

Dynamic Elastic-plastic Analysis of High-rise Steel Structure with Buckling-restrained Braces

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Abstract: Using finite element SAP2000, PKPM software to take seismic performance analysis of square concrete-filled steel tube column and steel beam combination frame structure which applied with support of BRB. dynamic elastic-plastic time history analysis was carried out on the model structure, it analyzed elastoplastic seismic performance of the model under strong earthquakes. it obtained that response performance of structure under different level earthquake, compared performance with the specification and investigated results under finite element analysis, verified if the structural seismic performance meet the design requirements or not.

Introduction

After the Japan kobe earthquake in 1995, Buckling-restrained Braces system has been widely used in Japan, more than three hundred buildings has been used so far. In mainland China, research and application has also large increased of Buckling-restrained Braces system. Buckling-restrained Braces has stable, symmetrical tension and compression hysteretic performance, at the same time, it has concentric braced and the function of the hysteretic energy dissipation type components. Buckling-restrained Braces frame has great seismic application value, it improves sexual energy consumption and the ductility of the framework - supporting system effectively.

General situation of the engineering

This engineering structure system is rectangle steel tube concrete frame add Buckling-restrained Braces, its total height is 98.55 m, its graphic rendering rectangle, the length from the east to west is 34.2 m, the width of the north to south is 27.6 m, the ground part of the main structure layer is 25, 1 ~ 4 layer are for commercial, 5 ~ 25 layer are for office buildings, the underground has 3 layers.

Structure design of use fixed number of year is 50 years, durable life fixed number of year is 100 years; the safety level of the building's main structure is the second level; seismic fortification intensity is 8 degrees, basic seismic acceleration for design is 0.2g, design earthquake group is the third group, the seismic fortification category of building is standard C class, siting category is III classes; sitting features period is 0.65 s, structural damping ratio is 0.035; the ground rough categories is C class. structure steel is Q345, the concrete strength grade of rectangular steel tube column is C40 ~ C60, beam is steel beam; all floors adopts steel reinforced concrete composite floor slab, concrete grade is C30, thickness is 120 mm. the load situation of main structure according to load code.

The size of the underlying side column of structure (concrete-filled steel tube column) is 600mm*600mm*18mm*18mm, the size of supporting column is 700mm*700mm*22mm*22mm, the column is filled with C60 concrete; podium pillars are united for the steel frame column, the section size is 400mm*400mm*14mm*14mm; the size of the steel girders is 650mm*240mm*12mm*16mm.

Dynamic elastic-plastic analysis

Structure model. SAP2000 structure model is based on the model of SATWE, the floor is defined as a shell element after imported the corresponding size of beam and column, and then

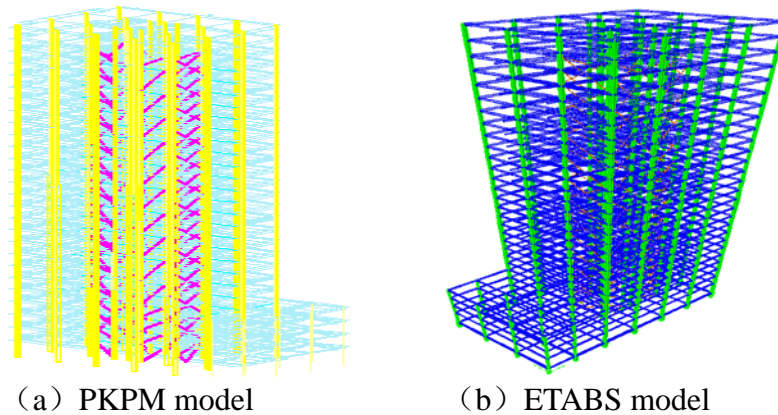
modified its load in the model to meet the load what is consistent with SATWE structure model; because the section form of rectangular concrete-filled steel tube column has changed, so the cross section design of concrete-filled steel tube column section should be designed again. in order to verify the accuracy of the structure model which established in the elastic-plastic time history analysis , compared the first three order cycle what get from the damping structure model calculated date that is established by SAP2000 with SATWE's. shown in the table 3-1:

