Effect of The Ratio of Equivalent Lateral Stiffness and The Level of Transfer Story on Seismic Behavior of Frame-supported Shear Wall Structure

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ABSTRACT :

The ratio of equivalent lateral stiffness and the level of transfer story are two main factors of the seismic behavior of structures with transfer story. To research the effect of these two factors on seismic behavior of partial frame-supported shear wall structure, the simulated structural models are established in SATWE software with various ratio of equivalent lateral stiffness and transfer story level. Thus, the natural vibration period, the seismic response force and the inter-story displacement angle of these models are compared.

KEYWORDS: frame-supported shear wall structure, transfer story level, equivalent lateral stiffness ratio, seismic analysis, inter-story displacement angle

1. INTRODUCTION

These days, the transfer story is widely used in high-rise building. In seismic region, the transfer story is usually at a higher location of structures, some at 3~6 story, some at 7~10 or more. The discontinuity of the vertical members near transfer story and its abrupt change in stiffness lead to the abrupt changes of internal force, stiffness and inter-story displacement angle of transfer story, and then the transfer story become weak story. Also, the weak story is unfavorable for seismic resisting of structure, especially for the structure with a higher transfer location (Fu Xueyi. 1999).

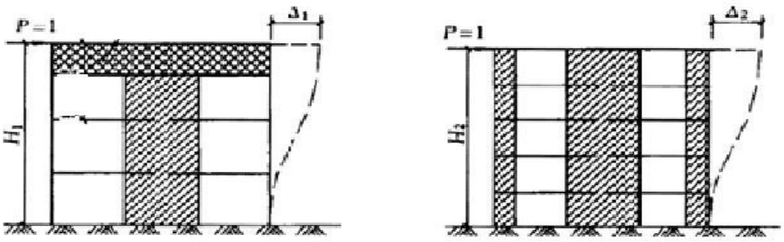
The ratio of equivalent lateral stiffness and the level of transfer story are two main factors of the seismic behavior of structures with transfer story (Xu Peifu, Wang Cuikun and Hao Ruikun. 2000). The structure with high transfer location has already been studied by some experts, focusing on the effect of the level of transfer story on seismic behavior of structure but their researches gave inconsistent results (K.T.Chau, Eddie S.S. Lam, Y L.Xu and Y L. Wong. 2002). The simulated structural models of partial frame-supported shear wall structure are established in the paper and the seismic behavior of the structure with various ratios of equivalent lateral stiffness and transfer story level are studied.

2. THE CALCULATION METHOD OF THE RATIO OF EQUIVALENT LATERAL STIFFNESS IN CHINESE CODE

If the story number of large space at lower part is more than 1, the equivalent lateral stiffness ratio can be calculated using Eqn. 2.1 (Xu Peifu. 2002):

$$\gamma_e = \frac{\Delta_1 H_1}{\Delta_2 H_2} \tag{2.1}$$

where γ_e is the equivalent lateral stiffness ratio, H_1 is the height of transfer story and the lower part (simulated structural model 1), Δ_1 is the lateral displacement under unit horizontal force on top of the transfer story (simulated structural model 1). H_2 is the height of structure above the transfer story (simulated structural model 2), Δ_2 is the lateral displacement under unit horizontal force on top of the structure above the transfer story (simulated structural model 2). (refer with: Figure 1).



