Seismic Control Research of the Multi-Ribbed Slab Structure Using the Ultra Low Yield Strength Steel

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ABSTRACT:
Multi-ribbed slab structure (MRSS) is a new type of composite structure with specific characteristics which is composed of prefabricated multi-ribbed composite wall slab, cast-in-place floor slab and cast-in-suit concealed outer frame. In this paper, ultra low yield strength steel panels are used in the multi-ribbed composite wall slab, seismic response control of the multi-ribbed slab structures using the ultra low yield strength steel was explored. The nonlinear dynamic time-history analysis of the MRSS seismic control systems under horizontal earthquakes waves were carried out. The earthquake responses and energy dissipation mechanisms as well as damage performance of the control structures were investigated. The effects of vibration reduction of the ultra low yield strength steel panel were discussed. The computing results show that the ultra low yield strength steel panel has obvious mitigation of seismic effects. MRSS with ultra low yield strength steel panels has a good energy dissipation and seismic capacity.

Keywords: Multi-ribbed slab structure, ultra low yield strength steel panel, seismic response control

1. INTRODUCTION

Ultra Low yield point steel has strong energy dissipation and stable performance, which is often used to make various types of energy-consuming or seismic damping device, attracting more and more attention in engineering field and becoming a hotspot for study [1-4]. Multi-Ribbed Slab Structure (MRSS) is a new type of composite structure with specific characteristics (see Figure 1) [5]. The MRSS is composed of prefabricated multi-ribbed composite wall slab, cast-in-place floor slab and cast-in-suit concealed outer frame, in which the multi-ribbed composite wall slab is the main bearing member of the MRSS that is composed of reinforced concrete frame made up of rib beams and rib columns as well as built-in infill silicate blocks or light-weight infill panels. In this paper, ultra low yield strength steel panels are used to partly replace built-in infill silicate blocks in the concrete frame of the multi-ribbed composite wall slab, thus a new kind of the seismic mitigation multi-ribbed composite wall slab are provided by locating ultra low yield strength steel panels within concrete frame. Seismic control technique of the multi-ribbed slab structure using the ultra low yield strength steel is explored. The nonlinear dynamic time-history analysis of the MRSS seismic control systems with ultra low yield strength steel panels under horizontal earthquakes waves were carried out. The earthquake responses and energy dissipation mechanisms as well as damage performance of the control structure were investigated. The effect of vibration reduction of the ultra low yield strength steel for MRSS were discussed, and the influence factors of seismic mitigation effects were carefully studied, which provides insight into earthquake responses of MRSS seismic control system. The computing results show that the ultra low yield strength steel has obvious mitigation of seismic effects. MRSS control system with ultra low yield strength steel panels has a good energy dissipation and seismic capacity.

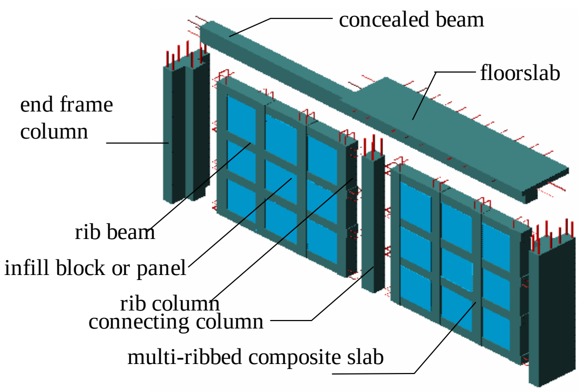


Figure 1. Multi-ribbed slab structure

2. THE STRUCTURAL ANALYSIS MODELS

2.1. Calculating Analysis Model

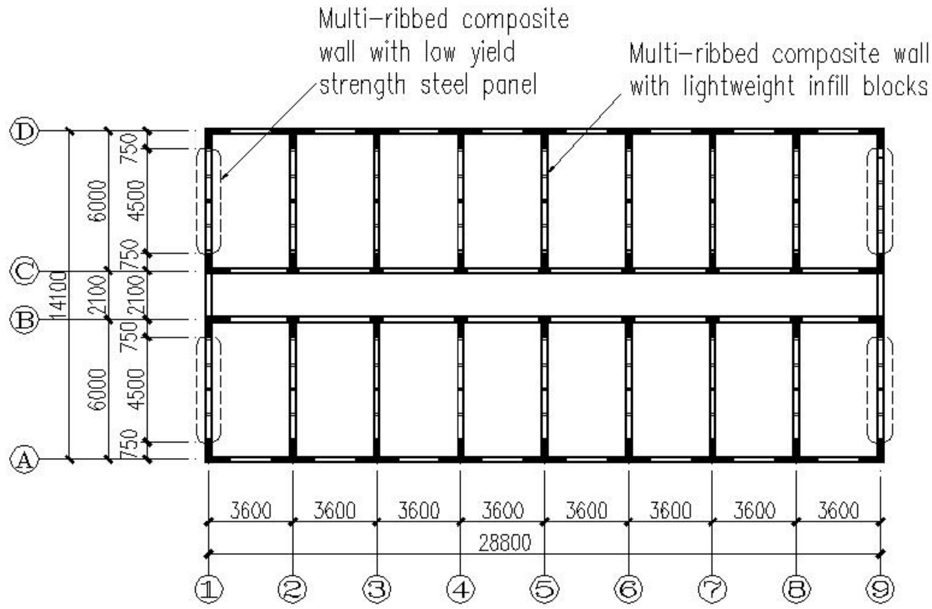
There are four calculating analysis models to been chosen. The model 1 is a 15-storey practical prototype building structure with the multi-ribbed composite wall slab built-in infill silicate blocks (see Figure 2 (a) and Figure 2 (b)). The model 2~model 4 are structural control systems using the ultra low yield strength steel that the location of the multi-ribbed composite wall slab built-in the ultra low yield strength panels are marked with dotted lines shown in Figure 2(a), in which the amount of the ultra low yield strength steel panel composite walls of model 2 are located from first storey to fifth storey(see Figure 2 (c)), the steel panel composite walls of model 3 are located from first storey to eighth storey(see Figure 2 (d)), the steel panels composite walls of model 4 are located from ninth storey to fifth storey(see Figure 2 (e)). The thickness of the steel panel composite walls is 300 mm. The ultra low yield strength steel (LYP100) is chosen which the computing yield stress $\sigma_y = 80\text{N/mm}^2$ and shear yield stress $\tau_y = 80\sqrt{3}\text{N/mm}^2$ [6].The thickness of ultra low yield strength steel panels is 4mm. The construction diagrams of the multi-ribbed steel panel composite walls are shown in Figure 3.

