ is the coefficient of concrete strength, the expression is that

$$\phi = 17 (D / t)^{-2} \left(f_y / f_c\right) \tag{9}$$

Where, $D$ is the length of square steel tube, $t$ is the thickness of steel tube.

Based on the analysis of research results, we can conclude that some deficiency also exists in the calculating methods of the bearing capacity of rectangular CFT columns.

The existing models of the bearing capacity have higher calculating precision only for the limited experimental data, but for large experimental data, the calculating models have the bigger errors among different countries specifications, so the calculating accuracy of the existing models need to be further improved.

Scholars have studied the effect of length to width ratio of rectangular steel tube on the bearing capacity, but these studies have been limited to experimental research. The approximate law that the bearing capacity changes with the length to width ratio of rectangular steel tube can be obtained by experimental study, but the numerical and theoretical relations between the length to width ratio and the bearing capacity are not proposed.

The existing study mainly concerned on plain rectangular CFT columns, but for high strength rectangular CFT columns, the study is not only few, but also lack of systematic analysis. Meanwhile, the confinement effect of rectangular steel tube to concrete is also affected by the concrete strength, how to reflect the effect of concrete strength on the calculating models of the bearing capacity is urgent to be solved.

The bearing capacity of plain concrete filled steel tube is different from that of thin-walled concrete filled steel tube, the effect of the thickness of thin-walled steel tube, and the longitudinal stiffened rib on the bearing capacity are not reflected in existing calculation methods.

The behavior of rectangular CFT columns differs from that of circular CFT columns owing to the confinement of core concrete provided by steel tube. It is shown that the confinement of rectangular CFT columns is not as good as its circular counterpart. This is due to the fact that the confinement of rectangular steel tube to concrete may be divided into the effective and non-effective confining zone. In existing calculating methods of the bearing capacity, the influence of the effective confining zone on the bearing capacity of rectangular CFT columns is not reflected.

## 3. THE PROPOSED UNIFIED MODELS OF THE BEARING CAPACITY

### 3.1 The Confining Action of Rectangular Steel Tube to Concrete

The confining action of rectangular CFT columns are much less than that of circular CFT columns. This is mainly because that the confining action of rectangular steel tube to concrete is uneven, and the local buckling is more likely to occur due to the stress concentration in the corner of rectangular steel tube. In addition, the effective confinement can not be fully provided in the middle of section side of rectangular CFT columns. It is considered that the confining stress of steel tube is applied to concrete by arch action, and the arch action occurs within the section of rectangular CFT columns, whose shape is quadratic parabola. The confining action of rectangular steel tube to concrete is shown in Fig.1, from the figure, we can conclude that the non-effective confining area is maximum at the top of arch, and the effective confining area is minimum at the same time. According to the analysis of large experimental data, this paper believes that the quadratic parabola of initial angle is about 10°. The effective confining area of core concrete by rectangular steel tube is that

$$A_e = A - A_u \tag{9}$$

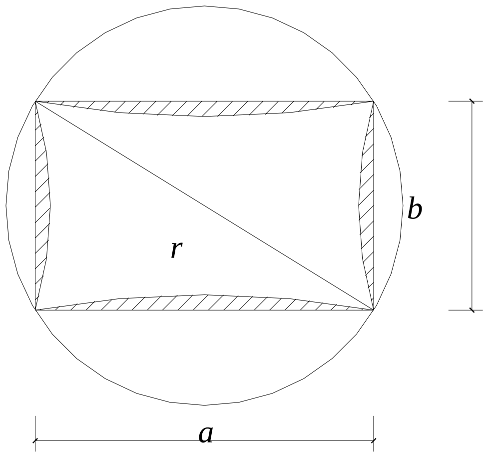


Figure 1. The Confining Action of Rectangular Steel Tube to Concrete

Where, $A_e$ is the effective confining area, $A$ is the area of rectangular CFT columns, $A_u$ is the non-effective confining area, whose expression is that

$$A_u = \frac{a^2 + b^2}{12ab} \tag{10}$$

This paper defines the coefficient of the effective confining area of rectangular CFT columns $k_s$ is that

$$k_s = \frac{A_e}{A} \tag{11}$$

Substituting Eq. 9 into Eq. 11, We can conclude that

$$k_s = 1 - \frac{a^2 + b^2}{12ab} \tag{12}$$

### 3.2 The Proposed Model of the Bearing Capacity

Based on the proposed calculating equation of the bearing capacity of circular CFT columns (Cai[16]), the effects of the section shape, the strength of in-filled concrete, the thickness of steel tube, the equivalent confinement effect coefficient and the longitudinal stiffener on the bearing capacity of rectangular CFT columns are well considered. According to the analysis of large experimental data, this paper presents a unfied calculating model for the bearing capacity of rectangular CFT columns. The expression of $N$ is that

$$N = k_s k_e N_c + A_{ss} f_{ss} \tag{13}$$

Where, $k_e$ is the area ratio of rectangular CFT to the circumcircle (shown in Figure 1), whose expression can be shown by Eq. 14; $A_{ss}$ and $f_{ss}$ are respectively the section area and yield strength of longitudinal stiffener; $N_c$ is the bearing capacity of the corresponding circular CFT columns, whose diameter is the circumcircle of rectangular CFT columns. The expression of $N_c$ can be shown by Eq. 15.

$$k_e = \frac{4ab}{\pi(a^2 + b^2)} \tag{14}$$

$$N_c = A_{ec} f_{co}^{'} \left(1 + k\xi_e\right) \tag{15}$$

Where, $A_{ec}$ is the circumcircle area of rectangular CFT columns, the expression is given by Eq.16. $f_{co}^{'}$ is the axial compressive strength of unconfined concrete, the conversion relation between $f_{co}^{'}$ and the cubic compressive strength is shown in Table 1. $\xi_e$ is the equivalent confinement effect coefficient, the expression is given by Eq. 17. $k$ is the increasing coefficient of the concrete strength, when $\xi_e \leq 1.235$, $k = 2$; when $\xi_e \leq 0.40$ and the concrete strength grade $\leq$ C50, $k = 2.6$; when $\xi_e \geq 1.235$, $k = 1/\sqrt{\xi_e} + 1.1$.

$$A_{ec} = \pi(a^2 + b^2)/4 \tag{16}$$

$$\xi_e = A_{es} f_{ey} / A_{ec} f_{co}^{'} \tag{17}$$

Where, $A_{es}$ and $f_{ey}$ are respectively the thickness of circumcircle steel tube and yield strength, which is same as those of rectangular CFT columns.

Table 1. Conversion Relation between
Axial Compressive Strength and Cubic Compressive Strength

| Concrete strength grade | C50 | C55 | C60 | C65 | C70 | C75 | C80 | C85 | C90 | C95 | C100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conversion coefficient | 0.67 | 0.693 | 0.716 | 0.739 | 0.762 | 0.785 | 0.808 | 0.831 | 0.854 | 0.877 | 0.900 |

### 3.3 The Test Verification of the Calculating Model

Using Eq.13, a large number of experimental data of rectangular CFT columns are analyzed and verified, the comparison between the calculating results and the experimental results are shown in Table 2. In Table 2, $N_e$ is the experimental results, $N_{c1}$ is the calculating results of the proposed equation in this paper, $N_{c2}$ and $N_{c3}$ are respectively the calculating results of China GB(2000) and EC4. The calculating results show that the average value of the ratio of $N_e / N_c$ of the models in this paper is 0.99, and the mean square deviation is 0.01; while the average value of the ratio of $N_e / N_c$ of China GB(2000) is 0.97, and the mean square deviation is 0.02; the average value of the ratio of $N_e / N_c$ of EC4 is 1.18, and the mean square deviation is 0.03. Therefore, the calculating model in this paper not only has higher calculation precision, but also may be applicable to predict the bearing capacity of different kinds of rectangular CFT columns. While the calculation precision of China GB(2000) takes second place, and the calculating results of EC4 is conservative, which is low ratio 18% compared with experimental data.

