Study on the Influence of the Thickness of Column on Axial Compression Behavior of Cold-Formed Steel Composite Wall

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Abstract. By changing the thickness of the column, the axial compression behavior of the one-side sheathed wall and the both-sides sheathed wall can be altered at different levels. Simulation and inspection of cold-formed thin-walled steel frame wall had been finished by using a finite element simulation software called ABAQUS, which was applied by test data from relevant literature. The axial carrying capacity of the sheathed wall was superior than the unsheathed wall, therefore, all models had been built and studied based on the one-side sheathed wall and both-sides similar sheathed wall. The analysis results proved that the axial compression behavior of the one-side sheathed wall and the both-sides sheathed wall could be increased substantially by adding the thickness of studs, and this change was more sensitive to the influence of the wall with one-side sheathed wall especially.

1. Introduction
The axial carrying capacity of the composite wall is mainly undertook by the columns. The composite walls consist of studs, track, and the sheathing fastened to the flanges of the studs. According to the literature [1], the load carrying performance of this wall was superior than the wall with no board. Therefore, the literature [2] was referred, ABAQUS finite element analysis was used to investigate the effect of the column thickness on the axial bearing capacity by changing the thickness of the column. These conclusions can be referred for subsequent research.

2. Finite element model analysis
According to this study(Vieira 2011), the size of the C-section studs was $93.577 \times 42.084 \times 12.982 \times 1.86\text{mm}$, 0.61m in length, which was shown as Fig 1. The yield strength was 382.9MPa. The size of the U-section tracks was $98.264 \times 30.719 \times 2.14\text{mm}$, 0.44m in length. The yield strength was 487.5MPa. The sheathing was oriented-strand board. The thickness of it was 11.1mm, yield strength was 3500MPa.

In practical engineering, the central column of the composite wall is considered as the main axial load bearing unit. In the software, the axial carrying performance of the composite wall can be studied by taking half of the structure of the composite wall, that is, selecting the middle column, which can not only simulate the actual working conditions, but also simplify the calculation [3].

According to the test conditions of the research [2], setting reasonable boundary conditions for tracks and columns may be considered. Self-tapping screws were used to connect column and column, column and track, track and the sheathing [4]. In ABAQUS finite element analysis, self-tapping screws were simulated by coupling constraints. The picture of finite element model for composite wall with one-side sheathing was shown as Fig 2.
3. Verification of the finite element modeling

From Table 1, the software analysis results and test results of one-side sheathed wall and both-sides sheathed wall can be compared intuitively. The model was verified by comparing the peak load of the test with the finite element analysis, the ratio of the test peak load to the peak load of the finite element analysis, and the limit state of the test and the analysis of ABAQUS.

**Table 1.** Comparison between numerical analysis results and test results.

| Model       | Experimental Peak Load (KN) | Numerical Peak Load (KN) | Experimental Limit State | Numerical Limit State | $\alpha$ |
|-------------|-----------------------------|--------------------------|-------------------------|-----------------------|----------|
| Bare-OSB    | 90.11                       | 95.41                    | L                       | L                     | 0.945    |
| OSB-OSB     | 96.43                       | 101.59                   | L                       | L                     | 0.949    |

*L*-Local buckling between self-tapping screws at the top of the column.

$\alpha$ -The ratio of experimental peak load to numerical peak load.

For a 0.61 meter long composite wall, the load is carried from the top of the column and transmitted to the sheathing. The sheathing does not directly bear the axial load, but it can share the axial load with the whole steel framing wall studs. The oriented-strand board not only plays a protective role, but also becomes a part of the structural load system [5]. The walls(Bare-OSB,OSB-OSB) are locally buckled between the self-tapping screws at the top of the column, with local damage to the sheathed board.

Comparing the results of the numerical analysis and test, it is found that the difference between the peak load is within 10%, and the limit state are completely consistent. This may be a conclusion that the finite element analysis results agree well with the experimental results and the axial carrying capacity and buckling modes of wall columns were reliably simulated in this model.

