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A multi-ribbed composite wall with low-yield strength steel for seismic mitigation

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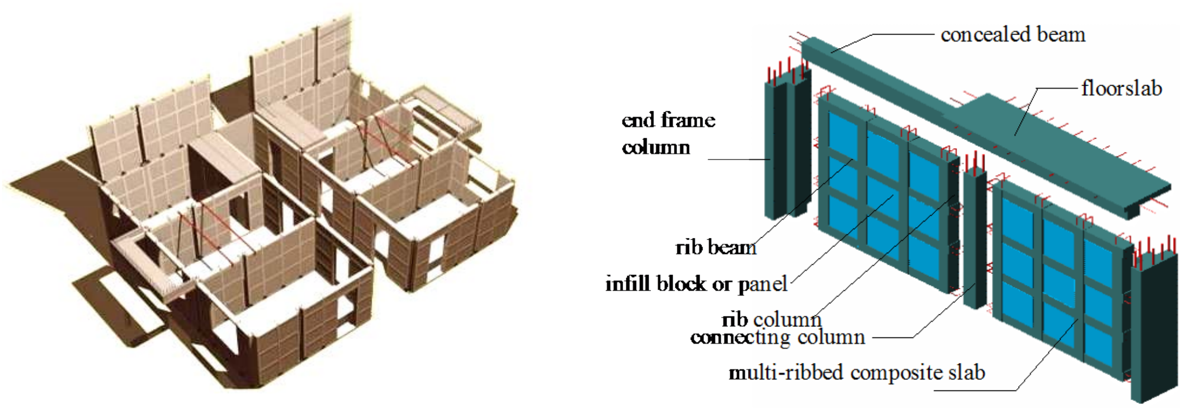
Abstract

Low yield strength steel is often used to make various type of energy-consuming or seismic damping devices because of its strong energy dissipation performance. Multi-ribbed composite wall structure (MRCWS) is composed of prefabricated multi-ribbed composite wall slab, cast-in-suit concealed outer frame and cast-in-place or precast floorslab, being a kind of lightweight, energy saving and environmental protection structure. In this paper, according to the basic component and construct characteristic of the multi-ribbed composite wall structure as well as high energy dissipation performance of low yield strength steel, a new multi-ribbed composite wall with low yield strength steel is provided for seismic mitigation of the structure, while the low yield strength steel of 100MPa, 160MPa and 225MPa grade is chosen. The earthquake response analysis of the control structure systems under horizontal earthquake wave has been carried out by using program IDARC2D. The seismic mitigation effect of the low yield point steel panel for the multi-ribbed composite wall structure was discussed. The calculating results show that the low yield strength steel panels have obvious seismic reducing effect for the multi-ribbed composite wall structure, which seismic damping rate is 15%~30% under the seismic frequent intensity, and is 30%~60% under the seismic fortification intensity and the seismic rare intensity at 8 degree seismic fortification region of China Code for seismic design of buildings, so a simple and effective seismic mitigation technique is provided for the multi-ribbed composite wall structure.

Keywords: multi-ribbed composite wall structure; low yield strength steel panel; seismic mitigation