Table 2. Comparison between Experimental Results and Calculating Values of the Bearing Capacity of Rectangular CFT Columns

| References | $a$ / mm | $b$ / mm | $t$ / mm | $f_y$ / Mpa | $f'_{co}$ / Mpa | $N_e$ / kN | $N_{c1}$ / kN | $\frac{N_e}{N_{c1}}$ | $\frac{N_e}{N_{c2}}$ | $\frac{N_e}{N_{c3}}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Shakir and Zeghiche [19] | 120.0 | 80.0 | 5.00 | 386 | 28.0 | 950.0 | 976.4 | 0.97 | 0.97 | 0.99 |
| | 120.0 | 80.0 | 5.00 | 386 | 25.5 | 950.0 | 941.4 | 1.01 | 0.96 | 1.01 |
| | 120.0 | 80.0 | 5.00 | 384 | 25.5 | 900.0 | 938.4 | 0.96 | 0.96 | 0.96 |
| | 120.0 | 80.0 | 5.00 | 384 | 28.0 | 910.0 | 973.3 | 0.93 | 0.97 | 0.96 |
| | 120.0 | 80.0 | 5.00 | 343 | 27.4 | 900.0 | 902.1 | 1.00 | 0.97 | 1.04 |
| | 120.0 | 80.0 | 5.00 | 343 | 28.6 | 900.0 | 918.3 | 0.98 | 0.98 | 1.03 |
| | 120.0 | 80.0 | 5.00 | 357 | 28.0 | 920.0 | 931.9 | 0.99 | 0.97 | 1.03 |
| Shakir and Mouli[20] | 120.0 | 80.0 | 5.00 | 357 | 26.5 | 850.0 | 911.4 | 0.93 | 0.97 | 0.96 |
| | 120.0 | 80.0 | 5.00 | 341 | 27.0 | 900.0 | 893.6 | 1.01 | 0.97 | 1.05 |
| | 120.0 | 80.0 | 5.00 | 341 | 29.4 | 920.0 | 925.9 | 0.99 | 0.98 | 1.05 |
| | 120.0 | 80.0 | 5.00 | 362 | 27.0 | 950.0 | 925.9 | 1.03 | 0.97 | 1.05 |
| | 120.0 | 80.0 | 5.00 | 362 | 26.0 | 955.0 | 912.1 | 1.05 | 0.96 | 1.07 |
| | 150.0 | 100.0 | 5.00 | 346 | 29.3 | 1370.0 | 1285.4 | 1.07 | 0.97 | 1.16 |
| | 150.0 | 100.0 | 5.00 | 346 | 29.3 | 1210.0 | 1285.4 | 0.94 | 0.97 | 1.03 |
| | 150.0 | 100.0 | 5.00 | 346 | 29.3 | 1340.0 | 1285.4 | 1.04 | 0.97 | 1.14 |
| | 150.0 | 100.0 | 5.00 | 346 | 29.3 | 1200.0 | 1285.4 | 0.93 | 0.97 | 1.02 |
| | 150.0 | 100.0 | 5.00 | 340 | 29.7 | 1300.0 | 1281.2 | 1.01 | 0.97 | 1.11 |
| | 150.0 | 100.0 | 5.00 | 340 | 29.7 | 1190.0 | 1281.2 | 0.93 | 0.97 | 1.02 |
| | 150.0 | 100.0 | 5.00 | 340 | 30.0 | 1320.0 | 1287.2 | 1.03 | 0.97 | 1.13 |
| | 150.0 | 100.0 | 5.00 | 340 | 30.0 | 1200.0 | 1287.2 | 0.93 | 0.97 | 1.02 |
| Schneider [21] | 152.3 | 76.6 | 3.00 | 430 | 25.0 | 819.0 | 790.6 | 1.04 | 0.85 | 1.01 |
| | 152.3 | 76.6 | 4.47 | 383 | 21.6 | 1006.0 | 870.5 | 1.16 | 0.84 | 1.05 |
| | 152.4 | 101.8 | 4.32 | 413 | 21.6 | 1144.0 | 1175.4 | 0.97 | 0.92 | 0.99 |
| | 152.7 | 102.8 | 4.57 | 365 | 19.8 | 1224.0 | 1100.9 | 1.11 | 0.92 | 1.13 |
| | 151.4 | 101.3 | 5.72 | 324 | 19.8 | 1335.0 | 1153.1 | 1.16 | 0.93 | 1.16 |
| | 152.4 | 102.1 | 7.34 | 358 | 19.8 | 1691.0 | 1456.1 | 1.16 | 0.93 | 1.10 |
| Jiang et al.[22] | 200.0 | 150.0 | 4.00 | 284 | 22.1 | 1423.0 | 1961.7 | 0.73 | 1.27 | 1.09 |
| | 300.0 | 150.0 | 4.00 | 284 | 22.1 | 1993.0 | 2578.3 | 0.77 | 1.19 | 1.11 |
| | 300.0 | 200.0 | 4.00 | 284 | 22.1 | 2410.0 | 3224.3 | 0.75 | 1.21 | 1.10 |
| Wang and Jiang [23] | 150.0 | 150.0 | 4.00 | 308 | 36.4 | 1358.0 | 1378.3 | 0.99 | 0.82 | 1.00 |
| | 150.0 | 125.0 | 4.00 | 308 | 36.4 | 1092.0 | 1230.9 | 0.89 | 0.85 | 0.92 |
| | 150.0 | 110.0 | 4.00 | 308 | 36.4 | 988.0 | 1139.1 | 0.87 | 0.86 | 0.91 |
| | 150.0 | 100.0 | 4.00 | 308 | 36.4 | 920.0 | 1076.4 | 0.85 | 0.88 | 0.90 |
| Han and Yang[24] | 100.0 | 100.0 | 2.86 | 228 | 39.7 | 760.0 | 819.9 | 0.93 | 1.14 | 1.36 |
| | 100.0 | 100.0 | 2.86 | 228 | 39.7 | 800.0 | 819.9 | 0.98 | 1.14 | 1.43 |
| | 120.0 | 120.0 | 2.86 | 228 | 39.7 | 992.0 | 1051.6 | 0.94 | 1.08 | 1.32 |
| | 120.0 | 120.0 | 2.86 | 228 | 39.7 | 1050.0 | 1051.6 | 1.00 | 1.08 | 1.39 |
| | 110.0 | 100.0 | 2.86 | 228 | 39.7 | 844.0 | 873.8 | 0.97 | 1.12 | 1.39 |
| | 110.0 | 100.0 | 2.86 | 228 | 39.7 | 860.0 | 873.8 | 0.98 | 1.12 | 1.42 |
| | 150.0 | 135.0 | 2.86 | 228 | 39.7 | 1420.0 | 1341.0 | 1.06 | 1.02 | 1.42 |
| | 150.0 | 135.0 | 2.86 | 228 | 39.7 | 1340.0 | 1341.0 | 1.00 | 1.02 | 1.34 |
| | 90.0 | 70.0 | 2.86 | 228 | 39.7 | 554.0 | 609.0 | 0.91 | 1.24 | 1.42 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 90.0 | 70.0 | 2.86 | 228 | 39.7 | 576.0 | 609.0 | 0.95 | 1.24 | 1.47 |
| | 100.0 | 75.0 | 2.86 | 228 | 39.7 | 640.0 | 679.2 | 0.94 | 1.20 | 1.43 |
| | 100.0 | 75.0 | 2.86 | 228 | 39.7 | 672.0 | 679.2 | 0.99 | 1.20 | 1.50 |
| | 120.0 | 90.0 | 2.86 | 228 | 39.7 | 800.0 | 861.9 | 0.93 | 1.12 | 1.34 |
| | 120.0 | 90.0 | 2.86 | 228 | 39.7 | 760.0 | 861.9 | 0.88 | 1.12 | 1.27 |
| | 140.0 | 105.0 | 2.86 | 228 | 39.7 | 1044.0 | 1064.6 | 0.98 | 1.07 | 1.36 |
| | 140.0 | 105.0 | 2.86 | 228 | 39.7 | 1086.0 | 1064.6 | 1.02 | 1.07 | 1.41 |
| | 150.0 | 115.0 | 2.86 | 228 | 39.7 | 1251.0 | 1192.3 | 1.05 | 1.04 | 1.43 |
| | 150.0 | 115.0 | 2.86 | 228 | 39.7 | 1218.0 | 1192.3 | 1.02 | 1.04 | 1.39 |
| | 160.0 | 120.0 | 7.20 | 228 | 39.7 | 1820.0 | 2527.2 | 0.72 | 1.45 | 1.27 |
| | 160.0 | 120.0 | 7.20 | 228 | 39.7 | 1770.0 | 2527.2 | 0.70 | 1.45 | 1.23 |
| | 130.0 | 85.0 | 2.86 | 228 | 39.7 | 760.0 | 873.4 | 0.87 | 1.11 | 1.24 |
| | 130.0 | 85.0 | 2.86 | 228 | 39.7 | 820.0 | 873.4 | 0.94 | 1.11 | 1.34 |
| | 140.0 | 80.0 | 2.86 | 228 | 39.7 | 880.0 | 878.3 | 1.00 | 1.10 | 1.41 |
| | 140.0 | 80.0 | 2.86 | 228 | 39.7 | 740.0 | 878.3 | 0.84 | 1.10 | 1.19 |
| Han and Yang [25] | 120.0 | 120.0 | 3.80 | 330 | 27.3 | 882.0 | 928.9 | 0.95 | 1.04 | 1.10 |
| | 120.0 | 120.0 | 3.80 | 330 | 31.2 | 921.7 | 960.2 | 0.96 | 1.02 | 1.12 |
| | 120.0 | 120.0 | 3.80 | 330 | 49.3 | 1080.0 | 1105.7 | 0.98 | 0.97 | 1.13 |
| | 120.0 | 120.0 | 3.80 | 330 | 52.5 | 1078.0 | 1131.5 | 0.95 | 0.96 | 1.10 |
| | 140.0 | 140.0 | 3.80 | 330 | 16.0 | 940.8 | 1002.7 | 0.94 | 1.05 | 1.09 |
| | 140.0 | 140.0 | 3.80 | 330 | 16.7 | 921.6 | 1010.4 | 0.91 | 1.05 | 1.06 |
| | 140.0 | 140.0 | 3.80 | 330 | 54.6 | 1499.0 | 1425.1 | 1.05 | 0.93 | 1.20 |
| | 120.0 | 120.0 | 5.90 | 321 | 30.0 | 1176.0 | 1312.6 | 0.90 | 1.10 | 1.06 |
| | 120.0 | 120.0 | 5.90 | 321 | 25.8 | 1195.0 | 1278.8 | 0.93 | 1.10 | 1.11 |
| | 120.0 | 120.0 | 5.90 | 321 | 52.5 | 1372.0 | 1493.5 | 0.92 | 1.05 | 1.09 |
