FINITE ELEMENT ANALYSIS OF THE SEISMIC BEHAVIOR OF CONCRETE PERFORATED BRICK MASONRY

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INTRODUCTION

The total height and floors of the high masonry structures are restricted by the “Design Criterion of Anti-earthquake in Structures” (GB50011-2001) used now. The height of clay solid brick building can be 8 floors and 24 meters in anti-earthquake fortify section 6, while the new wall material building is built with 7 floor and 21 meter height. So the “Solid-forbidden” is difficult in this local aspect. The 8 floor and 24 meter tall perforated concrete brick buildings with nonlinear dynamic finite element analysis is studied in this paper, and it is compared with the dynamic experimental results in order to study the possibility of the 8 floors and 24 meters perforated concrete brick buildings, which size is in Fig 1.

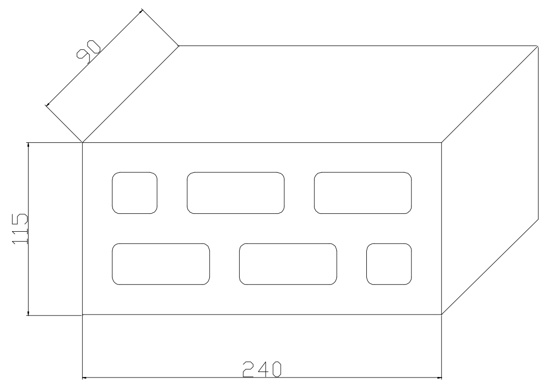


Fig 1 the perforated concrete brick building’s size

ESTABLISH THE FINITE ELEMENT MODEL

The pole system model is used in Fig 3. The constitutive relationship of the perforated concrete brick in reference 1 is described with MISO yield rule in ANSYS. Three lines are used to describe the three stages: elastic, yielding and dropping stage.

Establish the finite element model

The dimension of finite element model established is according to the model building designed in the dynamic experiment. It is convenient to take three opening rooms in the vertical direction and the floor height is 3 meters. The parameters of the model material is shown in Table 1. The finite element models established with ANSYS are shown in Fig 3-5.

Table1.The parameters of the model material

Element	Section dimension (m)	Concrete grade (MPa)	Elastic modulus E (MPa)	Poisson ratio
Wall	0.24	--	4.0E06	0.14
Floor	0.3	C30	3.0E10	0.20
Construct pole	0.24×0.24	C30	3.0E10	0.20
Loop girder	0.24×0.20	C30	3.0E10	0.20