2.2. Dynamic Analysis Method

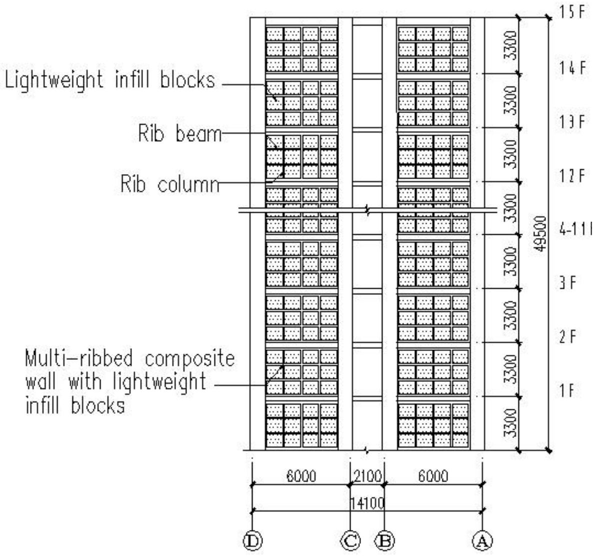
The nonlinear earthquake responses of the structures are calculated by using program IDARC2D Version 7.0 [7-8]. The nonlinear dynamic analysis models of the structures are established with retrogressive three-linear resilience model for beam and column elements, while a smooth hysteretic model is proposed for representing infill silicate blocks and low yield strength steel panels. The nonlinear dynamic time-history analysis of the structures under horizontal earthquakes has been carried out. The 4 natural earthquake ground motions El-Centro, Taft, San Fernando and Kobe waves were chosen(see Table2.1). Inputting peak ground motion acceleration is 0.4g being representative for design acceleration of ground motion at rare occurrence earthquake of Code in China [9] under seismic precautionary intensity 8 degree. Computing time t =25s, time interval being Δt =0.002s.

Table2.1. Input Earthquake Ground Motions

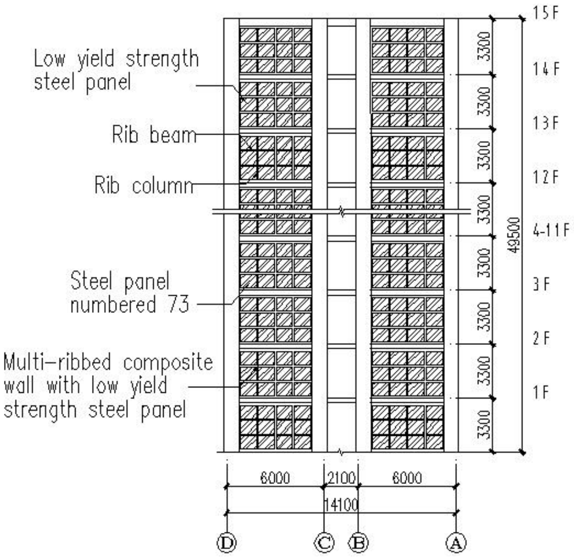
	Earthquake wave	File name	Station	Comp.	Mag. (Ms)	PGA (g)	PGV (cm/s)	PGA/ PGV	Duration
1	Imperial Valley(1940)	ELC	El Centro Array #9	S00E	6.7	0.342	33.5	1.02	53.76
2	Kern County(1952)	TAFT	Taft Lincoln School	S69E	7.7	0.176	17.7	0.99	54.40
3	San Fernando(1971)	SANF	Castaic-Old Bridge Route	ORR021	6.6	0.324	15.6	2.08	61.80
4	Kobe(1995)	KOBE	Shin-Osaka	SHI000	6.9	0.243	37.8	0.64	40.96