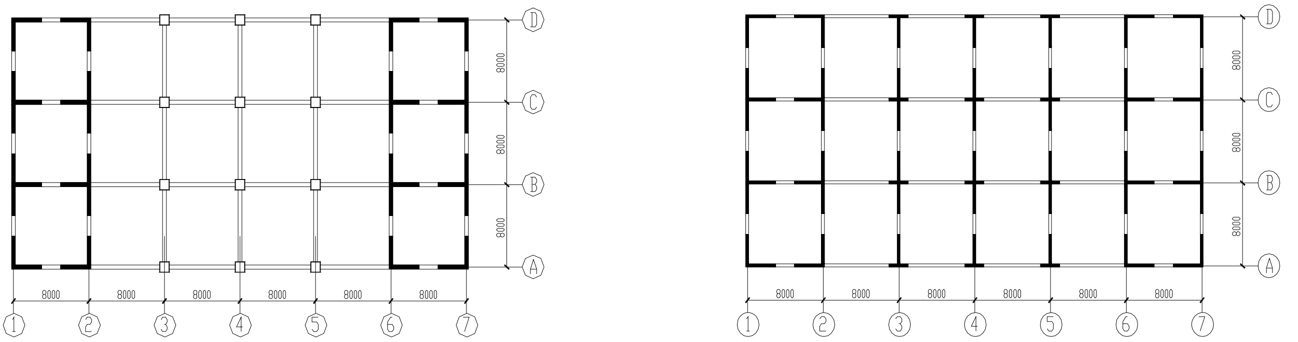
(a) Model 1 (b) Model 2

Figure 1 The structural model of the equivalent lateral stiffness ratio

3. STRUCTURAL MODEL

The model is a concrete partial frame-supported shear wall structure with 30 stories. The compressive strength of concrete below the transfer story is 19.1MPa, above the transfer story is 14.3MPa. There have frame and shear wall linked with the ground under the transfer story with the story height of 4.5m. The structure above the transfer story is shear wall structure with the story height of 3m. The layout plan is shown in Figure 2.

The analysis is divided into two cases with 30 models in all. Case 1: changing the level of transfer story to 3rd, 5th, 7th, 9th and 11th with the same plane layout; Case 2: changing the ratio of equivalent lateral stiffness γ_e to 0.63, 0.97, 1.29, 1.65, 1.91 and 2.34 by adjusting the length and thickness of the shear wall. SATWE (a Finite Element Analysis software) is used to conduct the elastic response spectrum analysis. The rigid diaphragm assumption is adopted in analysis and the seismic action direction is transverse.



(a) Frame structure under the transfer story (b) Shear wall structure above the transfer story

Figure 2 Layout plan of the partial frame-supported shear wall structure

4. RESULTS ANALYSIS

4.1. The Effect of The Level of The Transfer Story on The Natural Vibration Period

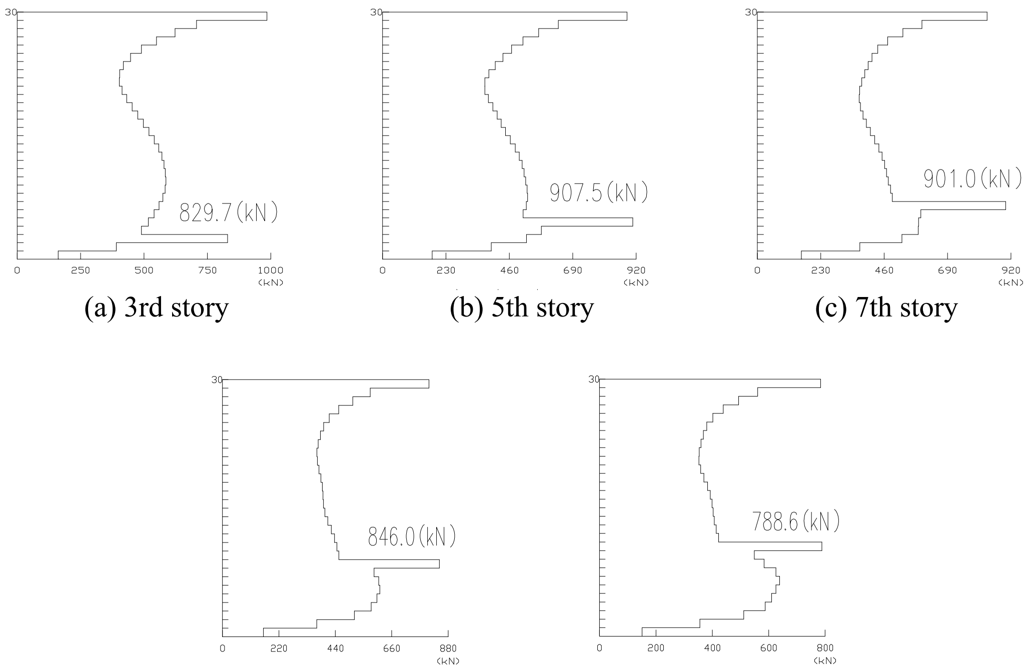
The natural vibration period of longitudinal direction of structure is shown in Table 4.1. The ratio of equivalent lateral stiffness is invariable, the natural vibration period increases when the level of transfer story changes from 3 to 11. The natural vibration period decreases with the increment of equivalent lateral stiffness ratio.