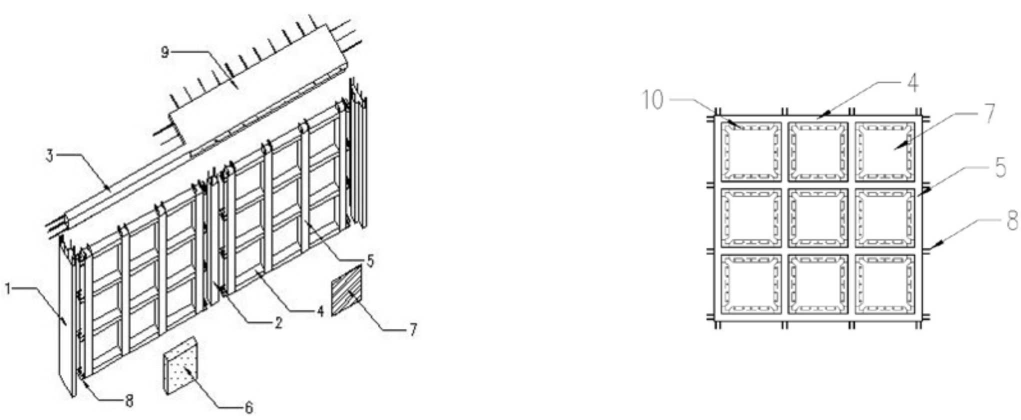
1. Introduction

Low yield strength steel is often used to make various types of energy-consuming or seismic damping devices because of its strong energy dissipation performance.Multi-ribbed composite wall structure (MRCWS) is composed of prefabricated multi-ribbed composite wall slab, cast-in-suit concealed reinforced concrete outer frame and cast-in-place or precast floorslab, in which the multi-ribbed composite wall slab is made up of reinforced concrete sash (formed by rib beam and rib column) and light filled blocks (such as aerated concrete block or other lightweight aggregate block), being a kind of lightweight, energy saving and environmental protection structure[1-5]，see Fig.1 (a)、(b). In this study, according to the basic component and construct characteristic of the MRCWS, combining high energy dissipation performance of low yield strength steel, we present a new type of the multi-ribbed composite wall by replacement of light filled block with low yield strength steel panels for seismic response control of the structure [6]，see Fig. 2(a)、(b). The seismic mitigation effect of the low yield strength steel panel for the MRCWS is discussed, the influence factors such as the location and amounts of the multi-ribbed composite wall with low yield strength steel panels are carefully studied,which provides more data information for the comprehension of earthquake responses of the MRCWS energy dissipation control system with the composite low yield strength steel panel wall.



(a) (b)

Fig.1 Multi-ribbed composite wall structure system: (a)MRCWS construction drawing; and(b) multi-ribbed composite wall slab with light filled blocks.



(a) (b)

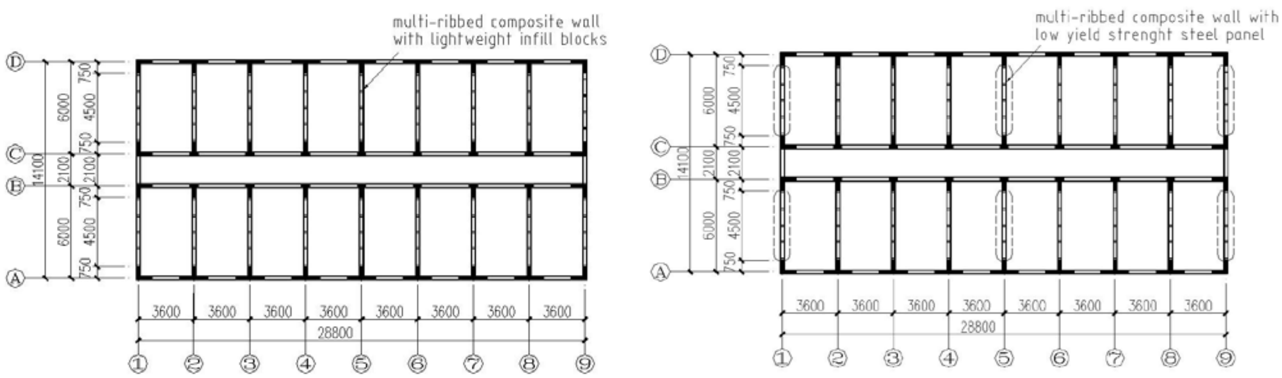
Note: 1.end frame column 2. connecting column 3. concealed beam 4. rib beam 5. rib column 6. light filled block 7. low yield strength steel panel 8. embedded reinforcement 9. floor slab 10. fishplate

Fig.2 Seismic energy dissipation control system of the MRCWS: (a) energy dissipation control structure drawing; and (b) multi-ribbed composite wall slab with low yield strength steel panels.