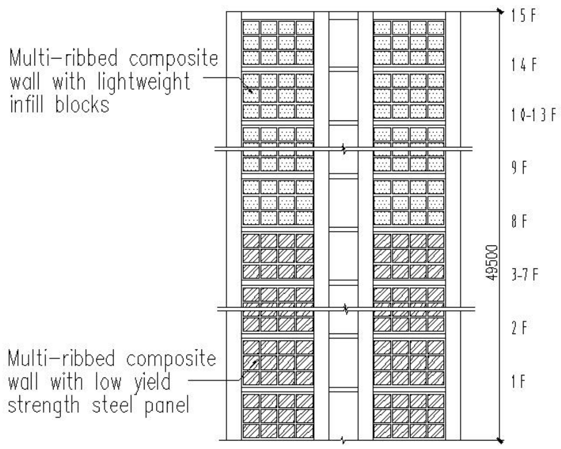
(a) Plans of model structures



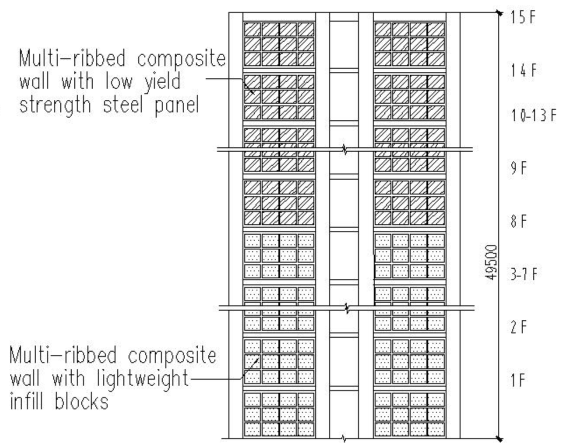
(b) The elevation of the①~⑨ axis in model 1 or the②~⑧ axis in model 2~ model 4



(c)The elevation of the① and ⑨axis in the model 2

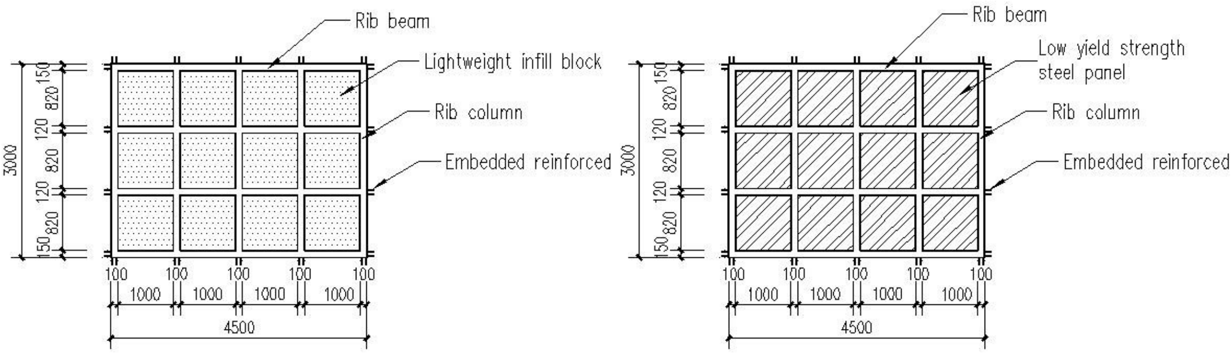


(d)The elevation of the① and ⑨axis in model 3



(e)The elevation of the① and ⑨axis in the model 4

Figure 2. The diagram of model structures

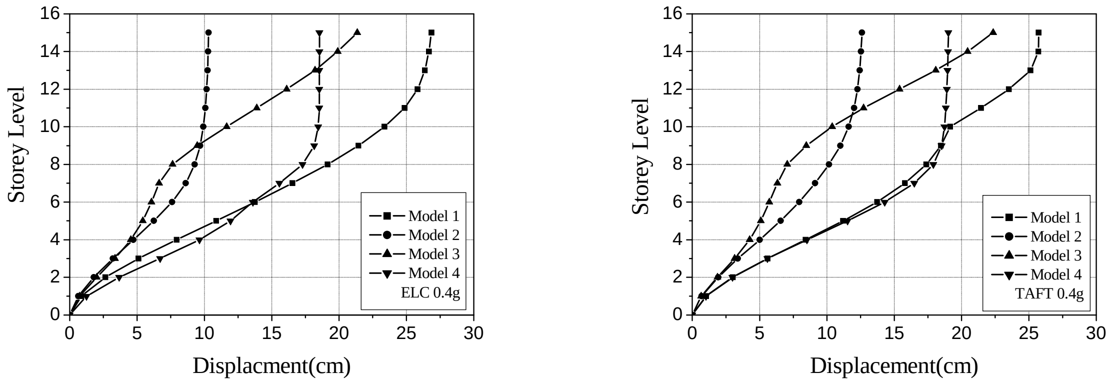


(a) built-in infill silicate blocks (b) built-in ultra low yield strength steel panels

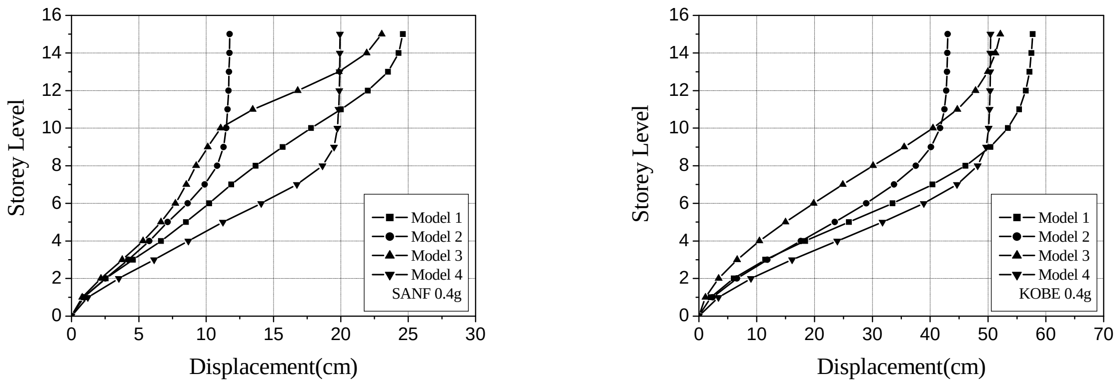
Figure 3. The construction diagram of a multi-ribbed composite wall slab

3. THE NONLINEAR EARTHQUAKE RESPONSES ANALYSIS OF THE STRUCTURE

The maximum displacement, interstorey drift, storey shear and acceleration responses of the structures subjected to El-Centro, Taft , San Fernando and Kobe waves are shown in Figure4~Figure 7.