Table 3-1 The contrast of calculation results between SAP2000 and SATWE

software	T1/S	T2/S	T3/S
SAP2000	3.5531	3.5232	3.1340
SATWE	3.6618	3.4883	3.2245
difference	2.9%	1.0%	2.8%

Note: the difference is : $(|SAP2000-SATWE|/SATWE)*100\%$

The periodic differential value in the table in the allowed range of 5%, then we can use the converted model of SAP2000 to analyse. structural model is as follows:



Picture 3-2 Concrete-filled rectangular steel tube structure model

Select the seismic wave.The project selected the five actual earthquake records (4、 57 wave, 93wave, 106 and 142 wave) and two artificial simulated acceleration time history curve (R1, R2 wave), the comparison of base shear of the calculation results between the response spectrum method and the elastic time history analysis is showed in the table 3-3:

Table 3-3 the bottom shear of damping structure elastic dynamic analysis

General Situation	Response Spectrum	4	57	93	106	142	R1	R2	The Average
Shear kN	X	9959	8548	8245	10924	10744	9254	10061	9718
	Y	9820	8469	9078	9844	10283	9700	11080	10212
Percentage %	X	100	85.8	82.8	109.7	107.9	92.9	101	96.8
	Y	100	86.2	92.4	100.2	104.7	98.8	112.8	99.9

From the above seismic waves's calculation results we can concluded that: the maximum base shear in X direction under the action of 93 wave was up to 109.7% ;the largest base shear in Y direction appeared under R1 wave's action has reached 112.8%, all dates meet the requirements, it indicated that the seismic wave selected is appropriate. took examples of the 93、 106 wave and R1 wave we can get the maximum value of earthquake acceleration time history under the various seismic fortification intensity, then respectively transformed the maximum acceleration peak value of above three wave selected into 1 cm/s², multiplied by the corresponding proportion coefficient then we can get the biggest earthquake acceleration that meet the requirements.

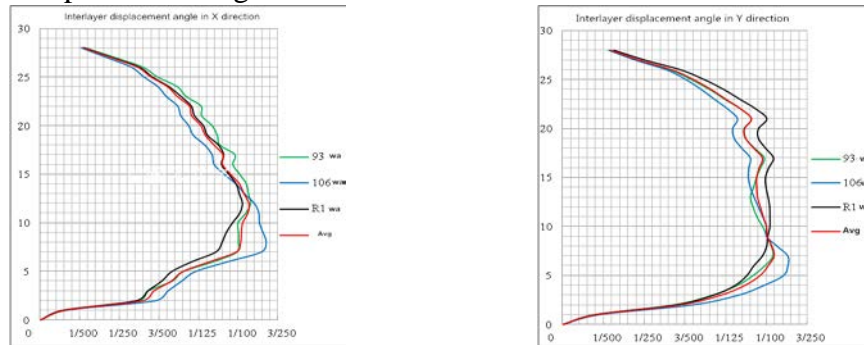
The settings of the structure under elastic-plastic analysis. When used SAP2000 to make elastic-plastic analysis of structure ,it made use of Link's Plastic properties (Wen) to simulate the Buckling-restrained Braces (BRB), the calculational stiffness of Buckling-restrained Braces is $E A_e / l$, yield strength ratio is 0.03, yield index is 2. the main structure frame and column's hinge are defined in the plastic hinge,the hinge of concrete filled steel tubular column is defined as P - M - M hinge, steel hinge is the M hinge of default program, hinge's layout position in 0.1 L and 0.9 L[4].

the materials of concrete-filled steel tube column is Mander model.