| | 140.0 | 140.0 | 5.90 | 321 | 16.3 | 1342.0 | 1428.3 | 0.94 | 1.07 | 1.11 |
| | 140.0 | 140.0 | 5.90 | 321 | 54.6 | 2009.0 | 1847.4 | 1.09 | 1.01 | 1.28 |
| | 200.0 | 200.0 | 5.90 | 321 | 17.6 | 2058.0 | 2178.7 | 0.94 | 1.05 | 1.10 |
| Tomii and Sakino [26] | 100.0 | 100.0 | 2.29 | 298 | 32.6 | 508.0 | 503.7 | 1.01 | 0.96 | 1.15 |
| | 100.0 | 100.0 | 2.20 | 346 | 21.8 | 521.0 | 480.5 | 1.08 | 1.01 | 1.25 |
| | 100.0 | 100.0 | 2.99 | 294 | 21.0 | 539.0 | 531.6 | 1.01 | 1.04 | 1.18 |
| | 100.0 | 100.0 | 4.25 | 290 | 20.2 | 680.0 | 693.8 | 0.98 | 1.08 | 1.15 |
| Tomii and Sakino [27] | 150.0 | 150.0 | 2.00 | 348 | 29.0 | 1191.8 | 1035.1 | 1.15 | 1.11 | 1.55 |
| | 150.0 | 150.0 | 3.20 | 306 | 29.0 | 1322.1 | 1235.4 | 1.07 | 1.13 | 1.43 |
| | 150.0 | 150.0 | 4.30 | 300 | 29.0 | 1502.1 | 1455.2 | 1.03 | 1.15 | 1.36 |
| | 150.0 | 150.0 | 2.00 | 348 | 22.1 | 1010.7 | 906.3 | 1.12 | 1.12 | 1.47 |
| | 150.0 | 150.0 | 3.20 | 306 | 22.1 | 1139.2 | 1106.6 | 1.03 | 1.14 | 1.35 |
| | 150.0 | 150.0 | 4.30 | 300 | 22.1 | 1321.0 | 1326.4 | 1.00 | 1.15 | 1.29 |
| | 150.0 | 150.0 | 2.00 | 348 | 14.4 | 800.3 | 761.4 | 1.05 | 1.12 | 1.35 |
| | 150.0 | 150.0 | 3.20 | 306 | 14.4 | 937.6 | 961.6 | 0.97 | 1.14 | 1.24 |
| | 150.0 | 150.0 | 4.30 | 300 | 14.4 | 1125.9 | 1181.4 | 0.95 | 1.14 | 1.20 |
| Kenji [28] | 148.0 | 148.0 | 4.38 | 262 | 25.4 | 1153.0 | 1111.3 | 1.04 | 1.02 | 1.20 |
| | 148.0 | 148.0 | 4.38 | 262 | 40.5 | 1414.0 | 1295.9 | 1.09 | 0.96 | 1.26 |
| | 148.0 | 148.0 | 4.38 | 262 | 77.0 | 2108.0 | 2207.4 | 0.95 | 1.13 | 1.38 |
| | 215.0 | 215.0 | 4.38 | 262 | 25.4 | 1777.0 | 1818.6 | 0.98 | 0.97 | 1.11 |
| | 215.0 | 215.0 | 4.38 | 262 | 41.1 | 2424.0 | 2223.8 | 1.09 | 0.91 | 1.22 |
| | 215.0 | 215.0 | 4.38 | 262 | 80.3 | 3837.0 | 4203.1 | 0.91 | 1.08 | 1.31 |
| | 323.0 | 323.0 | 4.38 | 262 | 25.4 | 3367.0 | 3226.9 | 1.04 | 0.91 | 1.16 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 323.0 | 323.0 | 4.38 | 262 | 41.1 | 4950.0 | 4665.6 | 1.06 | 0.96 | 1.30 |
| | 323.0 | 323.0 | 4.38 | 262 | 80.3 | 7481.0 | 8345.3 | 0.90 | 1.03 | 1.25 |
| | 144.0 | 144.0 | 6.36 | 618 | 25.4 | 2572.0 | 2962.2 | 0.87 | 1.12 | 1.02 |
| | 144.0 | 144.0 | 6.36 | 618 | 40.5 | 2808.0 | 3137.0 | 0.90 | 1.15 | 1.06 |
| | 144.0 | 144.0 | 6.36 | 618 | 77.0 | 3399.0 | 4572.9 | 0.74 | 1.62 | 1.13 |
| Zhang et al.[29] | 101.3 | 101.3 | 4.97 | 347 | 52.5 | 1310.0 | 1272.5 | 1.03 | 1.02 | 1.22 |
| | 103.6 | 103.6 | 4.90 | 347 | 52.5 | 1340.0 | 1300.0 | 1.03 | 1.00 | 1.22 |
| | 102.0 | 102.0 | 4.97 | 347 | 52.5 | 1370.0 | 1284.4 | 1.07 | 1.01 | 1.27 |
| | 142.0 | 142.0 | 5.11 | 347 | 52.5 | 2160.0 | 2069.1 | 1.04 | 0.94 | 1.21 |
| | 142.0 | 142.0 | 5.08 | 347 | 52.5 | 2250.0 | 2062.2 | 1.09 | 0.94 | 1.27 |
| | 142.0 | 142.0 | 5.07 | 347 | 52.5 | 2280.0 | 2059.8 | 1.11 | 0.94 | 1.28 |
| | 142.1 | 142.1 | 3.02 | 255 | 52.5 | 1360.0 | 1554.0 | 0.88 | 0.92 | 1.08 |
| | 142.1 | 142.1 | 3.02 | 255 | 52.5 | 1150.0 | 1554.0 | 0.74 | 0.92 | 0.91 |
| | 143.1 | 143.1 | 3.02 | 255 | 52.5 | 1328.0 | 1571.2 | 0.85 | 0.92 | 1.04 |
| | 142.1 | 142.1 | 2.01 | 305 | 38.3 | 1328.0 | 1178.3 | 1.13 | 0.93 | 1.37 |
| | 142.1 | 142.1 | 2.01 | 305 | 38.3 | 1364.0 | 1178.3 | 1.16 | 0.93 | 1.41 |
| | 140.9 | 140.9 | 2.01 | 305 | 38.3 | 1280.0 | 1163.0 | 1.10 | 0.93 | 1.34 |
| | 103.5 | 103.5 | 5.01 | 347 | 69.8 | 1500.0 | 1471.3 | 1.02 | 0.97 | 1.21 |
| | 102.1 | 102.1 | 4.97 | 347 | 69.8 | 1330.0 | 1436.4 | 0.93 | 0.97 | 1.10 |
| | 101.9 | 101.9 | 5.03 | 347 | 69.8 | 1440.0 | 1442.4 | 1.00 | 0.97 | 1.19 |
| | 142.3 | 142.3 | 5.09 | 347 | 69.8 | 2520.0 | 2362.6 | 1.07 | 0.90 | 1.23 |
| | 142.4 | 142.4 | 5.10 | 347 | 69.8 | 2610.0 | 2367.5 | 1.10 | 0.90 | 1.28 |
| | 139.1 | 139.1 | 5.06 | 347 | 69.8 | 1700.0 | 2276.8 | 0.75 | 0.91 | 0.87 |
| | 141.5 | 141.5 | 3.08 | 255 | 69.8 | 1920.0 | 1845.7 | 1.04 | 0.88 | 1.25 |
| | 142.4 | 142.4 | 3.05 | 255 | 69.8 | 2060.0 | 1858.2 | 1.11 | 0.88 | 1.33 |
| | 141.6 | 141.6 | 3.04 | 255 | 69.8 | 1960.0 | 1839.0 | 1.07 | 0.88 | 1.28 |
| | 143.2 | 143.2 | 2.03 | 305 | 69.8 | 1990.0 | 1736.1 | 1.15 | 0.84 | 1.32 |
| | 142.3 | 142.3 | 2.01 | 305 | 69.8 | 1855.0 | 1712.4 | 1.08 | 0.84 | 1.25 |
| | 140.5 | 140.5 | 2.00 | 305 | 69.8 | 1780.0 | 1673.4 | 1.06 | 0.84 | 1.23 |
| Ye [30] | 130.3 | 101.6 | 5.03 | 347 | 52.5 | 1580.0 | 1502.1 | 1.05 | 0.97 | 1.21 |
| | 130.3 | 102.3 | 5.14 | 347 | 52.5 | 1600.0 | 1530.9 | 1.05 | 0.97 | 1.21 |
| | 130.3 | 102.3 | 5.14 | 347 | 52.5 | 1640.0 | 1530.9 | 1.07 | 0.97 | 1.24 |
| | 162.9 | 101.5 | 2.00 | 305 | 52.5 | 1068.0 | 1151.9 | 0.93 | 0.85 | 1.05 |
| | 163.9 | 100.3 | 1.99 | 305 | 52.5 | 1080.0 | 1140.5 | 0.95 | 0.85 | 1.07 |
| | 160.8 | 102.7 | 2.04 | 305 | 52.5 | 1080.0 | 1164.9 | 0.93 | 0.86 | 1.06 |
| | 161.4 | 105.9 | 2.96 | 255 | 52.5 | 1420.0 | 1303.1 | 1.09 | 0.89 | 1.29 |
| | 158.2 | 105.7 | 2.93 | 255 | 52.5 | 1440.0 | 1279.2 | 1.13 | 0.90 | 1.34 |
| | 159.1 | 103.3 | 4.80 | 347 | 52.5 | 1875.0 | 1649.2 | 1.14 | 0.90 | 1.25 |
| | 156.7 | 102.4 | 4.80 | 347 | 52.5 | 1915.0 | 1623.5 | 1.18 | 0.90 | 1.30 |
| | 188.8 | 104.4 | 4.85 | 347 | 52.5 | 1820.0 | 1819.2 | 1.00 | 0.85 | 1.04 |
| | 166.3 | 120.2 | 2.94 | 255 | 52.5 | 1580.0 | 1491.5 | 1.06 | 0.90 | 1.27 |
| | 161.0 | 126.2 | 2.98 | 255 | 52.5 | 1580.0 | 1533.8 | 1.03 | 0.91 | 1.25 |
| | 160.3 | 126.0 | 2.92 | 255 | 52.5 | 1560.0 | 1514.0 | 1.03 | 0.90 | 1.24 |
| | 167.4 | 136.1 | 5.13 | 347 | 52.5 | 2510.0 | 2240.3 | 1.12 | 0.92 | 1.28 |
| | 170.8 | 135.3 | 5.07 | 347 | 52.5 | 2470.0 | 2242.6 | 1.10 | 0.91 | 1.25 |
| | 188.4 | 121.6 | 4.88 | 347 | 52.5 | 2260.0 | 2113.7 | 1.07 | 0.87 | 1.16 |
| | 190.9 | 120.4 | 4.83 | 347 | 52.5 | 2510.0 | 2097.1 | 1.20 | 0.87 | 1.29 |