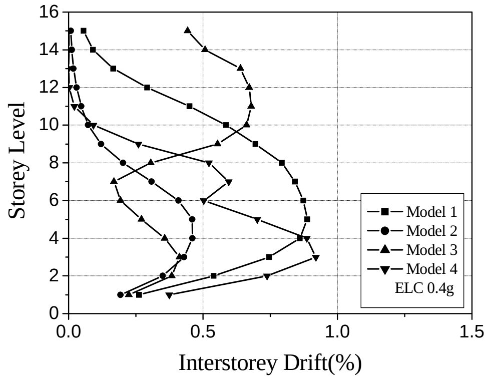


(a) El-Centro (b) Taft

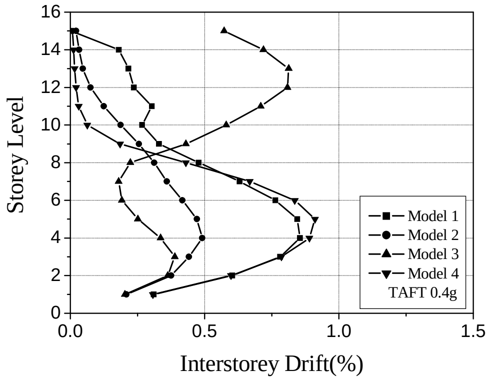


(c) Sanf (d) Kobe

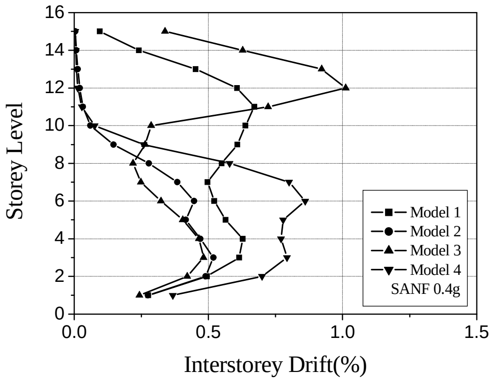
Figure 4. The maximum displacement responses of the models with different waves



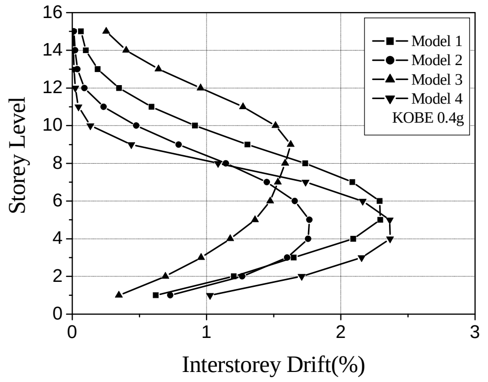
(a) El-Centro



(b) Taft

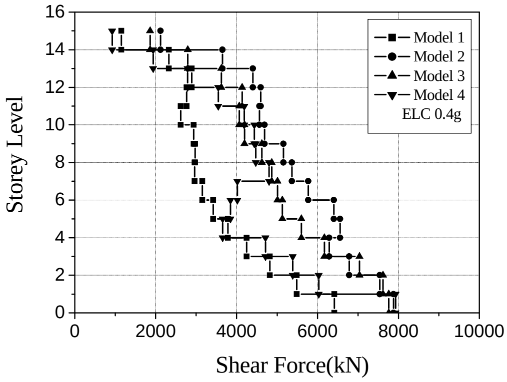


(c) Sanf

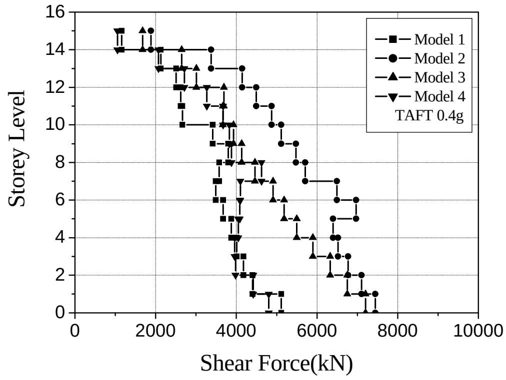


(d) Kobe

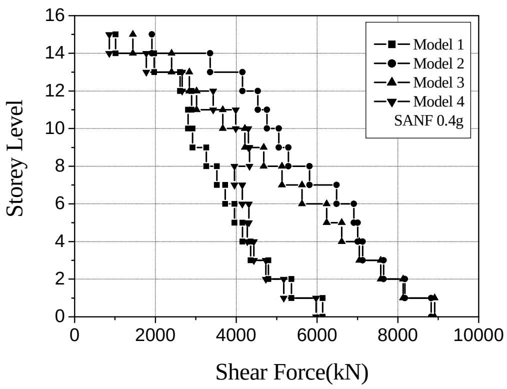
Figure 5. The maximum interstorey drift of the models with different waves



