Eccentric compressive behaviour of double steel-concrete shear wall constrained with ribs and bars

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Abstract. By adding ribs and bars to form the double steel-concrete shear wall constrained with ribs and bars, the steel plate of the whole steel-concrete shear wall can be strengthened of the constraint. The research on Eccentric compressive behavior of double steel-concrete shear wall constrained with rib and bar is less, this paper analyzes double steel plate concrete shear wall by using larger length-width rectangular CFST column research methods. Based on the constitutive relation of the rectangular CFST column with ribs and bars, the relative parameters are changed, and a program is written to compare and analyze eccentric compressive behavior of double steel-concrete shear wall constrained with ribs and bars compared with that double steel plate concrete shear wall only constrained with bars.

1. Introduction
The application of double steel-concrete shear wall in high-rise buildings has obvious advantages\textsuperscript{[1-2]}. Nie Jianguo et al.\textsuperscript{[3-4]} conducted tests and theoretical studies on the double steel steel-concrete combined with welded bolts and reinforcement, indicating that the combined shear wall has a high shear bearing capacity and good seismic performance. JI et al. \textsuperscript{[5]} proposed the combined shear wall form of double steel-concrete shear wall with circular steel tube concrete column as the edge constraint member, and the concrete-filled steel tube column as the edge constraint member can enhance the seismic performance of shear wall. Clubley et al.\textsuperscript{[6-7]} conducted tests and numerical simulation studies on the double steel-concrete shear wall with internal welded shear connectors, indicating that the internal welded shear connectors have strong shear resistance. Hossain et al.\textsuperscript{[8]} studied the shear performance of the double-sided compacted steel plate filled with concrete composite shear wall set with bolts and showed that the shear wall had good shear performance. Ma Kaize et al.\textsuperscript{[9]} pointed out that combined shear walls with stiffeners have better seismic performance through comparative tests.

The above researches mainly focus on the influence of the setting of bars and ribs on the seismic...
performance of such combined shear walls, but the influence of the setting of bars and ribs on the eccentric compression performance of such combined shear walls is less. In this paper, the double steel-concrete shear wall combined with bars and ribs is studied in the form of a combination of bars and ribs. The influence of bars and ribs on the eccentric compression performance of the combined shear wall is studied through the eccentric compression simulation analysis of the double steel-concrete shear wall combined with bars and ribs.

2. Constraint mechanism of double steel-concrete shear wall constrained with ribs and bars
The strong constraint mechanism of double steel-concrete shear wall with bars is shown in Fig.1. The shaded area in the Figure is the weak constraint area. By adding ribs on the inner wall of the steel plate, the double steel-concrete shear wall is restrained by ribs and bars. Mutual collocation of the ribs and bars, closely coordinated and complementary role improve the constraint effect of the bar, make the restriction of steel plate on the core concrete along the perimeter in a more balanced. It further improves the overall effect of restraint, and also can resist some pull (pressure) force of pull (pressure) to block the spread of local buckling and spread with layers of defenses, and ease the outside surface deformation between the bars. The bearing capacity and ductility of members are improved, it greatly reduces the thickness of steel plates, and the project cost is controlled.
3. Eccentric performance analysis

3.1 Sectional grid element method

A sectional grid element method can be effectively employed to the whole process analysis of the double steel-concrete shear wall with ribs and bars 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;

From (4), curvature shows as follows when the mid-span deflection is $u_m$.

$$\phi = \frac{\pi^2}{L^2} u_m$$

When eccentric compression occurs along the $x$ direction, a centroidal strain of cross-sectional units may be found:

$$\varepsilon_i = \varepsilon_0 + \phi x_i$$

When eccentric compression occurs along the $y$ direction, a centroidal strain of cross-sectional units may be found:

$$\varepsilon_i = \varepsilon_0 + \phi y_i$$

Where $\varepsilon_0$ represents the centroidal strain, it remains positive under pressure; $x_i$ displays calculated centroidal coordinates of the unit.

$\varepsilon_i$ is determined by the steel stress $\sigma_\alpha$ and the concrete stress $\sigma_i$.

The internal moment $M_{in}$ and the internal axial force $N_{in}$ are available as follows:

$$N_{in} = \sum_{j=1}^{m} \sum_{i=1}^{n} (\sigma_\alpha \Delta A_{\alpha i} + \sigma_i \Delta A_{\alpha i})$$

$$M_{in} = \sum_{j=1}^{m} \sum_{i=1}^{n} (\sigma_\alpha x_i \Delta A_{\alpha i} + \sigma_i x_i \Delta A_{\alpha i})$$

where $\sigma_\alpha$ is the longitudinal stress of steel;

$\sigma_\alpha$ is the ribs;

$\sigma_i$ is the longitudinal stress of concrete;

$m$ represents the division number of steel and concrete unit along the $x$ direction;

$n$ represents the division number of steel and concrete unit along the $y$ direction.