| | 125.7 | 102.7 | 5.15 | 347 | 69.8 | 1840.0 | 1691.4 | 1.09 | 0.94 | 1.27 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 130.0 | 120.4 | 5.03 | 347 | 69.8 | 1820.0 | 1937.2 | 0.94 | 0.92 | 1.10 |
| | 132.3 | 102.7 | 4.98 | 347 | 69.8 | 1725.0 | 1713.8 | 1.01 | 0.92 | 1.16 |
| | 160.2 | 102.1 | 2.00 | 305 | 69.8 | 1555.0 | 1377.6 | 1.13 | 0.82 | 1.27 |
| | 162.8 | 99.6 | 2.13 | 305 | 69.8 | 1460.0 | 1386.5 | 1.05 | 0.82 | 1.18 |
| | 162.3 | 98.5 | 2.00 | 305 | 69.8 | 1545.0 | 1340.0 | 1.15 | 0.81 | 1.28 |
| | 159.1 | 105.1 | 2.93 | 255 | 69.8 | 1610.0 | 1513.6 | 1.06 | 0.85 | 1.24 |
| | 163.8 | 102.2 | 2.93 | 255 | 69.8 | 1680.0 | 1500.4 | 1.12 | 0.84 | 1.29 |
| | 162.6 | 104.5 | 3.04 | 255 | 69.8 | 1640.0 | 1547.6 | 1.06 | 0.85 | 1.23 |
| | 156.9 | 103.4 | 4.71 | 347 | 69.8 | 2090.0 | 1851.1 | 1.13 | 1.00 | 1.25 |
| | 162.0 | 106.9 | 4.81 | 347 | 69.8 | 2320.0 | 1965.1 | 1.18 | 0.99 | 1.31 |
| | 158.9 | 102.6 | 4.74 | 347 | 69.8 | 2060.0 | 1856.6 | 1.11 | 0.99 | 1.22 |
| | 164.6 | 119.7 | 2.01 | 305 | 69.8 | 1800.0 | 1643.4 | 1.10 | 0.82 | 1.24 |
| | 157.1 | 122.5 | 2.01 | 305 | 69.8 | 1800.0 | 1622.5 | 1.11 | 0.83 | 1.27 |
| | 161.9 | 119.0 | 2.00 | 305 | 69.8 | 1740.0 | 1612.0 | 1.08 | 0.83 | 1.23 |
| | 160.4 | 125.1 | 2.85 | 255 | 69.8 | 1855.0 | 1777.4 | 1.04 | 0.86 | 1.23 |
| | 160.0 | 125.6 | 2.88 | 255 | 69.8 | 2030.0 | 1787.1 | 1.14 | 0.86 | 1.34 |
| | 161.1 | 125.0 | 2.81 | 255 | 69.8 | 2040.0 | 1773.1 | 1.15 | 0.85 | 1.35 |
| | 167.9 | 137.1 | 5.10 | 347 | 69.8 | 2600.0 | 2581.1 | 1.01 | 0.88 | 1.15 |
| | 172.7 | 133.2 | 5.08 | 347 | 69.8 | 2700.0 | 2560.1 | 1.05 | 0.88 | 1.19 |
| | 194.8 | 121.0 | 4.72 | 347 | 69.8 | 2700.0 | 2435.7 | 1.11 | 0.94 | 1.19 |
| | 189.6 | 121.7 | 4.81 | 347 | 69.8 | 2680.0 | 2432.2 | 1.10 | 0.95 | 1.20 |
| | 162.7 | 100.7 | 2.97 | 255 | 52.5 | 1080.0 | 1248.8 | 0.86 | 0.89 | 1.02 |
| | 160.2 | 122.7 | 2.03 | 305 | 52.5 | 1400.0 | 1372.8 | 1.02 | 0.87 | 1.19 |
| | 160.1 | 119.4 | 2.01 | 305 | 52.5 | 1420.0 | 1333.2 | 1.07 | 0.87 | 1.24 |
| | 161.5 | 124.3 | 2.00 | 305 | 52.5 | 1320.0 | 1389.4 | 0.95 | 0.87 | 1.11 |
| Tao and Yu[31] | 60.0 | 60.0 | 1.87 | 282 | 81.0 | 382.0 | 405.3 | 0.94 | 1.17 | 1.21 |
| | 60.0 | 60.0 | 1.87 | 282 | 81.0 | 350.0 | 405.3 | 0.86 | 1.17 | 1.11 |
| | 100.0 | 100.0 | 1.87 | 282 | 81.0 | 860.0 | 910.4 | 0.94 | 1.07 | 1.12 |
| | 100.0 | 100.0 | 1.87 | 282 | 81.0 | 840.0 | 910.4 | 0.92 | 1.07 | 1.10 |
| | 150.0 | 150.0 | 1.87 | 282 | 81.0 | 1662.0 | 1806.1 | 0.92 | 1.02 | 1.04 |
| | 150.0 | 150.0 | 1.87 | 282 | 81.0 | 1740.0 | 1806.1 | 0.96 | 1.02 | 1.09 |
| | 200.0 | 200.0 | 1.87 | 282 | 81.0 | 2890.0 | 2995.3 | 0.96 | 0.99 | 1.06 |
| | 200.0 | 200.0 | 1.87 | 282 | 81.0 | 2920.0 | 2995.3 | 0.97 | 0.99 | 1.07 |
| | 250.0 | 250.0 | 1.87 | 282 | 60.0 | 3304.0 | 3089.2 | 1.07 | 0.87 | 1.19 |
| | 250.0 | 250.0 | 1.87 | 282 | 60.0 | 3400.0 | 3089.2 | 1.10 | 0.87 | 1.22 |
| | 60.0 | 60.0 | 2.00 | 404 | 50.9 | 318.0 | 330.8 | 0.96 | 1.00 | 1.12 |
| | 60.0 | 60.0 | 2.00 | 404 | 50.9 | 322.0 | 330.8 | 0.97 | 1.00 | 1.13 |
| | 100.0 | 100.0 | 2.00 | 404 | 50.9 | 770.0 | 665.1 | 1.16 | 0.91 | 1.30 |
| | 100.0 | 100.0 | 2.00 | 404 | 50.9 | 772.0 | 665.1 | 1.16 | 0.91 | 1.31 |
| | 150.0 | 150.0 | 2.00 | 404 | 50.9 | 1300.0 | 1210.8 | 1.07 | 0.86 | 1.18 |
| | 150.0 | 150.0 | 2.00 | 404 | 50.9 | 1420.0 | 1210.8 | 1.17 | 0.86 | 1.29 |
| | 200.0 | 200.0 | 2.00 | 404 | 50.9 | 1990.0 | 2127.1 | 0.94 | 0.93 | 1.13 |
| | 200.0 | 200.0 | 2.00 | 404 | 50.9 | 2054.0 | 2127.1 | 0.97 | 0.93 | 1.17 |
| | 250.0 | 250.0 | 2.00 | 404 | 50.9 | 3100.0 | 3014.1 | 1.03 | 0.89 | 1.21 |
| | 250.0 | 250.0 | 2.00 | 404 | 50.9 | 2965.0 | 3014.1 | 0.98 | 0.89 | 1.16 |
| | 60.0 | 60.0 | 2.00 | 404 | 81.0 | 422.0 | 439.9 | 0.96 | 1.10 | 1.11 |
| | 60.0 | 60.0 | 2.00 | 404 | 81.0 | 406.0 | 439.9 | 0.92 | 1.10 | 1.06 |
| | 150.0 | 150.0 | 2.00 | 404 | 81.0 | 2060.0 | 2064.1 | 1.00 | 1.06 | 1.17 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 150.0 | 150.0 | 2.00 | 404 | 81.0 | 1980.0 | 2064.1 | 0.96 | 1.07 | 1.12 |
| Yu et al.[32] | 100.0 | 100.0 | 1.90 | 404 | 121 | 1220.0 | 1352.0 | 0.90 | 1.06 | 1.07 |
| | 100.0 | 100.0 | 1.90 | 404 | 121 | 1209.0 | 1352.0 | 0.89 | 1.06 | 1.06 |
| Tao et al.[33] | 249.9 | 250.2 | 2.50 | 234 | 50.1 | 3700.0 | 3588.8 | 1.03 | 0.83 | 1.18 |
| | 248.0 | 251.0 | 2.50 | 234 | 50.1 | 3530.0 | 3580.3 | 0.99 | 0.83 | 1.13 |
| | 248.7 | 252.3 | 2.50 | 234 | 50.1 | 3500.0 | 3564.4 | 0.98 | 0.82 | 1.11 |
| | 248.6 | 252.6 | 2.50 | 234 | 50.1 | 3620.0 | 3601.9 | 1.01 | 0.83 | 1.15 |
| | 190.1 | 190.2 | 2.50 | 234 | 54.8 | 2250.0 | 2391.4 | 0.94 | 0.85 | 1.10 |
| | 189.1 | 190.3 | 2.50 | 234 | 54.8 | 2240.0 | 2385.6 | 0.94 | 0.85 | 1.10 |
| | 189.5 | 190.9 | 2.50 | 234 | 54.8 | 2195.0 | 2369.0 | 0.93 | 0.84 | 1.07 |
| | 129.7 | 130.5 | 2.50 | 234 | 54.8 | 1310.0 | 1286.1 | 1.02 | 0.92 | 1.27 |
| | 129.6 | 130.5 | 2.50 | 234 | 54.8 | 1300.0 | 1288.3 | 1.01 | 0.92 | 1.26 |
| | 129.7 | 130.2 | 2.50 | 234 | 54.8 | 1300.0 | 1272.1 | 1.02 | 0.91 | 1.26 |
| | 129.7 | 130.5 | 2.50 | 234 | 54.8 | 1270.0 | 1286.1 | 0.99 | 0.92 | 1.23 |
| | 128.2 | 129.1 | 2.50 | 234 | 54.8 | 1150.0 | 1217.0 | 0.94 | 0.89 | 1.14 |
| | 249.0 | 126.0 | 2.50 | 234 | 50.1 | 2010.0 | 1830.2 | 1.10 | 0.79 | 1.19 |
| | 129.6 | 65.8 | 2.50 | 234 | 54.8 | 695.0 | 677.5 | 1.03 | 0.88 | 1.20 |
| Wang and Li [34] | 553.0 | 180.0 | 1.49 | 222 | 37.2 | 1788.0 | 2103.2 | 0.85 | 0.61 | 0.50 |
| | 553.0 | 180.0 | 1.49 | 222 | 15.6 | 1082.5 | 1070.5 | 1.01 | 0.63 | 0.61 |
| | 463.0 | 150.0 | 1.45 | 222 | 37.2 | 1300.0 | 1502.0 | 0.87 | 0.61 | 0.51 |
| | 463.0 | 150.0 | 1.45 | 222 | 15.6 | 943.0 | 782.6 | 1.20 | 0.63 | 0.73 |
| | 418.0 | 135.0 | 1.44 | 222 | 37.2 | 1216.0 | 1240.6 | 0.98 | 0.61 | 0.58 |
| | 418.0 | 135.0 | 1.44 | 222 | 18.3 | 779.8 | 729.7 | 1.07 | 0.63 | 0.65 |