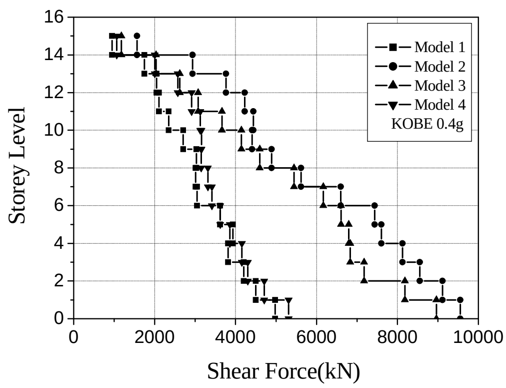
(a) El-Centro



(d) Taft

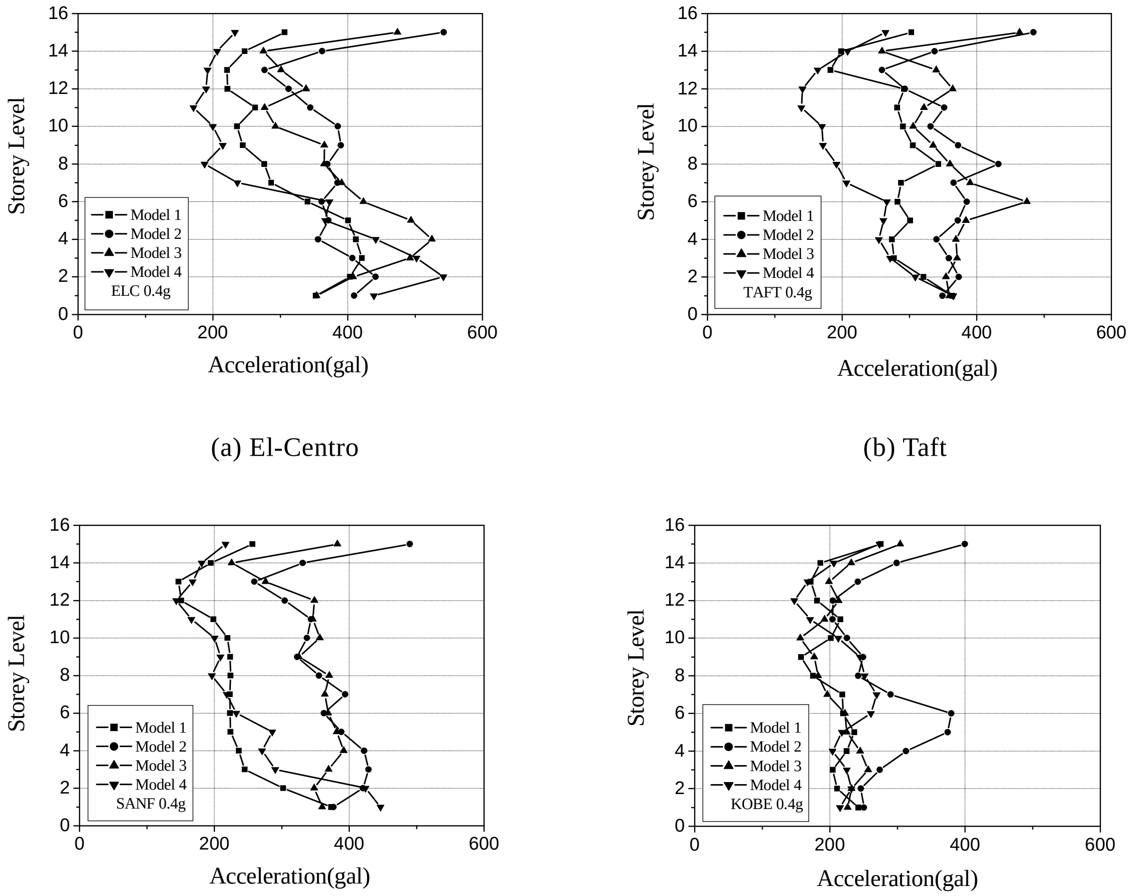


(c) Sanf



(d) Kobe

Figure 6. The maximum interstorey shear force of the models with different waves

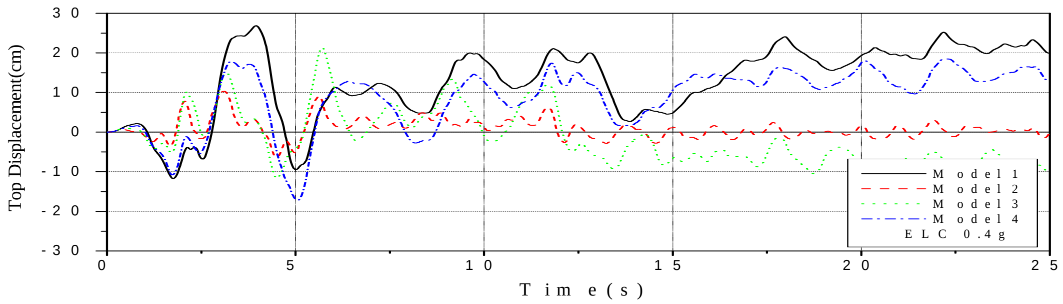


(a) El-Centro (b) Taft

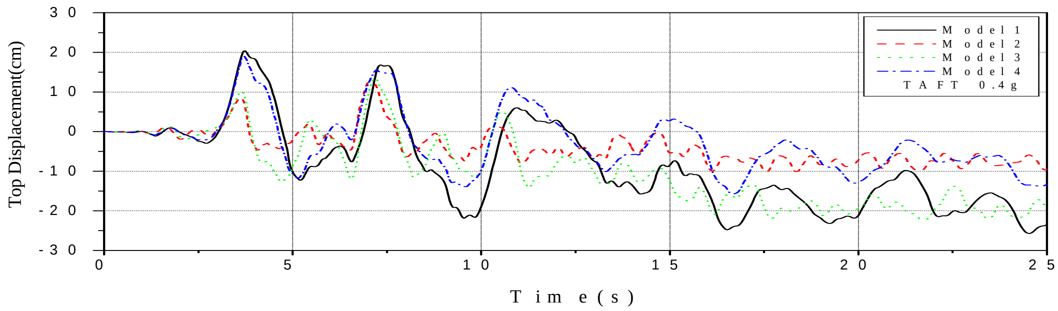
(c) Sanf (d) Kobe

Figure 7. The maximum acceleration responses of the models with different waves

Figure 4 (a)~(d) show that the maximum displacement responses of the model 2~model 4 at top storey under El-Centro, Taft , San Fernando and Kobe waves decrease, which reflects that the ultra low yield strength steel panels have obvious seismic mitigation effects. From Figure 5 (a)~(d) it can been seen that the maximum interstorey drift angles of the model 2~model 4 with the ultra low yield strength steel panel walls under different waves have big decreases, especially in model 2 when the ultra low yield strength steel panels composite walls are evenly located from first storey to fifth storey it have obvious advantage of seismic control which is a proposal of priority. Figure 6~Figure 7 indicated that the maximum interstorey shear force and acceleration responses have some decrease in the model 4 but have increase in the model 2 and model 3. Figure 8~Figure 9 give the time-history responses of displacement and acceleration at top storey.