2. Structural seismic control analysis

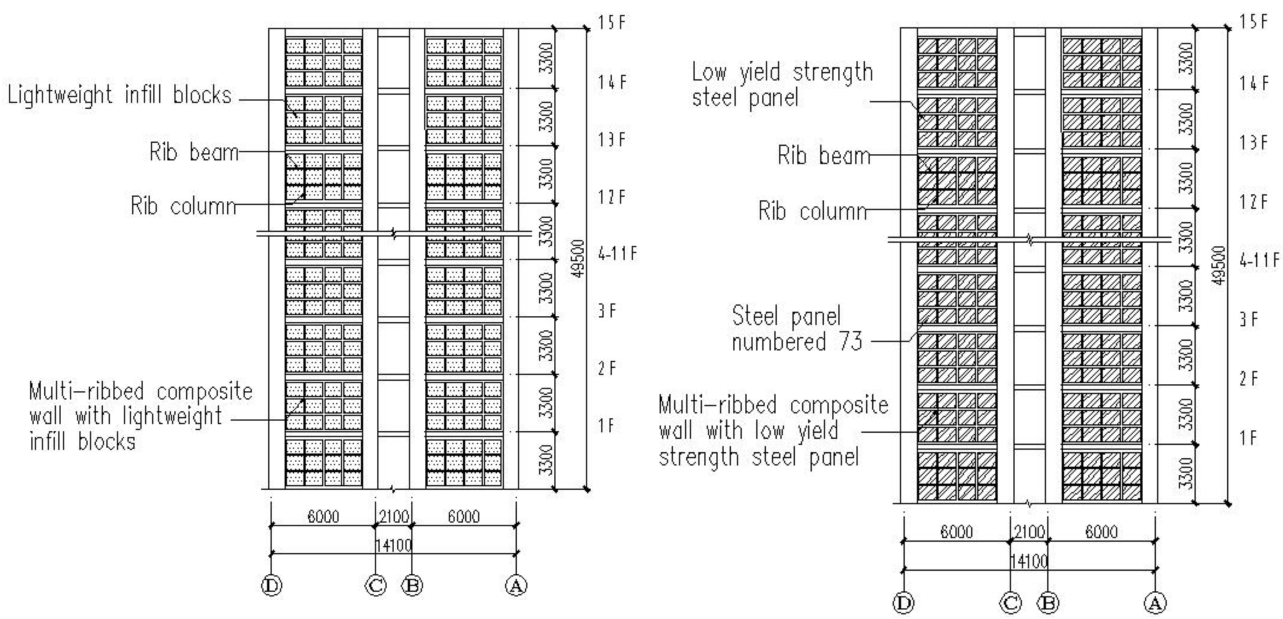
2.1 Calculating analysis model

The uncontrolled structure is a 15-storey practical prototype building structure with the multi-ribbed composite wall slab built-in infill silicate blocks，see Fig.3 (a) and Fig.4 (a). Structural control systems using the low yield strength steel panel wall is shown in Fig.3 (b) and Fig. 4 (b), the location of the multi-ribbed composite wall slab built-in the low yield strength panels are marked with dotted lines. The thickness of the multi-ribbed composite walls is 300mm. The low yield point steel of LYP100,LYP160 and LYP225 is chosen[7] , which computing yield stress is respectively $\sigma_y = 80$ N/mm^2, $\sigma_y = 140$ N/mm^2 and $\sigma_y = 205$ N/mm^2, while shear yield stress is respectively $\tau_y = 80/\sqrt{3}$ N/mm^2, $\tau_y = 140/\sqrt{3}$ N/mm^2 and $\tau_y = 205/\sqrt{3}$ N/mm^2.The thickness of low yield strength steel panels is separately 2mm,4mm and 6mm.



(a) (b)

Fig.3 Plan of the structure: (a) uncontrolled prototype structure; and (b) control structure.



(a) (b)

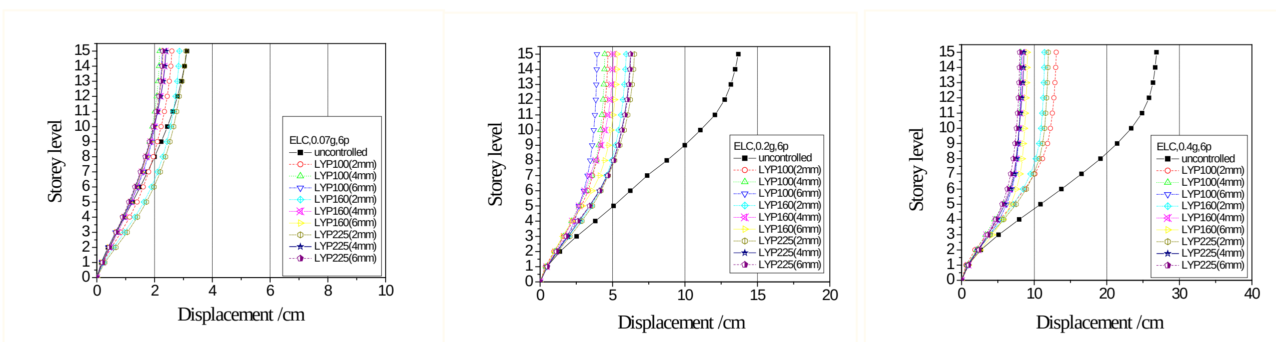
Fig.4 Elevation of the structures: (a) ①˜⑨axis of uncontrolled structure and ②˜④and⑥~ ⑧ axis of con and (b) ①and ⑤and ⑨axis of control structure.