4. Axial compression performance of composite wall in different studs thickness

One-side and both-sides sheathed model were used as the research object to load axial compression by finite element analysis. The thickness of the studs were controlled as 1.08mm, 1.29mm, 1.55mm, and 1.86mm, respectively. The thickness of the studs increase by a fixed multiple was guaranteed and the lengths of all the studs are 0.61m.
By changing the thickness of the column, it may be shown in Table 2 that the peak load were different under different thickness.

**Table 2.** The numerical results of walls with different thickness of studs.

| Model | Column Thickness (mm) | Numerical Peak Load (KN) | β | Numerical Limit State |
|-------|-----------------------|--------------------------|---|-----------------------|
| BS-1  | 1.08                  | 46.16                    | 0 | LB                    |
| BS-2  | 1.29                  | 58.97                    | 27.7 | LB |
| BS-3  | 1.55                  | 73.65                    | 59.5 | LB |
| BS-4  | 1.86                  | 90.11                    | 95.2 | LB |
| SS-1  | 1.08                  | 50.58                    | 0 | LB |
| SS-2  | 1.29                  | 64.57                    | 27.6 | LB |
| SS-3  | 1.55                  | 78.18                    | 54.5 | LB |
| SS-4  | 1.86                  | 96.43                    | 90.6 | LB |

*BS - One-side sheathing(Bare-OSB). SS - Both-sides sheathing(OSB-OSB). β - The magnitude of increasing peak load compared to the peak load when the column thickness is 1.08mm. LB - Local buckling between self-tapping screws at the top of the column.

By changing the thickness of the studs, the distributions of stress were different under different thickness(Fig 3, Fig 4).

**Figure 3.** Stress nephogram of the sheathing.  **Figure 4.** Stress nephogram of the composite wall.

For one-side sheathing(Bare-OSB), axial bearing capacity of composite walls with the column thicknesses of 1.29mm, 1.55mm, and 1.86mm is 27.75%, 59.55%, 95.21% higher than the wall with the column thickness of 1.08mm. For both-sides sheathing(OSB-OSB), axial bearing capacity of composite walls with the column thicknesses of 1.29mm, 1.55mm, and 1.86mm is 27.66%, 54.57%, 90.65% higher than the wall with the column thickness of 1.08mm.
Under the same thickness, in terms of axial bearing capacity, the composite wall with both-sides sheathing is about 7% higher than the wall with one-side sheathing. For the axial carrying capacity of composite walls, the sheathing has a significant effect [6].

Through comparison and analysis, it can be seen that changing the thickness of the column had a great impact on the ultimate axial bearing capacity of composite wall. Comparing the one-side sheathed and the both-sides sheathed wall, it can be found that it is more sensitive to one-side sheathed wall by changing the thickness of the studs.

After analysis, the main reason is that the both-sides oriented-strand board and the C-shaped steel column formed a closed structure, which had a sheeting diaphragm effect. The strength and stiffness of the OSB sheathed board on both sides were used to provide the necessary support for the composite wall to be stabilized. As the thickness of the column was increased gradually, the local buckling was no longer obvious. However, no sheathing was shown on another side in the composite wall with one-side sheathing, the column is more easily to be local buckled in flange than in web on the side without the sheathing.

Without changing any other factors of the composite wall, only the thickness of C-shaped steel has been changed. For one-side sheathed wall, the effective cross-sectional area of BS-2 was increased by 18.94% and the peak load was increased by 27.75% than BS-1. The effective cross-sectional area of BS-3 was increased by 42.17% and the peak load was increased by 59.55% than BS-1. The effective cross-sectional area of BS-4 was increased by 69.53% and the peak load was increased by 95.21% than BS-1. The cross-sectional characteristics was actually improved by the increasing of thickness of the column. The axial bearing capacity of the composite wall increases with the raising of the cross-sectional area and the inertia moment of the studs.

5. Conclusion

In this study, the axial compression performance of the wall with the one-side sheathing and the both-sides sheathing can be improved efficiently by increasing the thickness of studs, and it is more sensitive to the influence of the wall with one-side sheathing especially.

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