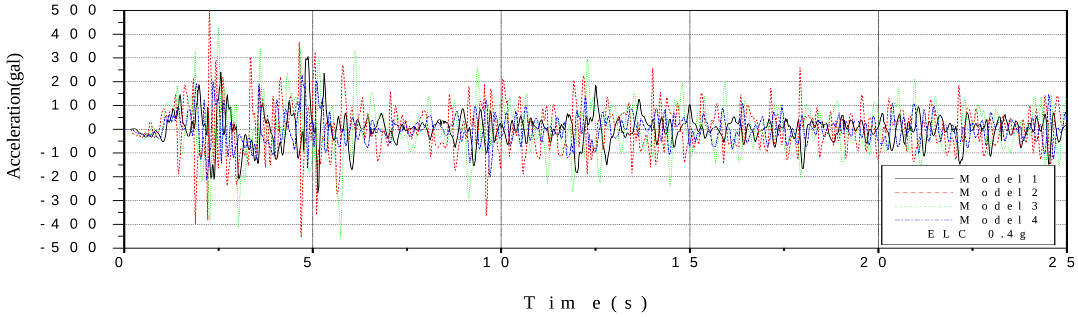


(a) El-Centro

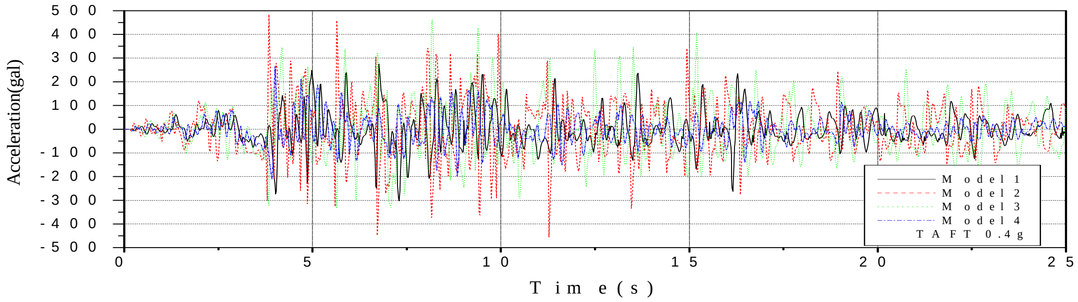


(b)Taft

Figure 8. Displacement time-history responses at top storey



(a) El-Centro



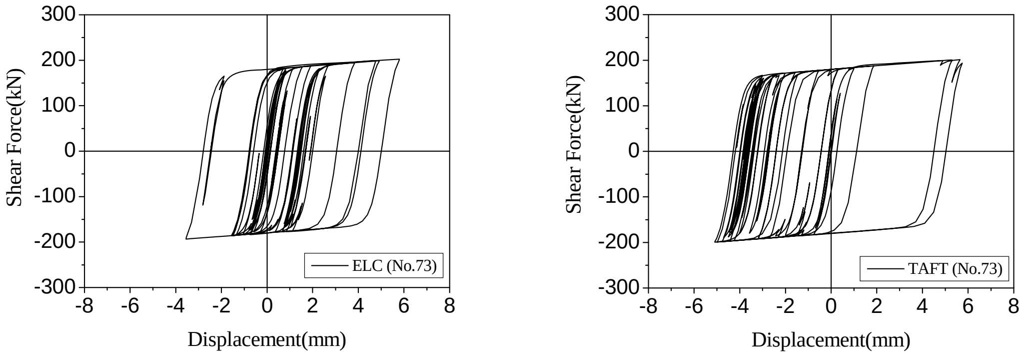
(b)Taft

Figure 9. Acceleration time-history responses at top storey

4. HYSTERETIC ENERGY DISSIPATION AND DAMAGE PERFORMANCE

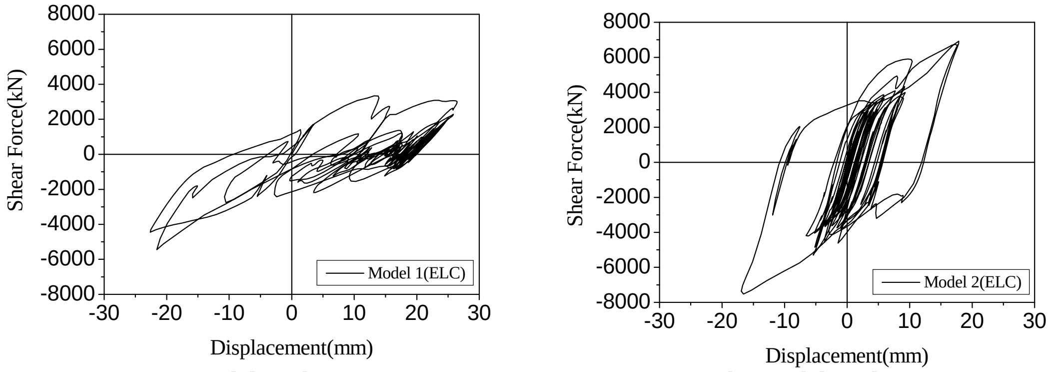
4.1. Hysteretic Energy Dissipation

Figure 10 give the hysteretic curves of a built-in ultra low yield strength steel panel numbered 73 in the model 2 subjected to El-Centro wave and Taft wave (see Figure 2(c)). It can be seen