2.2 earthquake response of the structure

The nonlinear earthquake responses of the structures are calculated by using program IDARC2D Version 7.0 [8]. The nonlinear dynamic analysis models of the structures are established with a retrogressive three-linear resilience model for representing reinforced concrete beam and column elements, while an equivalent strut approach integrated with a smooth hysteretic model for representing infill silicate blocks and low yield strength steel panels respectively, which the hysteretic model uses degrading control parameters for stiffness and strength degradation and slip pinching. The nonlinear dynamic time-history analysis of the structures under horizontal earthquake has been carried out. The natural earthquake ground motions El-Centro wave was chosen. Inputting peak ground motion acceleration is 0.07g, 0.2g and 0.4g, being respectively representative for design acceleration of ground motion at seismic frequent intensity, fortification intensity and rare intensity of 8 degree seismic fortification region of China Code for seismic design of buildings [9].

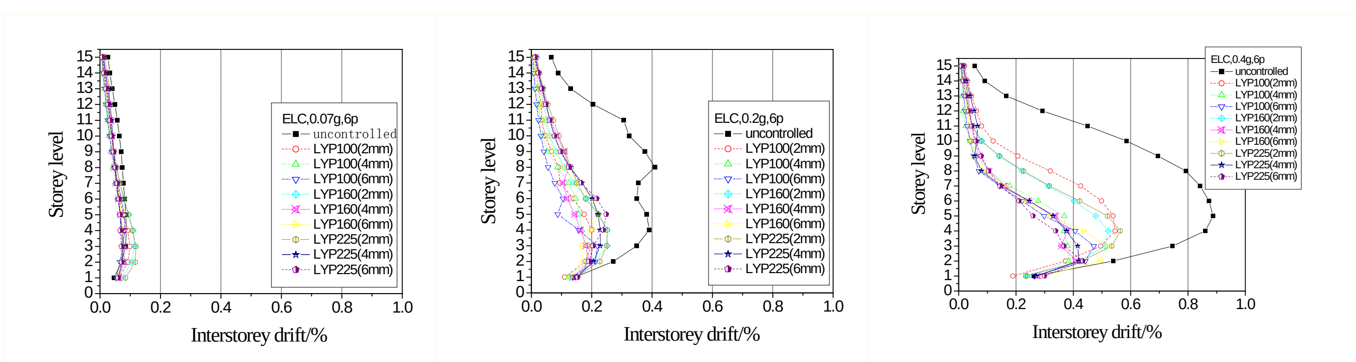
Maximum displacement responses of the structures with different earthquake acceleration amplitude are shown in Fig.5 (a)~(c); Maximum interstorey drift angle responses of the structures with different earthquake acceleration amplitude are shown in Fig.6(a)~(c); Time-history responses of displacement at top storey and Interstorey drift at 4th storey are shown in Fig.7(a)~(b). Hysteretic curves of an low yield point steel panel 73 being locateed in the fourth floor indicated in figure 4(b) are shown in Fig.8(a)~(c).

From the Fig.5 ~ Fig.7 it can be seen that maximum horizontal displacement and maximum interstorey drift angle responses of control structure with low yield point steel panels have obvious reduction, especially under 0.2g and 0.4g. Fig.8(a)~(c) show that the hysteresis curves of the embedded low yield point steel panel is full and smooth, which has high energy dissipation performance.



