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Study on Elastic-Plastic Performance Analysis of a Prefabricated Low Multi-Story Villa

Jun Xie, Difei Jiang and Zhentai Bao

Central South University, China

Abstract. Calculate the joint connection spring rigidity of prefabricated low multi-story villa according to relevant specification and take modeling analysis by using SAP2000 finite element analysis software. Respectively analyze elastic-plastic time-history under moderate earthquakes and major earthquakes, take checking calculation of structural safety and obtain the conclusion and support the project to complete smoothly so as to provide design basis for this kind of multi-story prefabricatedvilla.
Keywords: Spring rigidity; SAP2000; moderate earthquake; major earthquake; elastic-plastic

1. Project Profile

The project is located in Changde City, Hunan Province with the building floor of 3 and the height of 9.12m. The system adopts whole prefabricated wall structure and light-weight high-strength self-insulation wallboard is adopted. The thickness of wallboard (load bearing shear wall, floor, etc.) is 160mm, the building area is 354.2m^2 and the building elevation effect picture is shown in Figure 1.

Figure1. Building elevation effect picture

The design working life for the engineering structure is 50 years and the safety class of structure is II and the fire-proof grade of building is I. Fundamental wind pressure: Wo=0.30KN/m2 and the ground roughness category is B. The seismic basic intensity of the site is 7 and the seismic fortification category of building is standard fortification category (short for III category). Fortify by seismic intensity of 7 degrees and the design seismic group is the first group, II category site and the characteristic period value is0.35s.

2. Connection Node

2.1. Details

For prefabricated structure system, the connection node of all prefabricated parts in major structure is the reliable connection of components in the area where destroy is concentrated in case of earthquake, which has the direct bearing on the building integrity and stability. So the connection structure plays a key function to the safety performance of main building. The connection structure of design components in the project is shown in Figure 2-Figure 5.