| | 372.0 | 120.0 | 1.49 | 222 | 37.2 | 916.0 | 1011.3 | 0.91 | 0.62 | 0.54 |
| | 372.0 | 120.0 | 1.49 | 222 | 18.3 | 536.0 | 607.2 | 0.88 | 0.63 | 0.54 |
| He and Liu [35] | 298.0 | 100.0 | 0.92 | 229 | 14.1 | 398.0 | 419.7 | 0.95 | 0.63 | 0.77 |
| | 299.0 | 100.0 | 0.92 | 229 | 14.1 | 377.0 | 420.4 | 0.90 | 0.63 | 0.73 |
| | 296.0 | 100.0 | 0.92 | 229 | 17.7 | 429.0 | 495.7 | 0.87 | 0.63 | 0.71 |
| | 302.0 | 100.0 | 0.92 | 229 | 17.7 | 434.0 | 500.6 | 0.87 | 0.62 | 0.71 |
| | 358.0 | 120.0 | 0.89 | 229 | 14.1 | 483.0 | 572.4 | 0.84 | 0.63 | 0.69 |
| | 357.0 | 120.0 | 0.89 | 229 | 17.7 | 533.0 | 683.3 | 0.78 | 0.62 | 0.65 |
| | 358.0 | 150.0 | 1.45 | 223 | 14.1 | 877.0 | 854.3 | 1.03 | 0.70 | 0.92 |
| | 446.0 | 150.0 | 1.45 | 223 | 14.1 | 893.0 | 949.5 | 0.94 | 0.64 | 0.77 |
| | 453.0 | 150.0 | 1.45 | 223 | 17.7 | 958.0 | 1132.3 | 0.85 | 0.63 | 0.69 |
| | 447.0 | 150.0 | 1.45 | 223 | 17.7 | 976.0 | 1125.1 | 0.87 | 0.63 | 0.71 |
| Zhang and Chen [36] | 200.0 | 200.0 | 1.25 | 373 | 29.7 | 1590.0 | 1561.5 | 1.02 | 0.86 | 1.17 |
| | 200.0 | 200.0 | 1.25 | 373 | 29.7 | 1826.0 | 1748.0 | 1.04 | 0.97 | 1.34 |
| | 200.0 | 200.0 | 1.25 | 373 | 29.7 | 2002.0 | 1934.5 | 1.03 | 1.07 | 1.47 |
| | 300.0 | 300.0 | 1.25 | 373 | 32.9 | 4195.0 | 3324.7 | 1.26 | 0.80 | 1.38 |
| | 300.0 | 300.0 | 1.25 | 373 | 32.9 | 4240.0 | 3511.2 | 1.21 | 0.85 | 1.40 |
| | 300.0 | 300.0 | 1.25 | 373 | 32.9 | 4140.0 | 3697.7 | 1.12 | 0.89 | 1.36 |
| Lv et al.[37] | 200.0 | 200.0 | 5.00 | 227 | 24.7 | 2061.0 | 1893.4 | 1.09 | 0.93 | 1.24 |
| | 200.0 | 200.0 | 5.00 | 227 | 28.3 | 2530.0 | 2334.4 | 1.08 | 1.06 | 1.42 |
| | 200.0 | 200.0 | 5.00 | 227 | 32.5 | 2468.0 | 2474.4 | 1.00 | 1.03 | 1.30 |
| | 300.0 | 300.0 | 5.00 | 227 | 24.7 | 3621.0 | 3457.6 | 1.05 | 0.88 | 1.16 |
| | 300.0 | 300.0 | 5.00 | 227 | 28.3 | 4603.0 | 4209.2 | 1.09 | 0.97 | 1.36 |
| | 300.0 | 300.0 | 5.00 | 227 | 32.5 | 4872.0 | 4524.2 | 1.08 | 0.95 | 1.32 |
| | 100.0 | 100.0 | 2.29 | 198 | 32.6 | 507.0 | 549.5 | 0.92 | 0.98 | 1.17 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 100.0 | 100.0 | 2.29 | 198 | 32.6 | 508.0 | 549.5 | 0.92 | 0.98 | 1.17 |
| | 100.0 | 100.0 | 2.20 | 346 | 21.8 | 521.0 | 540.5 | 0.96 | 0.97 | 1.10 |
| | 100.0 | 100.0 | 2.20 | 346 | 21.8 | 520.0 | 540.5 | 0.96 | 0.97 | 1.10 |
| | 100.0 | 100.0 | 2.99 | 294 | 21.0 | 539.0 | 589.4 | 0.91 | 1.01 | 1.06 |
| | 100.0 | 100.0 | 2.99 | 294 | 21.0 | 538.0 | 589.4 | 0.91 | 1.01 | 1.06 |
| | 100.0 | 100.0 | 4.25 | 290 | 20.2 | 680.0 | 702.1 | 0.97 | 0.99 | 1.07 |
| | 100.0 | 100.0 | 4.25 | 290 | 20.2 | 679.0 | 702.1 | 0.97 | 0.99 | 1.07 |
| Zhang [38] | 120.0 | 120.0 | 3.50 | 330 | 27.3 | 882.0 | 981.0 | 0.90 | 0.98 | 1.04 |
| | 120.0 | 120.0 | 3.50 | 330 | 31.2 | 882.0 | 1027.8 | 0.86 | 0.97 | 0.99 |
| | 120.0 | 120.0 | 3.50 | 330 | 31.2 | 921.0 | 1027.8 | 0.90 | 0.97 | 1.03 |
| | 120.0 | 120.0 | 3.50 | 330 | 49.3 | 1080.0 | 1245.0 | 0.87 | 0.91 | 0.99 |
| | 140.0 | 140.0 | 3.50 | 330 | 16.0 | 941.0 | 989.6 | 0.95 | 0.98 | 1.06 |
| | 140.0 | 140.0 | 3.50 | 330 | 16.7 | 922.0 | 1008.6 | 0.91 | 0.99 | 1.03 |
| | 140.0 | 140.0 | 3.50 | 330 | 54.6 | 1499.0 | 1654.1 | 0.91 | 0.87 | 1.02 |
| | 140.0 | 140.0 | 3.50 | 330 | 54.6 | 1470.0 | 1654.1 | 0.89 | 0.87 | 1.00 |
| Fan [39] | 199.9 | 199.9 | 5.78 | 365 | 32.1 | 3193.0 | 3055.9 | 1.04 | 0.97 | 1.20 |
| | 200.1 | 200.1 | 5.78 | 365 | 44.1 | 3551.0 | 3461.5 | 1.03 | 0.93 | 1.18 |
| | 200.0 | 200.0 | 5.78 | 365 | 44.1 | 3593.0 | 3459.0 | 1.04 | 0.93 | 1.19 |
| | 250.1 | 250.1 | 5.78 | 375 | 32.1 | 4376.0 | 4228.7 | 1.03 | 0.94 | 1.18 |
| | 250.1 | 250.1 | 5.78 | 375 | 44.1 | 4824.0 | 4854.2 | 0.99 | 0.90 | 1.12 |
| | 250.2 | 250.2 | 5.78 | 375 | 44.1 | 4851.0 | 4857.0 | 1.00 | 0.90 | 1.13 |
| | 250.1 | 250.1 | 5.78 | 377 | 32.1 | 3747.0 | 4242.3 | 0.88 | 0.94 | 1.00 |
| | 250.1 | 250.1 | 5.78 | 377 | 44.1 | 4870.0 | 4867.8 | 1.00 | 0.90 | 1.13 |
| | 250.1 | 250.1 | 5.78 | 377 | 44.1 | 4467.0 | 4867.8 | 0.92 | 0.90 | 1.04 |
| Xu [40] | 120.0 | 120.0 | 5.60 | 321 | 30.0 | 1176.0 | 1339.1 | 0.88 | 1.03 | 1.01 |
| | 120.0 | 120.0 | 5.60 | 321 | 30.0 | 1117.0 | 1339.1 | 0.83 | 1.03 | 0.96 |
| | 120.0 | 120.0 | 5.60 | 321 | 25.8 | 1195.0 | 1254.5 | 0.95 | 1.01 | 1.06 |
| | 120.0 | 120.0 | 5.60 | 321 | 52.5 | 1460.0 | 1646.9 | 0.89 | 0.99 | 1.05 |
| | 120.0 | 120.0 | 5.60 | 321 | 52.5 | 1372.0 | 1646.9 | 0.83 | 0.99 | 0.99 |
| | 140.0 | 140.0 | 5.60 | 321 | 16.3 | 1342.0 | 1296.5 | 1.04 | 0.96 | 1.09 |
| | 140.0 | 140.0 | 5.60 | 321 | 16.2 | 1292.0 | 1293.6 | 1.00 | 0.96 | 1.05 |
| | 140.0 | 140.0 | 5.60 | 321 | 54.6 | 2009.0 | 2078.2 | 0.97 | 0.95 | 1.13 |
| | 140.0 | 140.0 | 5.60 | 321 | 54.6 | 1906.0 | 2078.2 | 0.92 | 0.95 | 1.07 |
| | 200.0 | 200.0 | 5.60 | 321 | 17.6 | 2058.0 | 2281.5 | 0.90 | 1.02 | 1.04 |
| | 200.0 | 200.0 | 5.60 | 321 | 17.6 | 1960.0 | 2281.5 | 0.86 | 1.02 | 0.99 |
| Tao and Han[41] | 250.0 | 250.0 | 4.60 | 377 | 29.7 | 2796.0 | 3078.6 | 0.91 | 0.96 | 1.03 |
| | 151.0 | 151.0 | 2.00 | 217 | 32.8 | 800.0 | 726.5 | 1.10 | 0.86 | 1.20 |
| | 148.0 | 148.0 | 2.00 | 217 | 24.7 | 600.0 | 604.9 | 0.99 | 0.90 | 1.09 |
| | 250.0 | 250.0 | 5.80 | 375 | 29.7 | 3289.0 | 3599.7 | 0.91 | 0.99 | 1.05 |
| | 199.9 | 199.9 | 5.80 | 365 | 29.2 | 2471.0 | 2646.4 | 0.93 | 1.02 | 1.08 |
| | 76.2 | 76.2 | 3.38 | 324 | 40.9 | 522.0 | 526.0 | 0.99 | 1.06 | 1.17 |
| | 199.9 | 199.9 | 5.80 | 365 | 37.8 | 3193.0 | 2838.3 | 1.12 | 1.00 | 1.30 |
| | 151.0 | 151.0 | 6.92 | 246 | 24.7 | 1640.0 | 1526.2 | 1.07 | 1.07 | 1.27 |
| | 250.0 | 250.0 | 5.80 | 375 | 51.9 | 4824.0 | 4374.4 | 1.10 | 0.93 | 1.25 |
| | 76.2 | 76.2 | 3.38 | 324 | 40.9 | 516.0 | 526.0 | 0.98 | 1.06 | 1.16 |
| | 250.0 | 250.0 | 5.80 | 375 | 51.9 | 4851.0 | 4374.4 | 1.11 | 0.93 | 1.26 |