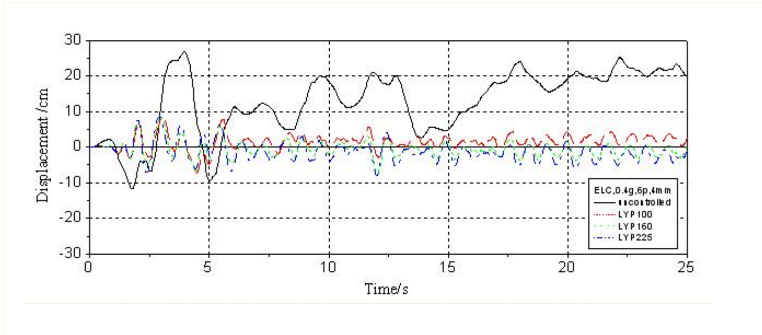
(a) (b) (c)

Fig.5 Maximum displacement responses of the structures with different earthquake acceleration amplitude:(a) 0.07g; (b) 0.2 g; and (c) 0.4 g.

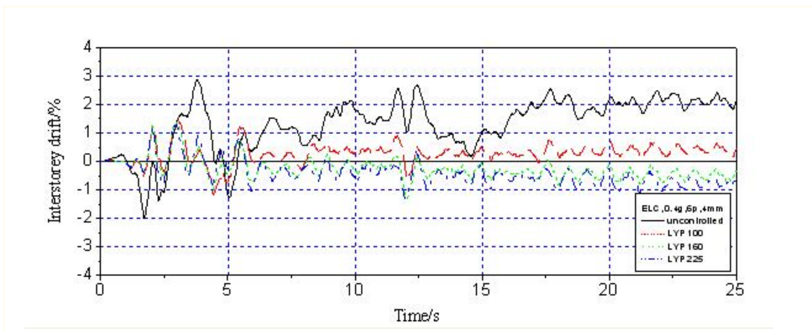


(a) (b) (c)

Fig.6 Maximum interstorey drift responses of the structures with different earthquake acceleration amplitude:(a) 0.07g; (b) 0.2 g; and (c) 0.4 g.

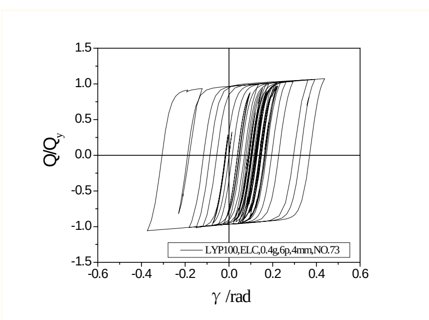


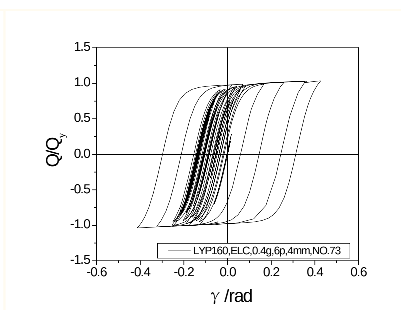
(a)

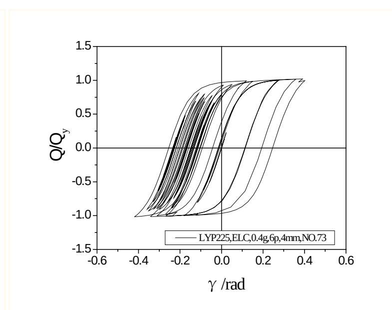


(b)

Fig.7 Time-history responses of displacement at top storey and interstorey drift at 4th storey under 0.4g: (a) displacement; and (b) interstorey drift.







(a) (b) (c)

Fig.8 Hysteretic curves of an low yield strength steel panel numbered 73 under 0.4g with different yield strength: (a) LYP100; (b) LYP160; and (c) LYP225.

2.3 Damping rate analysis

In order to further study the damping control effect of low yield strength steel panels, based on the prototype structure, the multi-ribbed composite wall with low yield strength steel panels has six kinds of layout scheme as follows: (a) 2 pieces of wall；(b) 4 pieces of wall；(c) 6 pieces of wall；d) 8 pieces of wall；(e) 10 pieces of wall；(f) 12 pieces of wall. The plane position of the multi-ribbed composite wall with the low yield strength steel panels being marked with dotted lines is shown in Fig. 9(a)~ (f)， while the composite steel panel walls are located from first storey to fifth storey(see Fig. 4 (b)).