Table 4.1 The natural vibration period of longitudinal direction of structure(s)

Stiffness ratio \ Transfer story	3	5	7	9	11
0.63	1.4843	1.5088	1.5493	1.6026	1.6663
0.97	1.4652	1.5095	1.5661	1.6316	1.7037
1.29	1.3458	1.4296	1.5218	1.6164	1.7108
1.65	1.3800	1.4935	1.6117	1.7281	1.8398
1.91	1.3846	1.5101	1.6372	1.7597	1.8752
2.34	1.2614	1.4039	1.5404	1.6681	1.7859

4.2. The Effect of The Level of The Transfer Story on The Seismic Response Force

The equivalent lateral stiffness ratio of the model is 1.29 and the level of transfer story is varying. The effect of the transfer story level on the seismic response force is shown in Figure 3. The seismic response force of partial frame-supported shear wall structure changes abruptly in the transfer story.



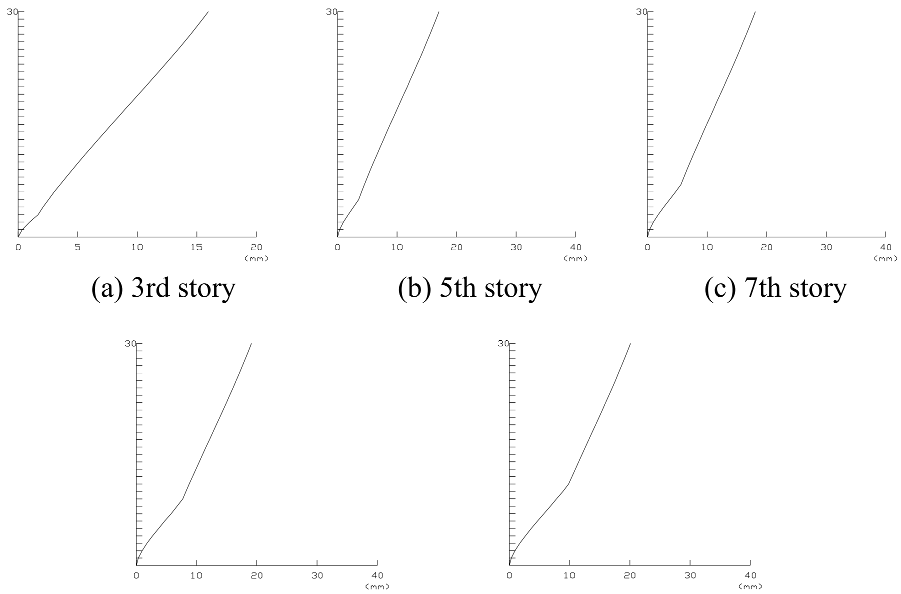
(a) 3rd story (b) 5th story (c) 7th story

(d) 9th story (e) 11th story

Figure 3 seismic response force with different level of transfer story

4.3. The Effect of The Level of The Transfer Story on The Floor Displacement

The equivalent ratio of lateral stiffness is 1.29 and the level of transfer story is varying. The effect of the transfer story level on the floor displacement is shown in Figure 4. The maximum transverse displacements of models transfer from 3rd to 11th story are 16, 17, 18.1, 19.1 and 20.1 (mm) respectively. The curve of floor displacement experiences an abrupt change in the transfer story. With the upward of the level of the transfer story, the inter-story displacement of transfer story is increasing.