that the ultra low yield strength steel panel have full shape of hysteretic curve and stable energy dissipation. Figure 11~ Figure 12 give separately the hysteretic curves of the storeies and the structures of model 1 and model 2. Because the ultra low yield strength steel panels have strong energy dissipation the structures and storeies of the model 2 have better energy dissipation capability.

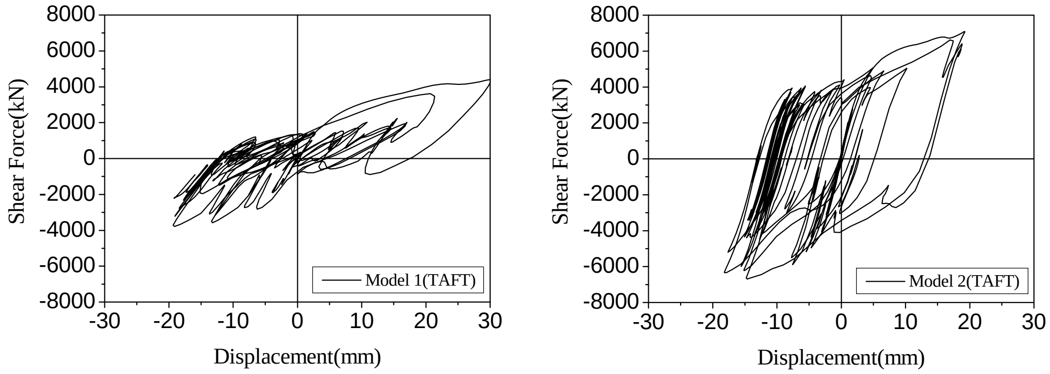


(a)El-Centro (b)Taft

Figure 10. Hysteretic curves of an ultra low yield strength steel panel

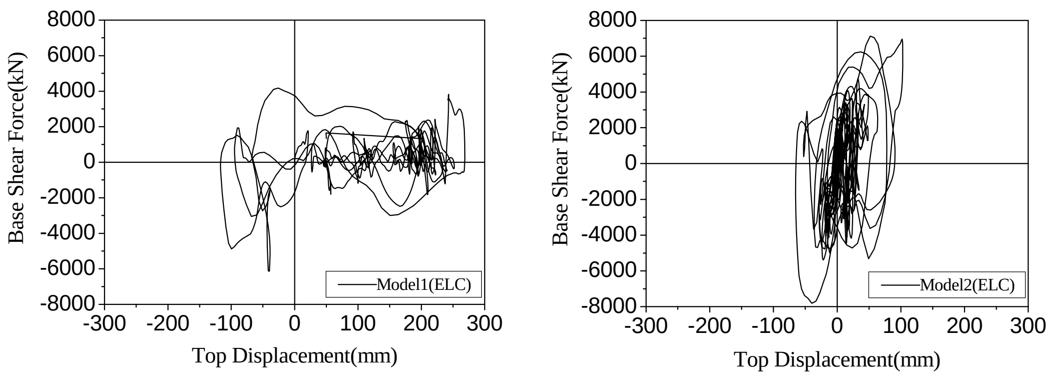


(a) Model 1(El-Centro) (b) Model 2(El-Centro)