The maximum horizontal displacement and maximum interstorey drift angle of the structure is taken as the control object. Damping control effect of low yield point steel panels is indicated by adopting the damping rate as follows:

$$\eta_{\Delta} = \frac{\Delta_0 - \Delta_w}{\Delta_0} \times 100\% \quad (1)$$

$$\eta_{\delta} = \frac{\delta_0 - \delta_w}{\delta_0} \times 100\% \quad (2)$$

In which, η_{Δ} is damping rate of the maximum horizontal displacement, Δ_0 and Δ_w is respectively the maximum horizontal displacement of the uncontrolled structure and the control structure; η_{δ} is damping rate of the maximum interstorey drift angle, δ_0 and δ_w is respectively the maximum interstorey drift angle of the uncontrolled structure and the control structure.

Variation of maximum displacement responses at top storey with the number of the composite steel panel walls are shown in Fig.10 (a)~(c); Variation of maximum interstorey drift angle responses with the number of the composite steel panel walls are shown in Fig.11 (a)~(c); The corresponding damping rate of maximum displacement responses at top storey and maximum interstorey drift angle responses are shown in Fig.12 and Fig. 13,respectively. The calculating results show that the low yield strength steel panels have obvious seismic mitigation effects, which seismic damping rate is 15%~30% under the seismic frequent intensity(0.07g), and is 30%~60% under the seismic fortification intensity(0.2g) and the seismic rare intensity(0.4g) at 8 degree seismic fortification region of China Code for seismic design of buildings.