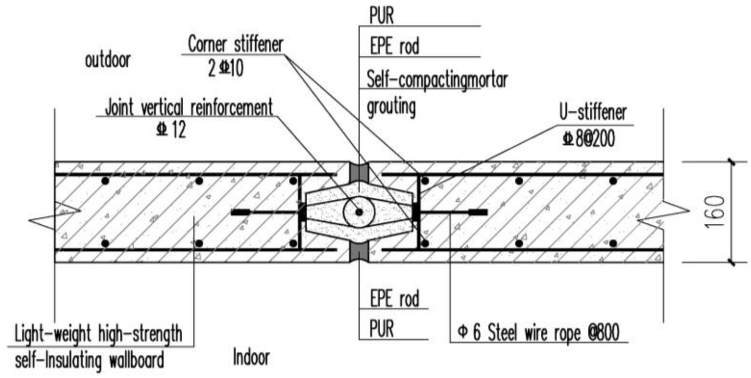

Figure 2. Connection node1

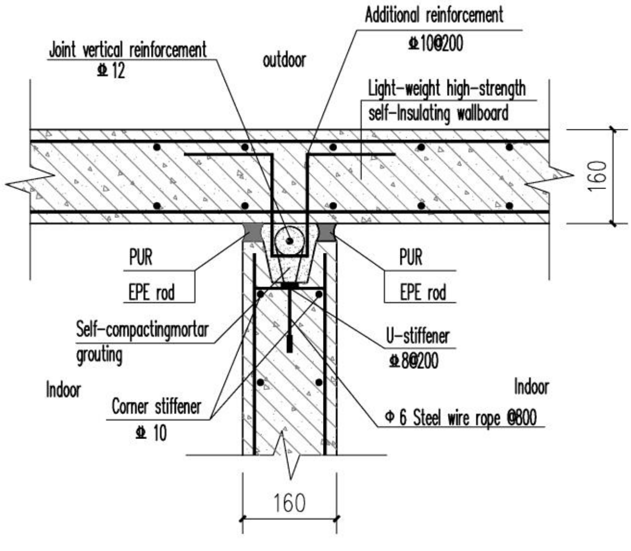

Figure 3. Connection node2

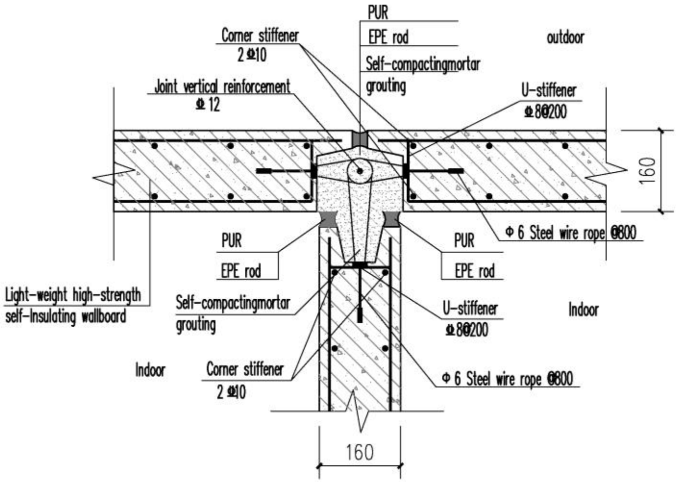

Figure 4. Connection node 3

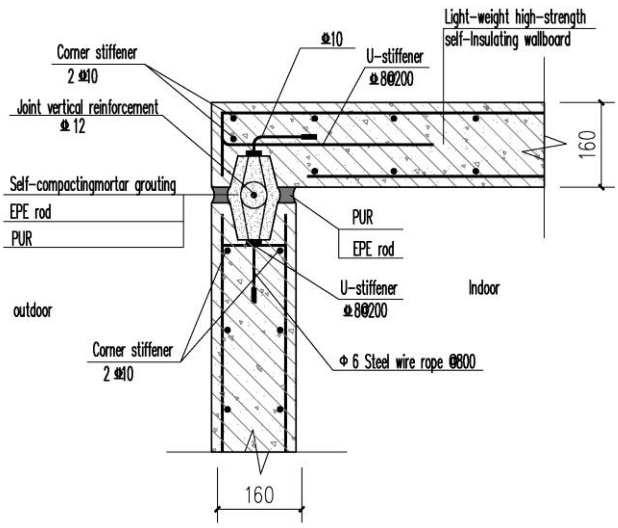

Figure 5. Connection node4

2.2. Determination of Spring Rigidity of the Node Graphical Method (Also Called Common Yield)

Moment method is adopted for reinforced concrete structure and the method is seen in *Anti-seismic of Reinforced Concrete Beam-Column Joints* [1]. According to common yield moment method, the shearing force V_e and the interface yield shear force V_y are shown in Table 1 when the joint interface slip of "steel wire rope" is 1mm.

Table1. Mechanics characteristic parameter of shearing resistantparts

Testpart name	Shear resistant part	V_y
Steel wire rope	Steel wire rope	1723

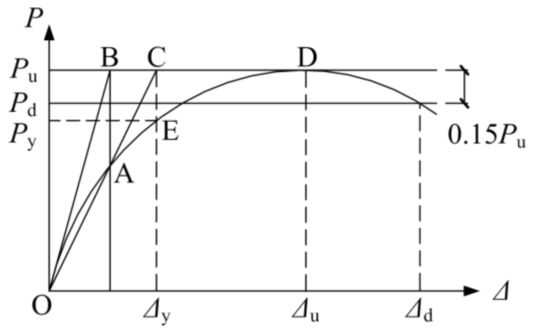

Figure 6. Determination of anti-shearing connection yield point of exterior wall cladding

3. SAP2000 Finite Element Model

It is connected through setting up prefabricated building model and setting the spring between wall pieces. SAP2000 is adopted to establish structure unitary analysis model and shell element simulation is adopted for wall and floor slab in the model. In analysis model, the elasticity modulus of concrete and reinforcement shall be valued according to *Code for Design of Concrete Structures* (GB50010-2010) [2]. The prefabricated model is shown in Figure 7.