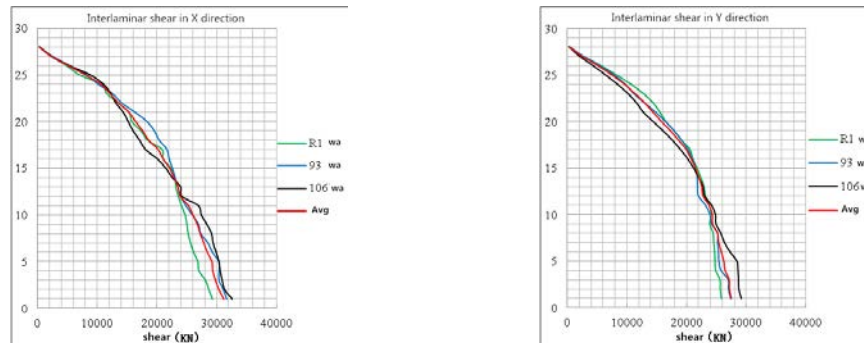
The process of elastic-plastic time history analysis has considered material nonlinearity, taking use of small deformation assumption, without considering geometric nonlinear of structure. it made amplitude modulation of selected seismic wave according to the specification in the process of elastic-plastic time history analysis, then the peak acceleration is 400 cm/s^2 .

The result of elastic-plastic analysis of major structure. For analyze the elastic-plastic performance of structure under different seismic wave and different seismic input direction, it made elastic-plastic dynamic properties's analyze of the structure under the action of the one-way seismic input, the corresponding results of structure under seismic action: interlayer displacement angle, earthquake shear force, lateral displacement, the plastic hinge distribution and so on, then take average of the three under seismic action is the final result.

(1) the interlayer displacement angle

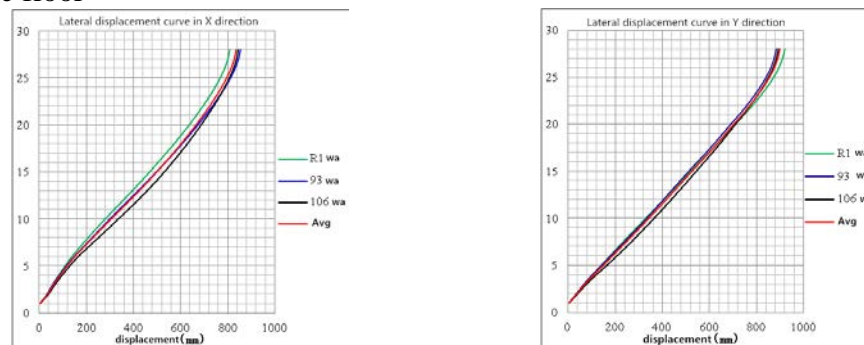


Picture 3-4 Interlayer displacement angle in X direction and Y direction under strong earthquake
(2) the interlaminar shear



Picture3-5 Interlaminar shear in X direction and Y direction under strong earthquake