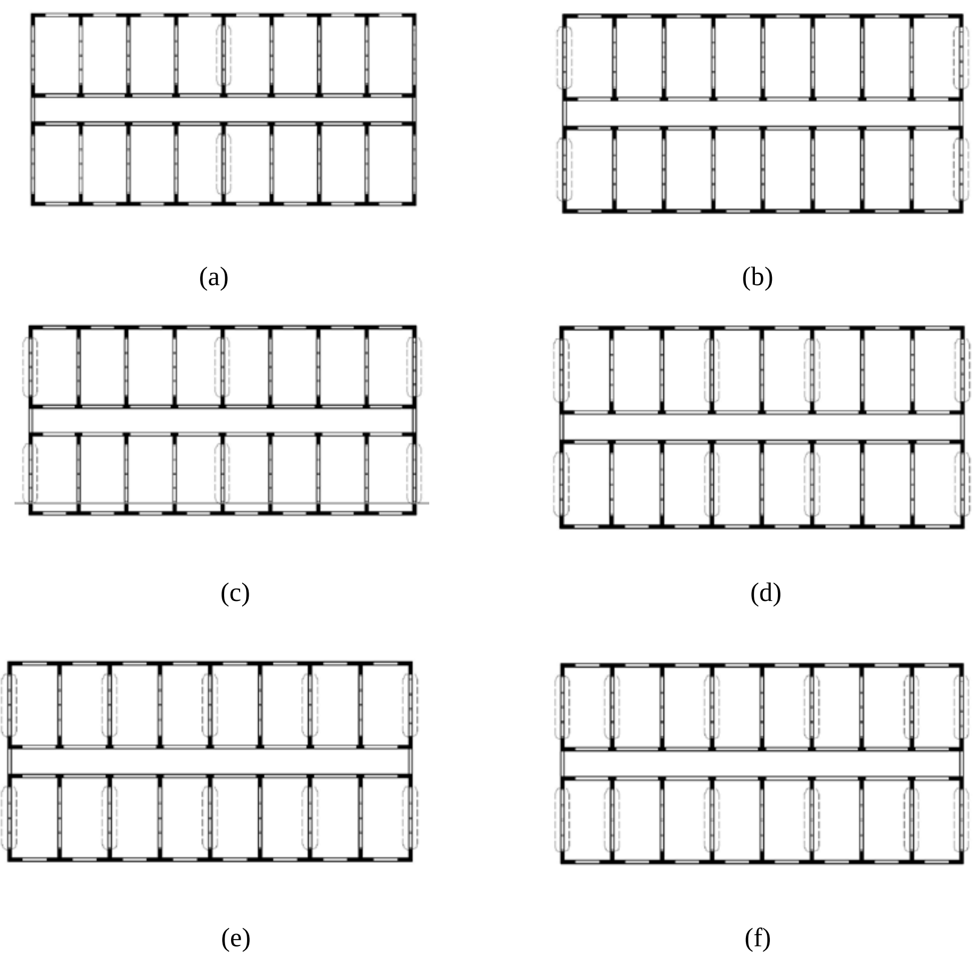
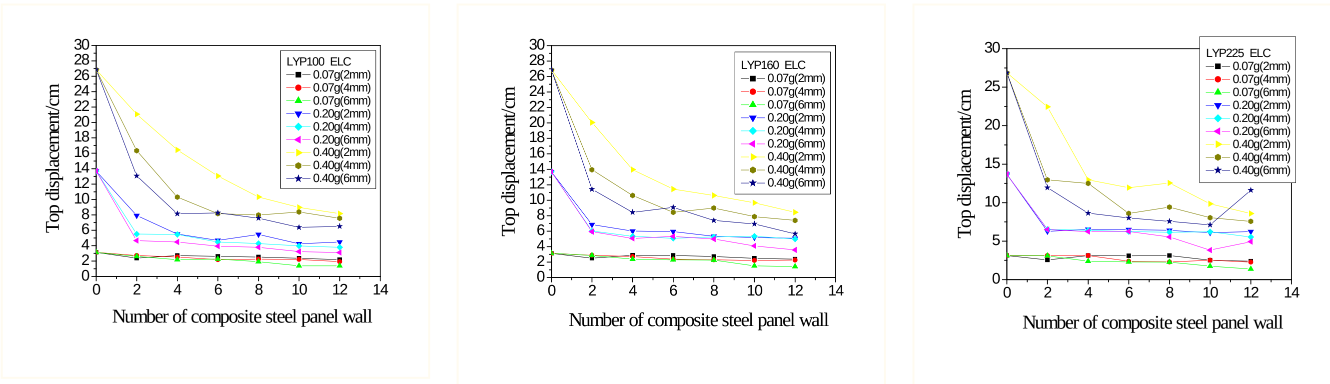
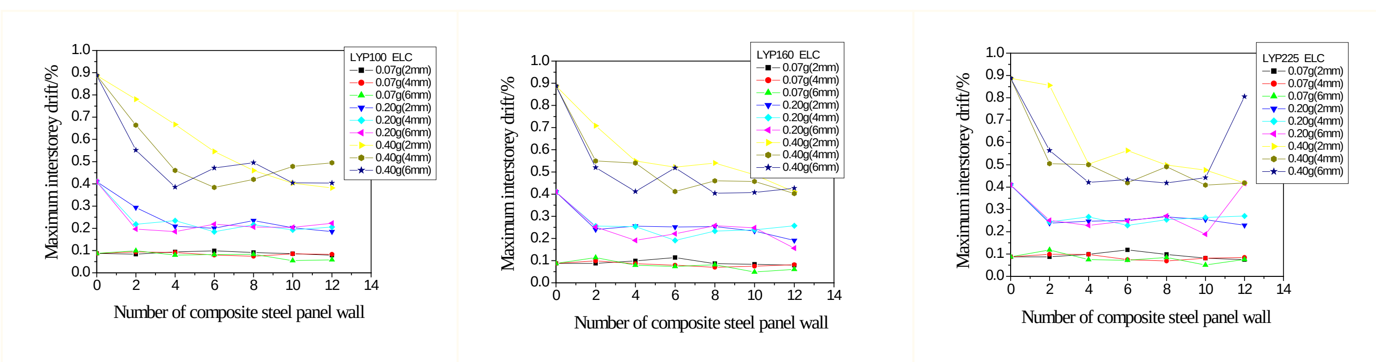


Fig.9 Plans layout of multi-ribbed composite wall with low yield strength steel panels: (a) 2 pieces of wall; (b) 4 pieces of wall; (c) 6 pieces of wall; (d) 8 pieces of wall; (e) 10 pieces of wall; and (f) 12 pieces of wall.