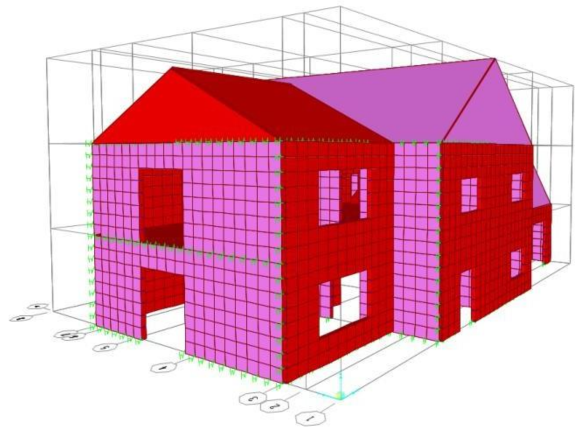

Figure 7. Prefabricated building model

The yield load P_y of test part is determined according to the skeleton line of test load-displacement curve and the principle is shown in 6. The spring rigidity of “steel wire rope” can therefore be calculated:

$$k_1 = \frac{1512}{16\times 1} = 94.5KN/mm \quad (1)$$

4. Elastic-Plastic Analysis under Moderate Earthquake

To investigate the seismic response under moderate earthquake (recurrence period is 475 years) effect, standard moderate earthquake response spectrum is adopted for analysis. The maximum value of seismic influence coefficient is $_{max}$=0.23[3], that is, seismic force multiply by amplification coefficient2.875.

The maximum story shift of two calculation models under moderate earthquake effect is shown in Table 2. The whole response analysis of moderate structure can provide reference for anti-earthquake analysis of follow-up exterior wall cladding connection based on performance.

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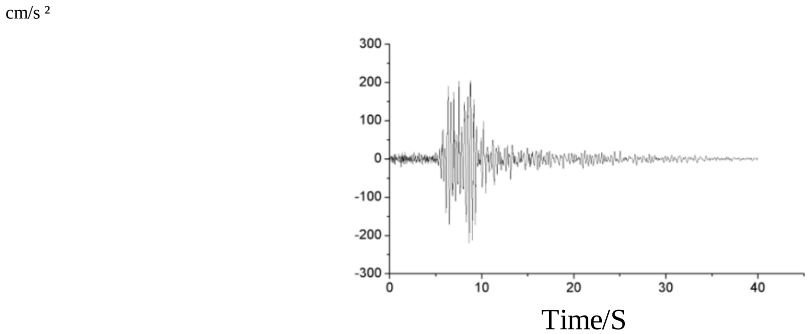
Table 2. Maximum story drift angle (rad) of calculation model under moderate earthquake effect

Prefabricated model	
X	Y
X-direction	Y-direction
1/3118	1/4132

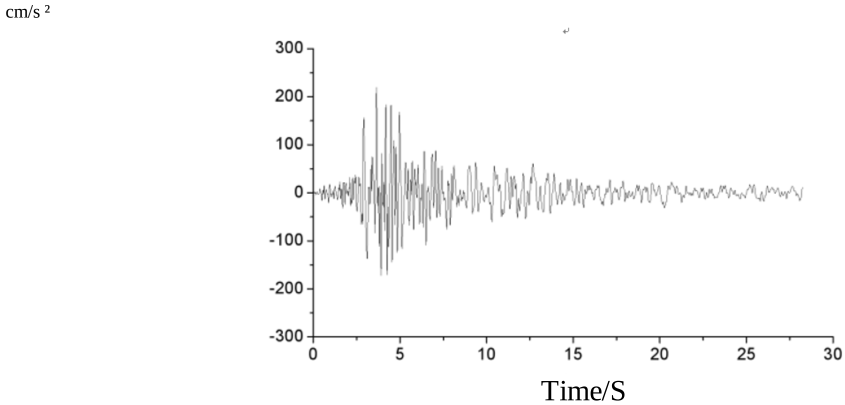
5. Elastic-Plastic Time-History Analysis under Rare Earthquake