| | 250.0 | 250.0 | 4.60 | 376 | 37.8 | 3747.0 | 3357.4 | 1.12 | 0.93 | 1.26 |
| | 149.0 | 149.0 | 4.30 | 246 | 38.7 | 1405.0 | 1222.7 | 1.15 | 0.96 | 1.32 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 127.0 | 127.0 | 4.30 | 485 | 44.9 | 1634.0 | 1652.9 | 0.99 | 1.03 | 1.15 |
| | 151.0 | 151.0 | 6.90 | 292 | 24.7 | 1735.0 | 1748.6 | 0.99 | 1.08 | 1.17 |
| | 114.0 | 114.0 | 4.39 | 254 | 32.1 | 915.0 | 832.2 | 1.10 | 1.09 | 1.29 |
| | 149.0 | 149.0 | 4.30 | 246 | 38.7 | 1425.0 | 1222.7 | 1.17 | 0.99 | 1.34 |
| | 250.0 | 250.0 | 5.80 | 375 | 37.8 | 4376.0 | 3882.3 | 1.13 | 0.97 | 1.29 |
| Wang and Shang [42] | 125.0 | 125.0 | 3.20 | 299 | 28.8 | 865.0 | 938.8 | 0.92 | 0.95 | 1.05 |
| | 125.0 | 125.0 | 4.50 | 296 | 28.8 | 1164.0 | 1159.9 | 1.00 | 1.00 | 1.17 |
| | 125.0 | 125.0 | 6.00 | 285 | 28.8 | 1444.0 | 1382.6 | 1.04 | 1.05 | 1.24 |
| | 125.0 | 125.0 | 3.20 | 299 | 38.3 | 1115.0 | 1062.5 | 1.05 | 0.91 | 1.19 |
| | 125.0 | 125.0 | 4.50 | 296 | 38.3 | 1312.0 | 1283.6 | 1.02 | 0.96 | 1.19 |
| | 125.0 | 125.0 | 6.00 | 285 | 38.3 | 1512.0 | 1506.3 | 1.00 | 1.01 | 1.19 |
| He et al.[43] | 273.0 | 273.0 | 3.00 | 380 | 42.8 | 3675.0 | 4565.4 | 0.80 | 0.90 | 0.96 |
| | 273.0 | 273.0 | 3.00 | 380 | 42.8 | 3689.0 | 4565.4 | 0.81 | 0.90 | 0.96 |
| | 203.0 | 203.0 | 3.00 | 380 | 42.8 | 3408.0 | 2888.0 | 1.18 | 0.95 | 1.46 |
| | 203.0 | 203.0 | 3.00 | 380 | 42.8 | 3361.0 | 2888.0 | 1.16 | 0.95 | 1.44 |
| | 233.0 | 233.0 | 3.00 | 318 | 42.8 | 2640.0 | 3298.5 | 0.80 | 0.90 | 0.96 |
| | 233.0 | 233.0 | 3.00 | 318 | 42.8 | 2603.0 | 3298.5 | 0.79 | 0.90 | 0.94 |
| | 203.0 | 203.0 | 3.00 | 318 | 42.8 | 2190.0 | 2656.6 | 0.82 | 0.93 | 1.00 |
| | 203.0 | 203.0 | 3.00 | 318 | 42.8 | 2240.0 | 2656.6 | 0.84 | 0.93 | 1.02 |
| | 183.0 | 183.0 | 3.00 | 380 | 42.8 | 2010.0 | 2177.9 | 0.92 | 0.86 | 1.02 |
| | 183.0 | 183.0 | 3.00 | 380 | 42.8 | 2070.0 | 2177.9 | 0.95 | 0.86 | 1.05 |
| | 153.0 | 153.0 | 3.00 | 380 | 42.8 | 1580.0 | 1657.1 | 0.95 | 0.88 | 1.06 |
| | 153.0 | 153.0 | 3.00 | 380 | 42.8 | 1490.0 | 1657.1 | 0.90 | 0.88 | 1.00 |
| | 153.0 | 153.0 | 4.50 | 340 | 42.8 | 1920.0 | 1938.4 | 0.99 | 0.93 | 1.14 |
| | 203.0 | 203.0 | 3.00 | 318 | 53.6 | 2405.0 | 3027.5 | 0.79 | 0.89 | 0.95 |
| | 153.0 | 153.0 | 3.00 | 380 | 53.6 | 1710.0 | 1867.8 | 0.92 | 0.85 | 1.02 |
| | 153.0 | 153.0 | 3.00 | 380 | 53.6 | 1680.0 | 1867.8 | 0.90 | 0.85 | 1.00 |
| | 153.0 | 153.0 | 3.00 | 318 | 53.6 | 1580.0 | 1940.1 | 0.81 | 0.94 | 1.01 |
| | 150.0 | 150.0 | 4.50 | 340 | 53.6 | 2010.0 | 2086.9 | 0.96 | 0.90 | 1.10 |
| | 203.0 | 203.0 | 3.00 | 318 | 25.7 | 2090.0 | 1795.5 | 1.16 | 0.89 | 1.29 |
| | 153.0 | 153.0 | 3.00 | 318 | 25.7 | 1470.0 | 1189.4 | 1.24 | 0.93 | 1.39 |
| | 150.0 | 150.0 | 4.50 | 340 | 25.7 | 1820.0 | 1563.7 | 1.16 | 1.00 | 1.35 |
| Kenji et al.[44] | 178.0 | 178.0 | 9.00 | 283 | 36.7 | 2671.0 | 3106.2 | 0.86 | 1.03 | 1.02 |
| | 179.0 | 179.0 | 5.50 | 248 | 36.6 | 2034.0 | 2128.2 | 0.96 | 0.92 | 1.10 |
| | 174.0 | 174.0 | 3.00 | 266 | 34.6 | 1642.0 | 1723.9 | 0.95 | 0.97 | 1.19 |
| Han [45] | 159.8 | 159.8 | 6.30 | 483 | 53.4 | 2350.0 | 3426.2 | 0.69 | 1.01 | 0.80 |
| | 115.9 | 115.9 | 4.90 | 309 | 53.4 | 1174.0 | 1425.0 | 0.82 | 0.95 | 0.97 |
| | 141.8 | 141.8 | 4.30 | 433 | 53.4 | 1618.0 | 2139.4 | 0.76 | 0.93 | 0.87 |
| | 141.8 | 141.8 | 3.90 | 357 | 53.4 | 1150.0 | 1825.5 | 0.63 | 0.90 | 0.72 |
| | 165.7 | 165.7 | 5.10 | 373 | 53.4 | 2309.0 | 2707.7 | 0.85 | 0.92 | 0.98 |
| | 133.1 | 133.1 | 4.50 | 324 | 53.4 | 1145.0 | 1703.2 | 0.67 | 0.92 | 0.78 |
| | 111.3 | 111.3 | 2.00 | 354 | 53.4 | 894.0 | 1034.2 | 0.86 | 0.94 | 1.07 |
| | 130.6 | 130.6 | 2.30 | 243 | 53.4 | 1250.0 | 1206.3 | 1.04 | 0.88 | 1.23 |
| Tan et al.[46] | 125.0 | 125.0 | 1.00 | 232 | 84.7 | 1275.0 | 1280.6 | 1.00 | 0.75 | 1.06 |
| | 125.0 | 125.0 | 1.00 | 232 | 84.7 | 1239.0 | 1280.6 | 0.97 | 0.75 | 1.03 |
| | 127.0 | 127.0 | 2.00 | 258 | 84.7 | 1491.0 | 1540.0 | 0.97 | 0.81 | 1.10 |
| | 127.0 | 127.0 | 2.00 | 258 | 84.7 | 1339.0 | 1540.0 | 0.87 | 0.81 | 0.99 |
| | 133.0 | 133.0 | 3.50 | 352 | 84.7 | 1995.0 | 2252.7 | 0.89 | 0.93 | 1.11 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 133.0 | 133.0 | 3.50 | 352 | 84.7 | 1991.0 | 2252.7 | 0.88 | 0.93 | 1.11 |
| | 133.0 | 133.0 | 3.50 | 352 | 84.7 | 1962.0 | 2252.7 | 0.87 | 0.93 | 1.09 |
| | 133.0 | 133.0 | 4.70 | 352 | 84.7 | 2273.0 | 2285.8 | 0.99 | 0.88 | 1.15 |
| | 133.0 | 133.0 | 4.70 | 352 | 84.7 | 2158.0 | 2285.8 | 0.94 | 0.88 | 1.09 |
| | 133.0 | 133.0 | 4.70 | 352 | 84.7 | 2253.0 | 2285.8 | 0.99 | 0.88 | 1.14 |
| | 127.0 | 127.0 | 7.00 | 429 | 84.7 | 3404.0 | 2936.3 | 1.16 | 1.04 | 1.39 |
| | 127.0 | 127.0 | 7.00 | 429 | 84.7 | 3370.0 | 2936.3 | 1.15 | 1.04 | 1.38 |
| | 127.0 | 127.0 | 7.00 | 429 | 84.7 | 3364.0 | 2936.3 | 1.15 | 1.04 | 1.38 |
| Liu et al.[47] | 142.0 | 142.0 | 3.00 | 255 | 60.0 | 1952.0 | 1673.9 | 1.17 | 0.90 | 1.42 |
| | 141.8 | 141.8 | 3.00 | 255 | 60.0 | 1834.0 | 1670.1 | 1.10 | 0.90 | 1.33 |
| | 143.4 | 143.4 | 3.00 | 255 | 60.0 | 2010.0 | 1700.5 | 1.18 | 0.90 | 1.43 |
| | 143.0 | 143.0 | 3.00 | 255 | 70.0 | 2030.0 | 1863.3 | 1.09 | 0.87 | 1.31 |
| | 141.6 | 141.6 | 3.00 | 255 | 70.0 | 1773.0 | 1833.5 | 0.97 | 0.87 | 1.16 |
| | 140.9 | 140.9 | 3.00 | 255 | 70.0 | 1754.0 | 1818.6 | 0.96 | 0.88 | 1.16 |
| | 142.3 | 142.3 | 2.00 | 305 | 60.0 | 1762.0 | 1544.4 | 1.14 | 0.86 | 1.33 |
| | 139.7 | 139.7 | 2.00 | 305 | 60.0 | 1868.0 | 1498.0 | 1.25 | 0.86 | 1.46 |
| | 142.5 | 142.5 | 2.00 | 305 | 60.0 | 1909.0 | 1548.0 | 1.23 | 0.86 | 1.44 |
| | 140.7 | 140.7 | 2.00 | 305 | 70.0 | 1914.0 | 1680.8 | 1.14 | 0.84 | 1.32 |
| | 142.1 | 142.1 | 2.00 | 305 | 70.0 | 1932.0 | 1709.1 | 1.13 | 0.84 | 1.30 |
| | 142.6 | 142.6 | 2.00 | 305 | 70.0 | 2030.0 | 1719.3 | 1.18 | 0.84 | 1.36 |