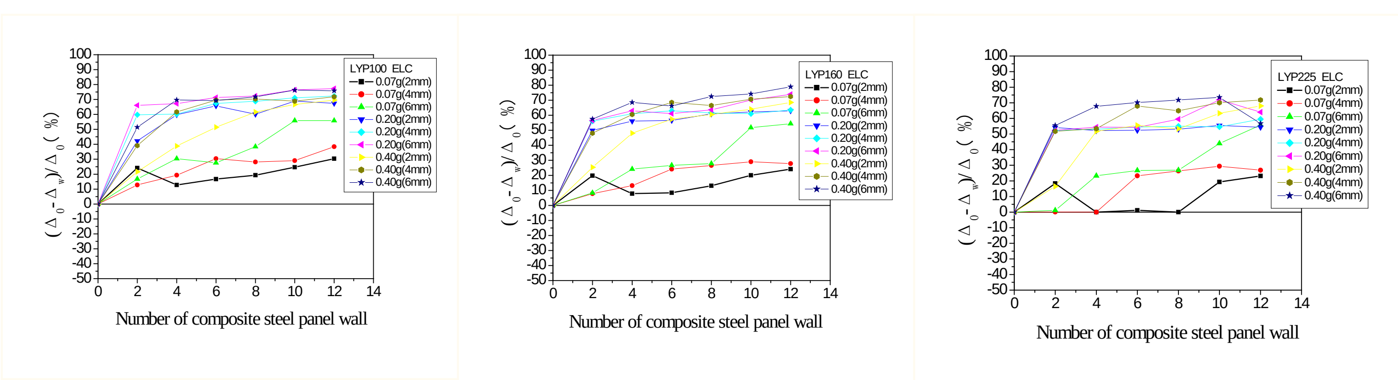
(a) (b) (c)

Fig.10 Variation of maximum displacement responses at top storey with the number of the composite steel panel walls: (a) LYP100; (b) LYP160; and (c) LYP225.



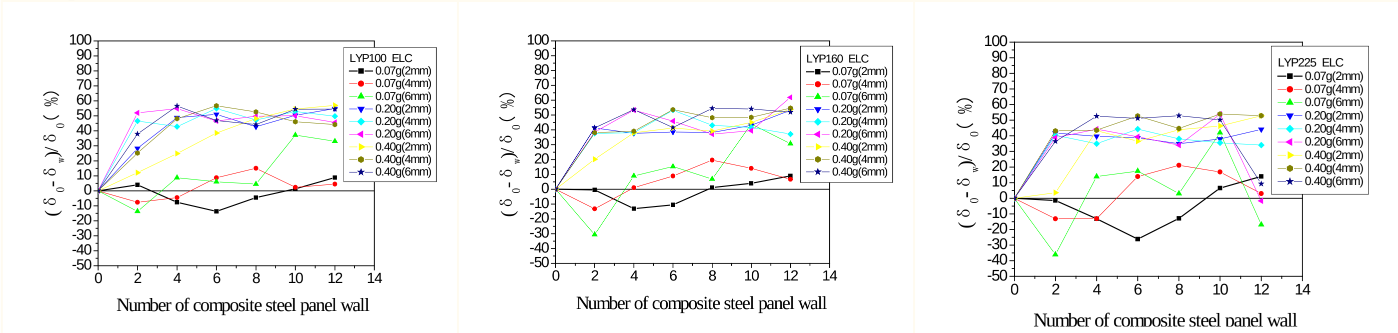
(a) (b) (c)

Fig.11 Variation of maximum interstorey drift angle responses with the number of the composite steel panel walls: (a) LYP100; (b) LYP160; and (c) LYP225.



(a) (b) (c)

Fig.12 Damping rate of maximum displacement responses at top storey with the number of the composite steel panel walls : (a) LYP100; (b) LYP160; and (c) LYP225.



(a) (b) (c)

Fig.13 Damping rate of maximum interstorey drift angle responses with the number of the composite steel panel walls: (a) LYP100; (b) LYP160; and (c) LYP225.

3. Conclusion

A new type of multi-ribbed composite wall with low yield strength steel is provided for seismic response control of the multi-ribbed composite wall structure (MRCWS).The calculating results of the earthquake responses of the control structure systems show that the low yield strength steel panels have obvious seismic mitigation effect for the multi-ribbed composite wall structure, which seismic damping rate is 15%~30% under the seismic frequent intensity, and is 30%~60% under the seismic fortification intensity and the seismic rare intensity at 8 degree seismic fortification region of China Code for seismic design of buildings, so a simple and effective seismic mitigation technique is provided for the multi-ribbed composite wall structure. The research is numerical, and a further step should be obtaining design considerations of the new wall and proving its value with experimental tests.

4. Acknowledgements

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