5.1. Seismic WaveInput

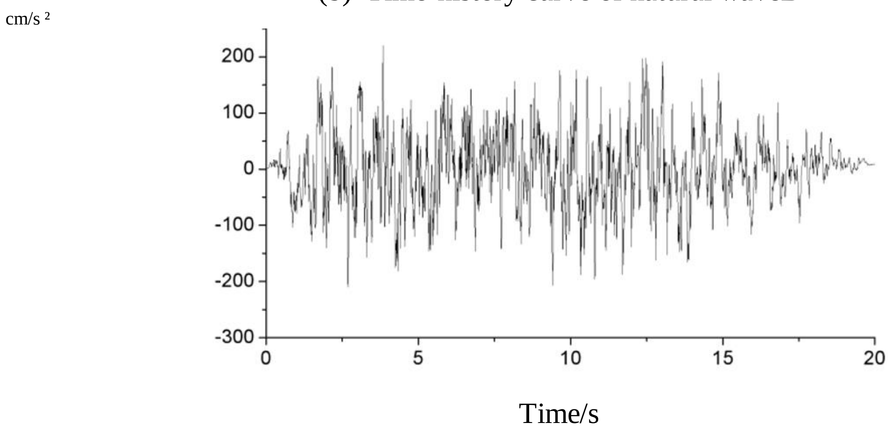
Adopt the seismic wave acceleration record used for elastic dynamic analysis and take it as rare earthquake analysis time-history record after peak value adjustment (220cm/s^2).



(a) Time-history curve of natural wave A



(b) Time-history curve of natural waveB



(c) Time-history curve of man-made wave

Figure 8. Seismic acceleration curve of dynamic and time-history analysis

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5.2. Nonlinear Dynamic and Time-Historical Analysis Research the Whole ProcessfromElasticityto

Elastoplasticity, gradual crack, damage and till collapse and explore the condition of controlling damage degree and further seek for the measures of preventing structure collapse and take elastoplastic earthquake response time-history analysis of structure. Time-earthquake analysis is to input the oscillatory differential equation of structural system after numeralization to seismic wave by time segment and adopt successive integration method to take structure dynamic elasto-plastic response analysis and calculate the structure's overall oscillating regime process in the whole seismic time domain, give internal force and deformation of all member bars at all moments and the sequence of plastic hinge appeared by all member bars. It is to inspect the structural safety and seismic reliability from intensity and deformation two aspects and judge the structure yield mechanism and types.

During the analysis, the infliction of gravity
load and input of seismic wave will be taken in two steps.

First step, inflict the gravity load representative value and take the working condition after inflicting gravity load representative value as the initial state of elastic-plastic time-history analysis.

Second step, inflict seismic action along the overall coordinate X, Y and Z direction. The peak value proportion of main direction, secondary direction and vertical acceleration time-history is: 1:0.85:0.65.

5.3. AnalysisResult

The maximum story drift of all calculation models under rare earthquake effect is shown in Table 3. The floor drift and story drift angle of all calculation models under rare earthquake effect are shown in Figure 9-Figure 12. The maximum story drift angle of all calculation models under rare earthquake effect is shown in Table 3. It can be seen that the story drift angle of all calculation models is smaller than 1/100, which satisfies the elastic-plastic story drift angle limit stipulated in *Code for Seismic Design of Building* GB50011-2010[3].

Table 3. Maximum story drift of calculation model under rare earthquake (rad)