Initial eccentric specimens should meet this formula:

$$M_{in} / N_{in} = \varepsilon_0 + u_m$$

While changing $u_m$, $\varepsilon_0$ is automatically adjusted to meet the balance.

The specific steps involved in the process:

1) Dividing the sectional grid cells;
2) The centroidal strain, $\varepsilon_i$, found on each grid cell, is derived by designating the centroidal sectional strain $\varepsilon_o$. Sub-routine 2 is set by the constitutive relation of concrete and steel. The centroidal strains $\sigma_\alpha$ and $\sigma_i$ of each stress unit for concrete, steel and stiffeners can be calculated.
3) Compiling sub-routine 1 for the calculation of the sectional internal-axial force and movement. The output results meet $M_{in} / N_{in} = \varepsilon_0 + u_m$; conversely $\varepsilon_0$ constantly adjusts. Then steps 2) and 3) are
repeated until \( M_u / N_u = e_0 + u_m \) is reached.

By changing \( u_m \), the \( N - w \) curve can be created (axial force-deflection in the middle of the column), and the \( M - \phi \) curve (moment-curvature curve) can be created while repeating the above steps 2) and 3). The peak values of the curves respectively indicate the ultimate bearing capacity \( N_{max} \) and the ultimate bending moment \( M_{max} \) of specimens in the initial conditions of eccentricity.

According to the sectional grid units, the paper compiled a numerical analysis, method program containing a section of finite elements. Setting the eccentric compression along the x direction, the whole process of \( N - w \) curves and \( M - \phi \) curves are calculated. Initial deflections are enhanced by \( L/1000 \), a calculation to consider the effect of initial defects on the longitudinal loading conditions while making and installing other factors. This method considers the constraint effect of ribs and bars. It can be applied to engineering design.

3.2 Eccentric compressive behavior of double steel-concrete shear wall constrained with ribs and bars

Take the long side width of the research model as 1000mm and the eccentricity \( e_0 = 200 \text{mm} \). The constitutive relation of the double steel-concrete shear wall with bars is used to constrain it, relevant parameters are changed, and a program is written to solve its eccentric performance, as shown in Fig.3 and Fig.4. The characteristic values of the eccentric bearing capacity of the double steel-plate concrete shear wall with bars are shown in Table 1.

![Fig.3 curve comparison of WB N-w](image)

![Fig.4 curve comparison of WB M-Ø](image)

Table 1 Eccentric compressive characteristic values of double steel-concrete shear wall with bars

| Model | \( N_{max} \)(MN) | \( W_{max} \)(mm) | \( M_{max} \)(kN·m) | \( \phi_{max} \)(10^{-5}) |
|-------|-----------------|-----------------|------------------|----------------------|
| WB    | 5.887           | 1               | 1187.1           | 0.548                |

3.3 Eccentric compressive performance of double steel-concrete shear wall with bars

Take the long side width as 1000mm, and the short side width as 200mm. The RSNZ-1 and RSNZ-5, RSNZ-6 of the double steel-concrete shear wall with ribs and bars are established. The research model of RSNZ-6 is set up (to speed up the program, change the width and thickness of stiffener, and take the integral value), and the eccentric distance \( e_0 = 200 \text{mm} \).

Its eccentric performance is solved by the program, as shown in Fig.5 and Fig.6. The characteristic values of the eccentric bearing capacity of the double steel-concrete shear wall with ribs and bars are shown in Table 2.
As can be seen from Fig. 5, Fig. 6 and Table 2, the peak eccentric bearing capacity and ultimate bending moment of the double steel-concrete shear wall are increased with the increase of the width-thickness ratio of the rib, and the corresponding ultimate deflection is the same, indicating that the increase of the width-thickness ratio of ribs is beneficial to the improvement of the bearing capacity of the double steel-concrete shear wall.

4. Conclusion
1) Based on the constitutive relation of the core concrete of the double steel-concrete shear wall with ribs and bars, the sectional grid element method is applied to calculate the eccentric bearing capacity of the double steel-concrete shear wall with ribs and bars.

2) The setting of ribs can effectively improve the eccentric performance of double steel-concrete shear walls with ribs and bars. Under the condition of the same eccentricity and other conditions, the peak eccentric bearing capacity and the ultimate bending moment both increase with the increase of the width-thickness ratio of the rib.

3) Under the same other conditions, the setting of ribs has little influence on the initial stiffness of the elastic stage, but has a great influence on the yield moment. When the rib is set, the yield moment of the component increases, the descending section of the curve tends to be more gentle, and the ductility of the component increases.

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