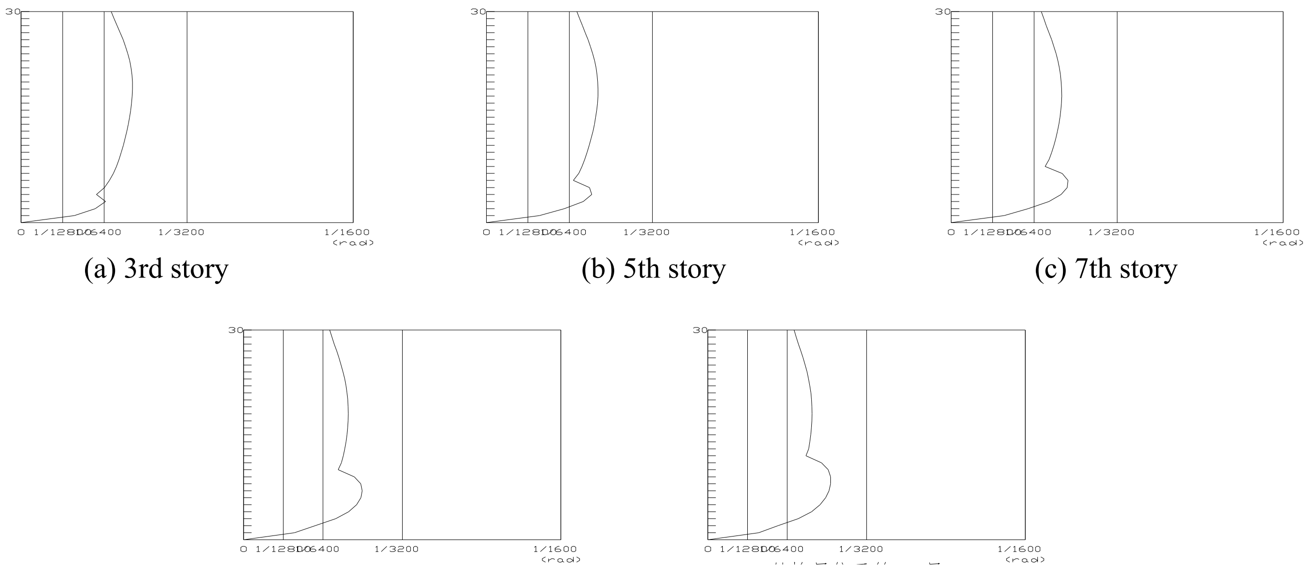
(a) 3rd story (b) 5th story (c) 7th story

(d) 9th story (e) 11th story

Figure 4 Floor displacement curve of partial frame-supported shear wall structure

4.4. Effect of The Level of Transfer Story and The Equivalent Lateral Stiffness Ratio on Inter-story Displacement Level

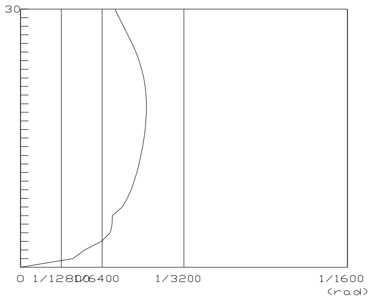
The equivalent lateral stiffness ratio of the model is 1.29. Figure 5 shows that inter-story displacement angle of partial frame-supported shear wall structure has changed abruptly, the inter-story displacement angle become larger with the upward of the transfer location. The model with transfer story located in the fifth floor is picked up to study the effect of equivalent lateral stiffness ratio on the inter-story displacement angle. From Figure 6, one can notice that the inter-story displacement angle change abruptly at the transfer story and increase with the increment in equivalent lateral stiffness ratio.



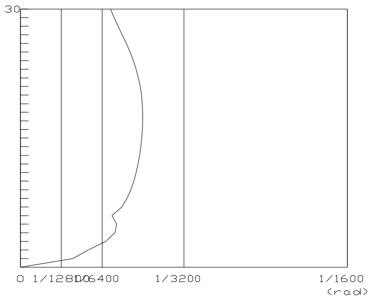
(a) 3rd story (b) 5th story (c) 7th story

(d) 9th story (e) 11th story

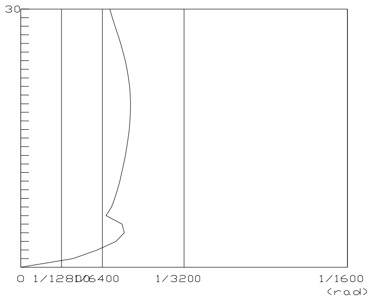
Figure 5 Inter-story displacement angle curve of partial frame-supported shear wall structure