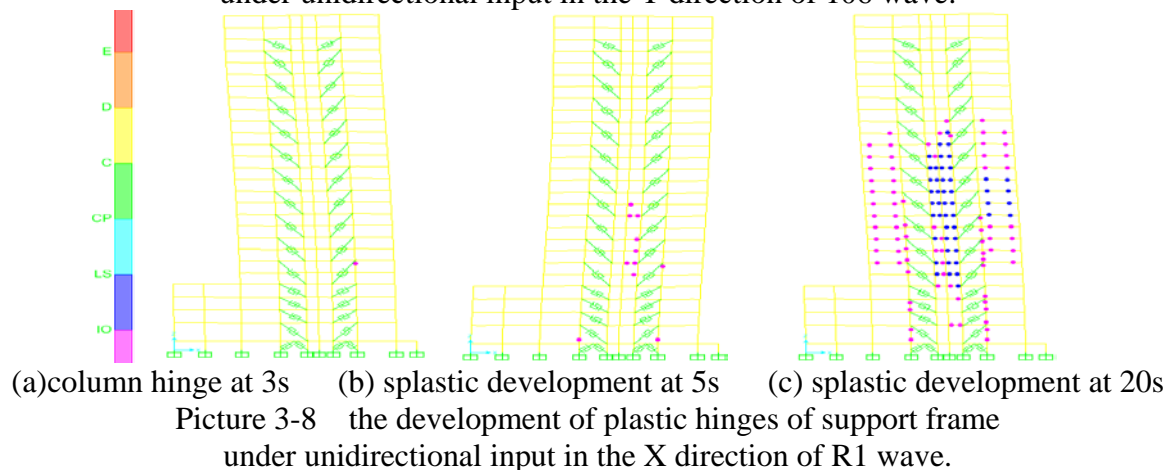
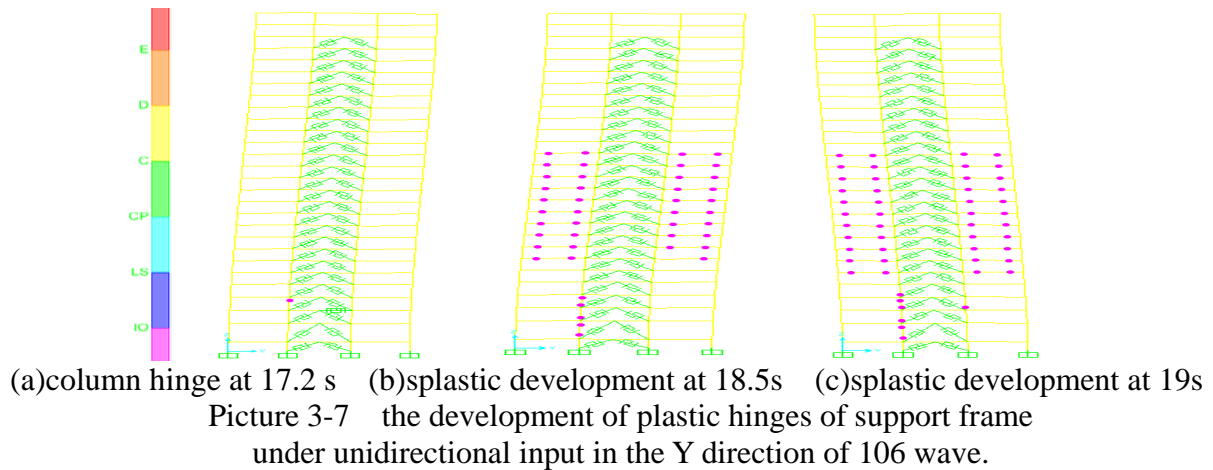
(3) lateral structure floor



Picture 3-6 Lateral displacement curve in X direction and Y direction under strong earthquake

(4) the distribution of plastic hinge

Taking examples of 106 and R1 wave, by analysis of the hinge's emerging order of structure under one-way input in Y、X direction to illustrate the changes in the process of elastic-plastic analysis of structure.



Summary

1. The maximum interlayer displacement angle in the X direction appeared in 8th layer, the size is $1/88$, and the maximal displacement between layers is 43.4 mm; the maximum interlayer displacement angle in the Y direction appeared in 6th and 7th layer, the size is $1/90$, and the maximal displacement between layers is 42 mm. All of the data are meet the requirements that less than $1/55$ expectations in both directions.

2. Under the effect of R1、93 and 106 wave, the maximum lateral in X direction is 855.2 mm, the maximum lateral in Y direction is 919 mm, the displacement curve under effect of the three wave is consistent, the difference is not big.

3. No matter the support frame in X or Y direction, its plastic hinge generally appeared in the first column, this situation is deviated with the structural design that usually let the beam into the plastic yield, and the reason is that with the increase of the lateral and axial force ,the more obvious of P - Δ effect is, the column bending capacity may have fallen sharply, but this is also normal under the elastic-plastic analysis. the overall performance of structure is still of "strong column weak beam", it meet the requirements of structural design.

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