Study on the Eccentric Compression Performance of Stiffened Square CFST

Xinzhi Zheng1,2,3,* Zhixiang Zhou1 Shuang Zheng4 Taotao Wang3
1Post-doctoral research station of civil engineering, Chongqing Jiaotong University, Chongqing 40074, China;
2Henan engineering laboratory of ecological architecture and environment construction, Henan Polytechnic University, Jiaozuo 454000, China;
3Institute of bridge detection and reinforcement technology, Huanghe Jiaotong University, Jiaozuo 454950, China;
4School of civil Engineering, Zhengzhou Institute of Technology, Zhengzhou 450044, China.
*Corresponding author’s e-mail: zxz@hpu.edu.cn

Abstract: Concrete-filled steel tubular columns (CFST) have high bearing capacity, high stiffness and good ductility. The columns with square or rectangular section are more suitable for compression bending than round. However, its lateral binding force is small in the middle of the section, and local buckling is easy to occur. Stiffened Square Concrete Filled Steel Tubular columns (SSCFST) are proposed to solve the problem that ordinary square concrete filled steel tubular columns(SCFST) are prone to appear local buckling before reaching the limits of carrying capacity in 3 cases such as the thinner steel tube wall, the larger diameter to thickness ratio or width to thickness ratio. SSCFST are SCFST added with stiffening ribs, stiffening hoops and binding bars. By its set, the lateral stiffness and the resistance ability of the local buckling of the steel tube are effectively enhanced, so the confinement effects of the steel tube to core concrete become stronger and more uniform. To compare the improved effects of SSCFST and SCFST with binding bars under eccentric compression, the paper compiles the solving procedure of the cross section grid unit method which can accurately solve the whole process curve of SSCFST under eccentric compression. The whole process curves show that the eccentric bearing capacity and ductility of SSCFST are obviously improved with respect to SCFST with binding bars.

1. Introduction
The binding effects of SCFST upon internally filled concrete, center in the corner. The lateral constraints depend on the out-of-the-plane rigidity of the steel tubular walls. Commonly used CFST have a relatively large width to thickness ratio. Thus the lateral binding is smaller. The deformability of columns makes it difficult to achieve the desired effects of improved bearing capacity [1-3]. Measures such as increasing the thickness of steel tubular walls can improve the lateral binding force. Unfortunately it requires great amounts of steel consumption, and with the currently weak economy, this becomes an obstacle.
The scholars at home and abroad have undertaken numerous endeavors to improve the performance of SCFST placed under axial compression. The reference[4-6] studied the axial compression properties of SCFST with binding bars. Studies show that a set of binding bars is helpful in improving the carrying capacity of an axial-load. They can also improve the ductility of SCFST. The reference[7-10] studied eccentric compression properties of SCFST with binding bars. The research shows that a set of binding bars is helpful in improving the carrying capacity of an eccentric-load. The study also confirms that binding bars improve the ductility of SCFST. Susantha et al. [11] proposed a study of the buckling mode bearing capacity and ductility of stiffeners, in a structured form and at the midpoint of the surrounding sides of CFST. Zhou Jizhong calculated and compared the cost of SCFST with rib to the cost of ordinary SCFST that have been placed under the typical conditions of axial and eccentric pressure[12]. Liang, Liu, and Uy then investigated the local buckling of CFST[13-15].

All these studies have shown that simple measures, such as setting binding bars and/or stiffeners, can significantly enhance the restriction from the steel tubes to concrete. Confinement effects also significantly improve, effectively delay the local buckling of steel and consequently improve the bearing capacity and ductility of present members.

Based on the findings above, this paper proposes that upon a foundation of SCFST with binding bars, SSCFST should be set with stiffening ribs, stiffening hoops and binding bars. It does not significantly increase the amount of steel needed, while delaying and preventing the local-buckling of the steel. It improves the utilization of steel strength and constraints capacity on the core concrete, shown in Fig.1.

Binding bars uniformly transfer constraint force upon steel plates. This uniformity causes binding bars to administer linear constraint and avoid the over concentration of stress, which, in turn, divides the plates into segments along the longitudinal and sectional length direction. The division reduces the steel plates' height-to-width and width-to-thickness ratios, thus greatly reducing the semi-buckling wavelength. The set of stiffening ribs slow local buckling between the binding bars that are found along the vertical portion of the observed component. This process allows for the full display of lateral strength exerted by the binding strips[16].

2. Sectional grid element method
As is illustrated in Fig.2, a sectional grid element method can be effectively employed to the analysis of SSCFST that have been found under eccentric compression.

Sectional grid element method divides the specimen cross-section into various grids, and assumes that the strains of each grid are consistent while stress is evenly distributed. A numerical analysis is dependent upon the following assumptions:

1. Sectional strain is linear;
2. Any relative slip between steel and concrete is not considered;
3. Tensile strength of concrete is not considered;
4. Specimen ends are hinged and the deflection curve shows a half sine-wave curve;

### 3. Eccentric compression bearing capacity of SCFST only with binding bars and SSCFST

| Model    | $b_{jh}$(mm) | $t_{jh}$(mm) | $b_{jv}$(mm) | $t_{jv}$(mm) | $N_{max}$(MN) | $W_{max}$(mm) | $M_{max}$(Mpa) | $\phi_{max}$(10^-4) |
|----------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|--------------------|
| SDB      | 0             | 0             | 0             | 0             | 1.6410        | 7             | $81.7281$       | 0.493              |
| NZWH-1   | 10            | 8             | 8             | 10            | 1.8178        | 7             | $98.5377$       | 2.413              |
| NZWH-4   | 16            | 5             | 5             | 16            | 1.8436        | 7             | $101.3336$      | 2.193              |
| NZWH-6   | 20            | 4             | 4             | 20            | 1.8547        | 7             | $102.5204$      | 2.084              |

It can be seen from Table 1: with the width-to-thickness ratio of the stiffening hoops decreasing, or the width-to-thickness ratio of the stiffening ribs increasing, SSCFST experience an increasing peak eccentric bearing capacity and an increasing ultimate moment. With the width-to-thickness ratio of the stiffening hoops decreasing, or the width-to-thickness ratio of the stiffening ribs increasing, SSCFST experience an increasing peak eccentric bearing capacity and an increasing ultimate moment. These effects are beneficial in improving the eccentric bearing capacity of SSCFST. It is consistent with the changing trend of the axial compression bearing capacity.

### 4. Conclusion

This paper established a analytical model by taking the sectional grid units to accurately calculate, communicated with data, and discussed the eccentric bearing capacity of SSCFST. The main conclusions are withdrawn from the study as follows:

1. SSCFST don't significantly increase the amount of steel needed, while delaying and preventing the local-buckling of the steel, it improves the utilization of steel strength and constraints capacity on the core concrete.
2. Sectional grid element method divides the specimen cross-section of SSCFST into various grids, it can be effectively employed to the analysis of SSCFST that have been found under eccentric
(3) The optimized stiffening ribs and stiffening hoops can effectively improve the eccentric performance of SSCFST. The peak capacity and the ultimate moment of SSCFT significantly increase with respect to SCFST with only binding bars installed.

(4) Under the same conditions, with the increase of the width to thickness ratio of the stiffening ribs or the decrease of the stiffening hoops, the peak eccentric bearing capacity and ultimate moment of the specimens are both increasing accordingly, but the corresponding ultimate deflection and sectional curvatures changed little.

(5) With the increase of the width to thickness ratio of the stiffening ribs or the decrease of the stiffening hoops, the changing trend of the eccentric bearing capacity is consistent with the axial compression bearing capacity to SSCFST.

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