## 4. CONCLUSIONS

According to the analysis of this paper, we can obtain the following conclusions:

The calculating precision of existing calculation models of bearing capacity are not high, the calculating results appears the bigger error among different countries specifications. Moreover, the cross-sectional aspect ratios, the effects of the thickness of thin-walled steel tube, the longitudinal stiffened rib and the concrete strength on the bearing capacity are not reflected in existing models, the calculating precision needs to be further enhanced.

Due to the confinement of rectangular steel tube to core concrete, the bearing capacity and ductility can be increased, but the increasing effect of rectangular CFT column is not as good as its circular counterpart. This is mainly because the confinement of rectangular steel tube to concrete may be divided into the effective and non-effective confining zone, so this paper firstly presents a calculating method for the coefficient of the effective confining area of rectangular CFT columns.

Based on the proposed coefficient of the effective confining area, considering the effect of the cross-sectional aspect ratios, the concrete strength, the thickness of thin-walled steel tube, the longitudinal stiffened rib on the bearing capacity, a calculating model for the bearing capacity of rectangular CFT columns are proposed, the model can be used to calculate the bearing capacity of common concrete filled steel tubular column, high strength concrete filled steel tubular column, concrete filled thin-walled steel tubular column and stiffened concrete filled steel tubular column.

The characteristic of rectangular CFT columns are reflected in the proposed model, the effects of the effective confining zone and other factors on the bearing capacity are well considered. The proposed model is not only simple, but agrees well with large experimental data.

## ACKNOWLEDGEMENTS

The work presented in this paper is sponsored by National Natural Science Foundation of China (50725842, 51008001) and the Natural Science Foundation of Anhui Province(KJ2010A046). The authors are grateful for their financial support.