Prefabricated model	
X direction	Y direction
1/165	1/180

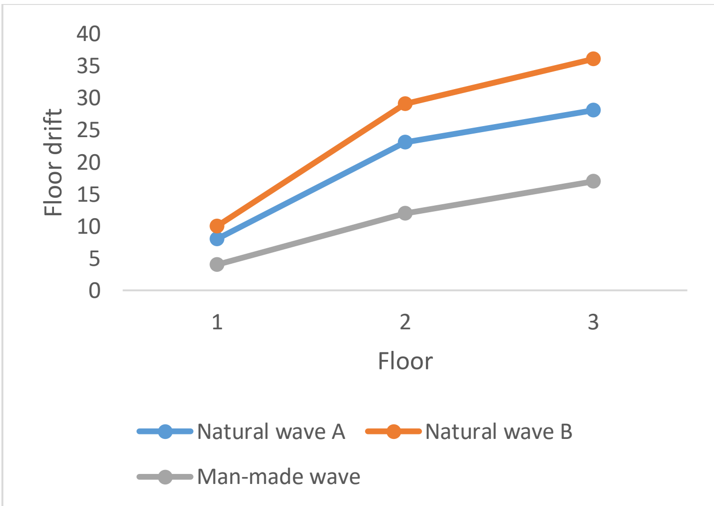

Figure 9. Floor drift of prefabricated model X-direction under rare earthquake

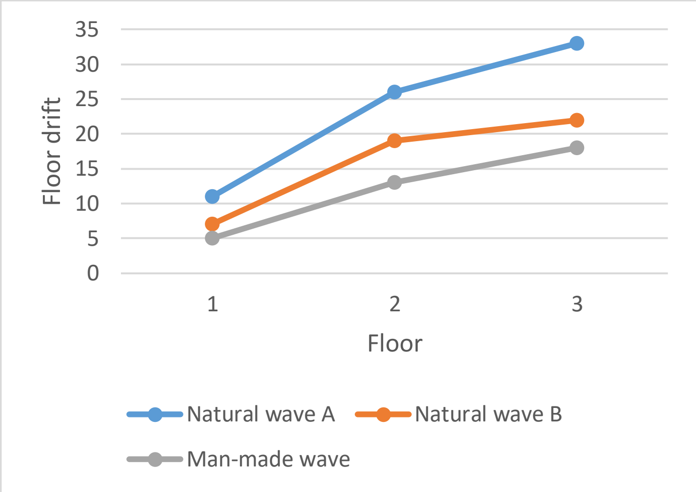

Figure 10. Floor drift of prefabricated model under Y-direction rare earthquake

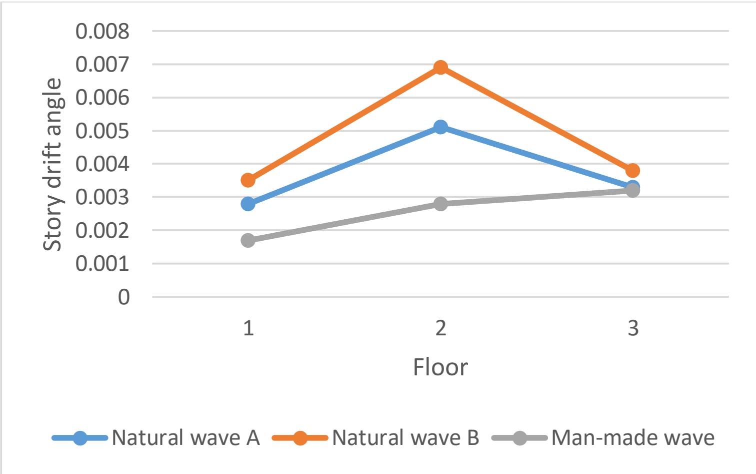

Figure 11. Story drift of prefabricated model X-direction under rare earthquake

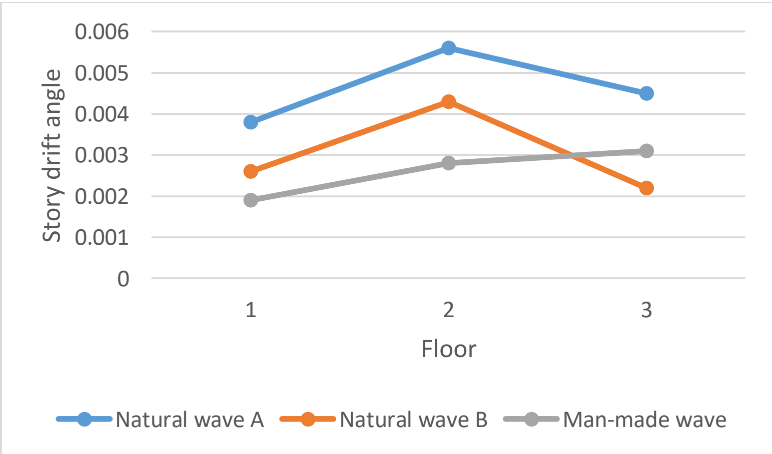

Figure 12. Story drift of prefabricated model X-direction under rare earthquake

6. Conclusions

(1) Under fortification earthquake (moderate earthquake) effect, the maximum story drift angle of structure is 1/3118 and the stress state is elastic loading state, which can meet the requirements of repairable under moderate earthquake.

(2) Under rare earthquake (major earthquake) effect, the maximum elastic-plastic story

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drift angle is 1/165 and the elastic-plastic story drift angle under rare earthquake effect meets the provision of GB50011-2010 *Code for Seismic Design of Building* and can satisfy the requirements of no collapsing with strong earthquake.

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