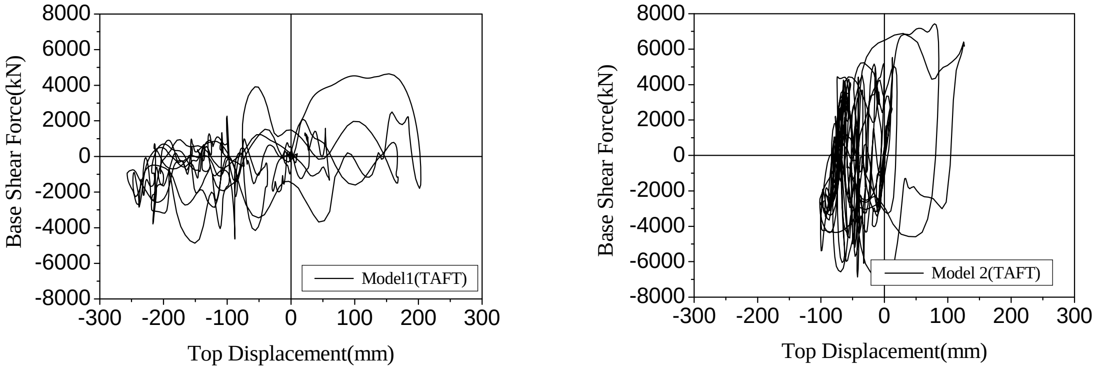


(c) Model 1(Taft) (d) Model 2 (Taft)

Figure 11. Hysteretic curves of the second storey



(a) Model 1(El-Centro) (b) Model 2(El-Centro)

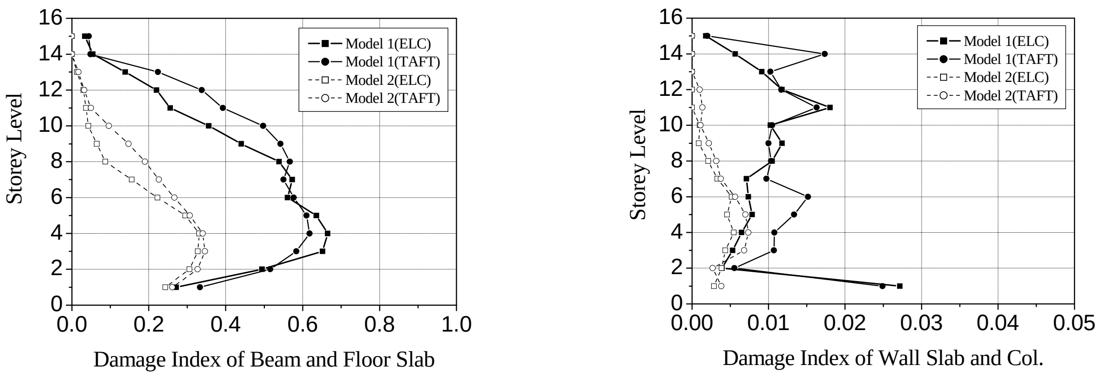


(c) Model 1(Taft) (d) Model 2 (Taft)

Figure 12. Hysteretic curves of model structures

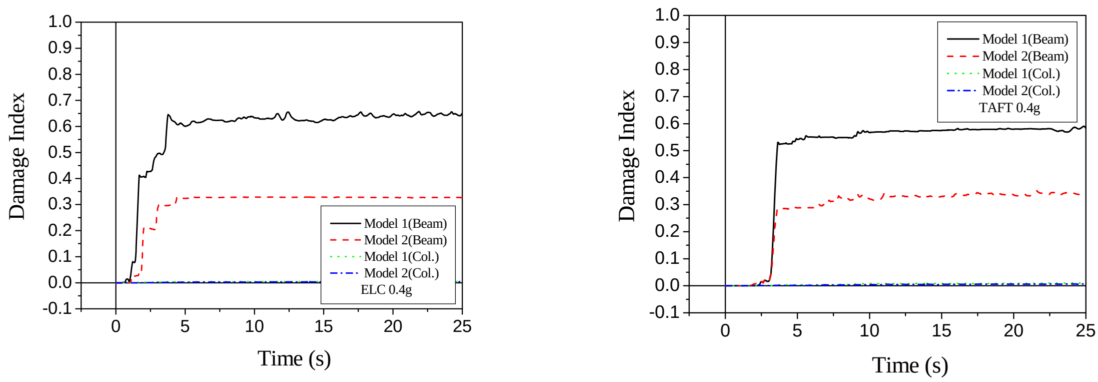
4.2. Damage Performance

The damage assessment method was built by employing the dual-failure model of structural components considering both deformation and accumulative hysteretic energy, a fatigue based damage model introduced by Reinhorn and Valles (1995) was proposed in the paper [7-8].Figure 13 give damage index distribution of beam and floor slab as well as wall slab and column of model 1 and model 2 along storey. Figure 14 give damage time-history response curves of model 1 and model 2 at third storey. Table4.1 gives the structural overall damage index of model 1 and model 2. The results shows that damage index of members and structures of model 2 are much smaller than damage index of model 1,which indicated that the ultra low yield strength steel panel can reduce and postpone damage of members and structures.



(a) Beam and floor slab (b) Wall slab and column

Figure 13. Damage indexes of models along storey



(a)El-Centro (b)Taft

Figure 14. Damage time-history response curves at third storey

Table 4.1. The structural overall damage index

Damage index	El-Centro	Taft	Sanf	Kobe
Model 1	0.490	0.504	0.451	>1
Model 2	0.261	0.279	0.335	0.826

5. CONCLUSIONS

The computing results show that the ultra low yield strength steel panels have obvious mitigation of seismic effects. The ultra low yield strength steel panel composite walls being evenly located along storey have obvious advantage of seismic response control which is a proposal of priority. The ultra low yield strength steel panels have full shape of hysteretic curve and stable energy dissipation, which can reduce and postpone damage of members and structures. MRSS control structure with ultra low yield strength steel panel composite walls has a good energy dissipation and earthquake collapse resistance capacity to encounter earthquake motions.

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