## REFERENCES

[1] ACI Committee 318, "Building Code Requirement for Structural Concrete and Commentary", American Concrete Institute, Detroit, USA, 2005.
[2] China Engineering Construction Standardization Institute Standard, "Design and Construction Rules of Concrete Filled Steel Tube Structure (CECS28:90)", China Planning Press, Beijing, 1990.
[3] European Committee for Standardization, "Design of Composite Steel and Concrete Structures-Part1.1: General Rules and Rules for Buildings", Eurocode, 2004.
[4] China Power Industry Standard, "Design Rules of Steel-concrete Composite Structure (DL/T5085-1999)", China Power Press, Beijing, 1999.
[5] Han, L.H., "Concrete Filled Steel Tube Structure-theory and Practice". Science Press, Beijing, 2007.
[6] Zhong, S.T., "Concrete Filled Steel Tube Structure", Tsinghua University Press, Beijing, 2002.
[7] ASCCS, "Concrete Filled Steel Tubes-A Comparison of International Codes and Practices", ASCCS, Seminar, Innsbruck, Austria, 1997.
[8] AIJ, "Recommendations for Design and Construction of Concrete Filled Steel Tubular Structures", Architecture Institute of Japan, Tokyo, Japan, 1997.
[9] China Building Materials and Industry Bureau Standard, "Design and Construction Rules of Concrete Filled Steel Tube Structure (JCJ 01-89)", Tongji University Press, Shanghai, 1989.
[10] China Engineering Construction Standardization Institute Standard, "Technical Rules of Rectangular Concrete Filled Steel Tube Structure (CECS159-2004)", China planning Press, Beijing, 2004.
[11] China Military Standard, "Technical Specifications for Early-strength Model Composite Structure Used for Navy Port Emergency Repair in Wartime (GBJ 4142-2000)", Chinese pla General Logistics, Beijing, 2000.
[12] Fujian Engineering Construction Standard, "Technical Rules of Concrete Filled Steel Tube Structure (DBJ13-51-2003)", 2003.
[13] Furlon R.W., "Strength of Steel-Encased Concrete Beam Columns", Journal of the Structural Division, 1967, Vol. 93, No. 5, pp. 113-124.
[14] Yu, F. and Niu, D.T., "Analysis on Bearing Capacity of FRP-confined Concrete Filled Steel Tubes", Journal of Harbin Institute of Technology, 2007, Vol. 39, No. 2, pp. 44-46.
[15] Uy. B., "Strength of Short Concrete Filled High Strength Steel Box Columns", Journal of Constructional Steel Research, 2001, Vol. 57, No. 2, pp. 113-134.
[16] Cai, S.H., "Modern Concrete Filled Steel Tube Structures", China Communication Press, Beijing, 2003.
[17] AISC, Load and Resistance Factor Design (LRFD), "Specification for Structural Steel Buildings", American Institute of Steel Construction, Inc., Chicago, 1994.
[18] Yu, Y., "Study on Behavior of Concrete-filled Rectangular Tubular Columns", Doctor Dissertation of Tongji University, 2002.
[19] Shakir Khalil, H. and Zeghiche, J., "Experimental Behavior of Concrete Filled Rolled Rectangular Hollow-Section Columns", Structural Engineer, 1989, Vol. 67, No. 19, pp. 346-353.

[20] Shakir Khalil, H. and Mouli, M., “Further Tests on Concrete-Filled Rectangular Hollow-Section Columns”, Structural Engineer, 1990, Vol. 68, No. 20, pp. 405-413.

[21] Schneider, S.P., “Axially Loaded Concrete-Filled Steel Tubes”, Journal of Structural Engineering, 1998, Vol. 124, No. 10, pp. 1125-1138.

[22] Jiang, T., Shen, Z.O. and Yu,, Z.W., “Calculation of Load Capacity of Concrete Filled Rectangular Steel Tube under Axial Load”, Special Structures, 2002, Vol. 19, No. 2, pp. 4-6.

[23] Wang, L. and Jiang, X., “Calculation of Load Capacities for Short Concrete- Filled Steed Tube Columns with Rectangular Section”, Journal of Guilin Institute of Technology, 2003, Vol. 23, No. 4, pp. 441-444.

[24] Han, L.H. and Yang, Y.F., “Study on Axial Bearing Capacity of Concrete-filled Steel Tube Columns with Rectangular Section”, China Civil Engineering Journal, 2001, Vol. 34, No. 4, pp. 21-31.

[25] Han, L.H. and Yang, Y.F., “Study on Behavior of Concrete Filled Square Steel Tubes under Axial Load”, China Civil Engineering Journal, 2001, Vol. 34, No. 2, pp. 17-25.

[26] Tomii, M. and Sakino, K., “Experimental Studies on the Ultimate Moment of Concrete Filled Square Steel Tubular Beam-Columns”, Journal of Structural and Construction Engineering, 1979, No. 275, pp. 55-63.

[27] Tomii, M. and Sakino, K., “Experimental Studies of Concrete Filled Steel Tubular Columns under Concentric Loading”, In: Proceedings of the International Colloquium on Stability of Structures under Static and Dynamic Loads, SSRC/ASCE/Washington, D.C./March, 1977, pp. 17-19.

[28] Sakiuo, K., “Behaviors of Concrete Filled Steel Tubular Columns under Concentric Loadings”, The Third International Conference on Steel-Concrete Composite Structures, Fukuoka, 1991, pp. 295-309.

[29] Zhang, S.M., Guo, L.H., Ye, Z. and Wang, Y.Y., “Experimental Research on High Strength Concrete Filled SHS Stub Columns Subjected to Axial Compressive Load”, Journal of Harbin Institute of Technology, 2004, Vol. 36, No. 12, pp. 1610-1614.

[30] Ye, Z.L, “Study on Behavior of High-strength Concrete Filled Square and Rectangular Steel Tubes”, Master Dissertation of Harbin Institute of Technology, 2001.

[31] Tao, Z. and Yu, Q., “Experiment, Theory and Method of New Hybrid Structural Columns”, Beijing, Science Press, 2006.

[32] Yu, Q. and Tao, Z. and Wu, Y.X., “Experimental Behavior of High Performance Concrete-filled Steel Tubular Columns”, Thin-Walled Structures, 2008, No. 46, pp. 362-370.

[33] Tao, Z., Han, L.H. and Wang, Z.B., “Experimental Behavior of Stiffened Concrete-filled Thin-walled Hollow Steel Structural (HSS) Stub Columns”, Journal of Constructional Steel Research, 2005, No. 61, pp. 962-983.

[34] Wang, Q.P. and Li, H.W., “Experimental Study on the Concrete Filled Square Thin-walled Steel Tubes Subjected to Axial Compression”, Low Temperature Architecture Technology, 2005, No. 3, pp. 51-52.

[35] He, M.S. and Liu, X.Y., “Study on Behavior of Lightweight Aggregate Concrete Filled Square Thin-walled Steel Tubes under Axial Load”, Sichuan Building Science, 2008, Vol. 34, No. 2, pp. 18-21.

[36] Zhang, Y.C. and Chen, Y., “Experimental Study and Finite Element Analysis of Square Stub Columns with Straight Ribs of Concrete-filled Thin-walled Steel Tube”, Journal of Building Structures, 2006, Vol. 27, No. 5, pp. 16-22.

[37] Lv, X.L., Yu, Y. and Chen, Y.Y., “Behavior of Axially Loaded Concrete-filled Rectangular Tubular Columns”, Experiment, Building Structures, 1999, No. 10, pp. 41-43.

[38] Zhang, Z.G., “Mechanism and Capacity Analysis of Concrete Filled Square Steel Tubular Columns”, Industrial Construction, 1989, No. 11, pp. 2-7.

[39] Fan, Z., “Analysis of Ultimate Axial Loads of Concrete-filled Steel Columns with Rectangular Section”, Engineering Mechanics, 1994, Vol. 11, No. 3, pp. 80-86.

[40] Xu, M., “Study on Experiment, Theory and Application of the Confined Steel Reinforced Concrete Columns”, Doctoral Dissertation of Southeast University, 2000.
[41] Tao, Z. and Han, L.H., “Design of Concrete Filled Square Steel Tubular Members”, Journal of Harbin University of Civil Engineering and Architecture, 2001, Vol. 34, No. 3, pp. 16-22.
[42] Wang, H.J. and Shang, Z.Q., “Experimental Research on the Behavior of Square Concrete Filled Steel Tubes under Axial Compression”, Journal of Shenyang University of Technology, 2005, Vol. 27, No. 1, pp. 98-102.
[43] He, F., Zhou, X.H. and Tang, C.H., “Experimental Research on the Bearing Behavior of High-strength-concrete-filled Steel Tube under Axial Compression”, Engineering Mechanics, 2000, Vol. 17, No.4, pp. 61-66.
[44] Kenji, S., Hiroyuki, N. and Shosuke, M., “Behavior of Centrally Loaded Concrete Filled Steel Tube Short Columns”, Journal of Structural Engineering, 2004, Vol. 130, No. 2, pp. 180-188.
[45] Han, L.H., “Theoretical Analysis and Experimental Researches for the Behaviors of High Strength Concrete Filled Steel Tubes Subjected to Axial Compression”, Industrial Construction, 1997, Vol. 27, No. 11, pp. 39-44.
[46] Tan, K.F., Pu, X.C. and Cai, S.H., “Study on the Mechanical Properties of Steel Extra-high Strength Concrete Encased in Steel Tubes”, Journal of Building Structure, 1999, Vol. 20, No. 1, pp.10-16.
[47] Liu, J.P., Zhang, S.M. and Guo, L.H., “Axial Compression of Behavior Square Tube Confined High Strength Concrete (HSC) Short Columns”, Journal of Harbin Institute of Technology, 2008, Vol. 40, No. 10, pp. 1542-1545.