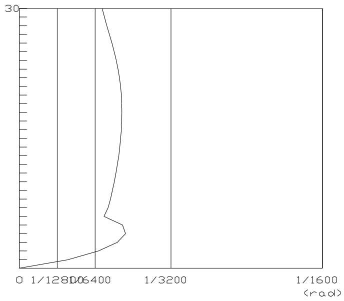
(a) $\gamma_e = 0.63$



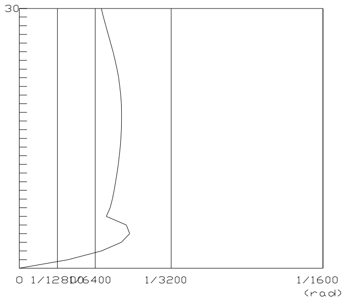
(b) $\gamma_e = 0.97$



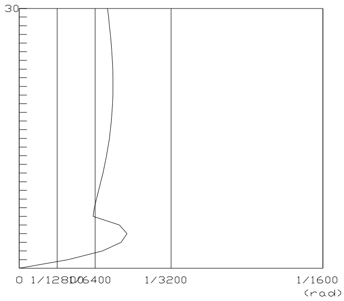
(c) $\gamma_e = 1.29$



(d) $\gamma_e = 1.65$



(e) $\gamma_e = 1.91$



(f) $\gamma_e = 2.34$

Figure 6 Inter-story displacement angle curve of structures with different lateral stiffness ratio

4.5. The variation of shear force of transfer member upper and lower transfer story.

V_1 is the sum of bottom shear force of frame-supporting column in the transfer story, and V_2 is the sum of bottom shear force of shear wall above the transfer story. The variation value of shear force near transfer story is $(V_2 - V_1)/Q_0$, Q_0 is base shear force. Figure 7 shows the variation of shear forces of transfer member near transfer story.

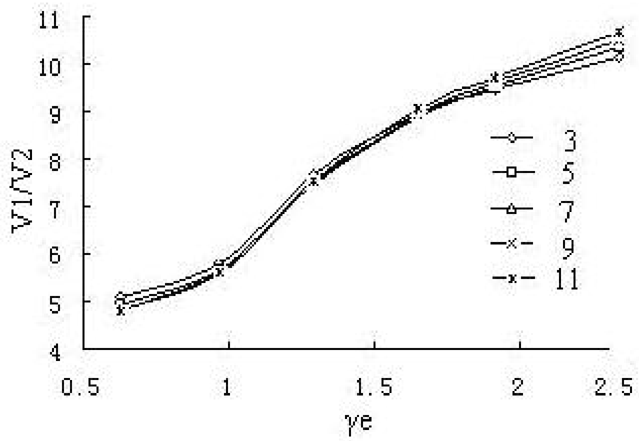


Figure 7 Curve of shear force ratio of the stories upper and lower transfer story (v_1/v_2) against the equivalent stiffness ratio

The level of transfer story is unchanged, the shear force increase obviously in Frame-supported Wall while experiencing a little changes in frame-supported column with the increase of equivalent lateral stiffness ratio from 4.8 to 10.4, when the level of transfer story increases, V_1/V_2 changes slightly.

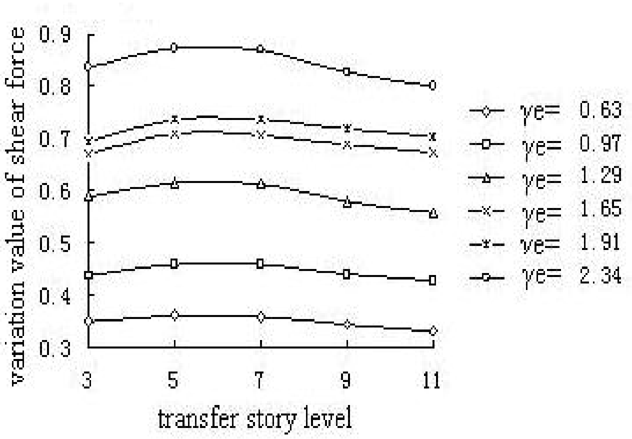


Figure 8 Abrupt curve of shear force upper and lower transfer story

From Figure 8, when the level of transfer story is constant, variation value of shear force near transfer story increase with the equivalent lateral stiffness ratio γ_e. If γ_e is constant, the variation value of shear force is larger when the story transfers from 3 to 5. However, variation values of shear force becomes smaller when the transfer story keeps rising. That is to say, there is a specific height, when the transfer story is located higher than this specific height, the higher the level of transfer story, the smaller the shear force of the floor.

5. CONCLUSIONS

Based on this study, the following conclusions can be drawn:

(1) The higher the level of the transfer story, the smaller the integral rigidity of structure. The natural vibration period, the displacement on top of the structure and the maximum inter-story displacement angle increase. The inter-story displacement angle and internal force change abruptly.

(2) With the increase of γ_e, the inter-story displacement angle also increase and the curve changed abruptly at transfer story.

(3) There is a specific height, when the transfer story is located higher than this specific height, the higher the level of transfer story, the smaller the shear force of the floor.

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