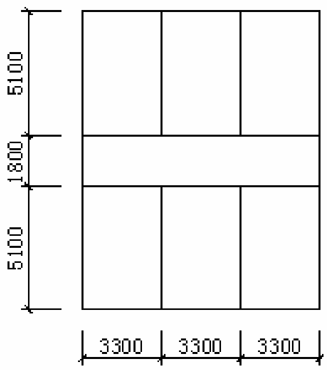


Fig 2 model dimension

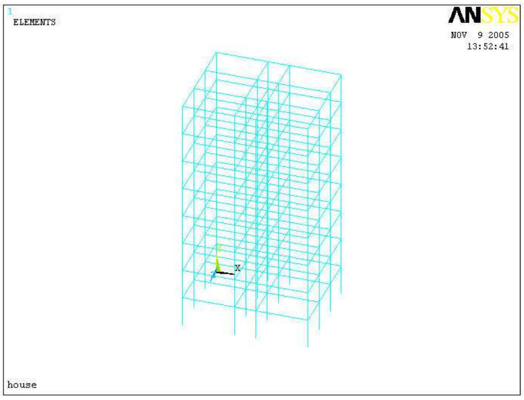


Fig 3 grider-pole model

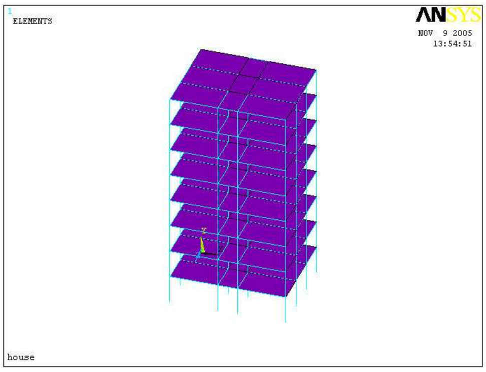


Fig 4 floor model

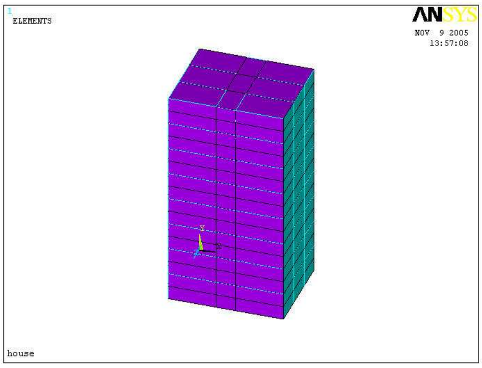


Fig 5 general building model

ANALYSIS OF THE SELF-QUAKE CHARACTERISTIC OF THE PERFORATED CONCRETE BRICK BUILDING

The earthquake response of structure is determined by the earthquake dynamic characteristic and the structure itself. The important dynamic characteristics of structure system are the undamped mode shapes and frequencies. For huge structures, not all the eigenvalues are needed. Only the controlling rank eigenvalues are calculated. So the mode of the finite element model established is analysed. The first 10 frequencies and two mode shapes are shown in Table 2 and Fig 6-7.

Table 2 characteristics of free-quake of perforated concrete brick building

	1 rank quake-pattern	2 rank quake-pattern	3 rank quake-pattern	4 rank quake-pattern	5 rank quake-pattern
frequency	0.529	0.533	0.629	1.591	1.601
period	1.890	1.876	1.590	0.629	0.625
	6 rank quake-pattern	7 rank quake-pattern	8 rank quake-pattern	9 rank quake-pattern	10 rank quake-pattern
frequency	1.890	2.705	2.707	3.159	3.765
period	0.529	0.370	0.369	0.317	0.266

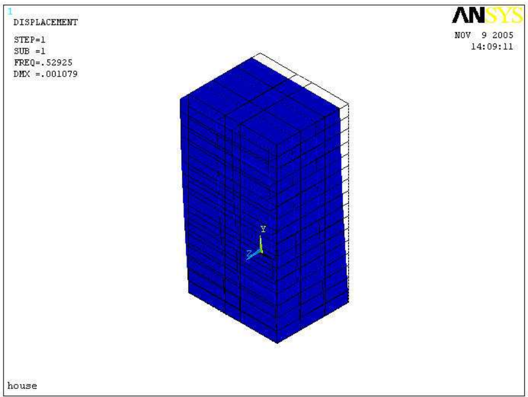


Fig 6 1 rank quake-pattern

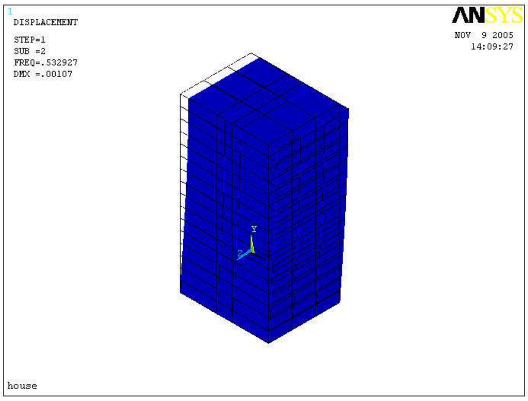


Fig 7 2 rank quake-pattern

ANALYSIS OF THE RESPONSE CHART OF THE PERFORATED CONCRETE BRICK BUILDING

Nowadays, the earthquake response spectrum in the construction antiseismic design criterion takes the ground conditions and the epicenter into account, which is followed in Fig 8. The corresponding response spectrum categories are shown in Table 3-4.

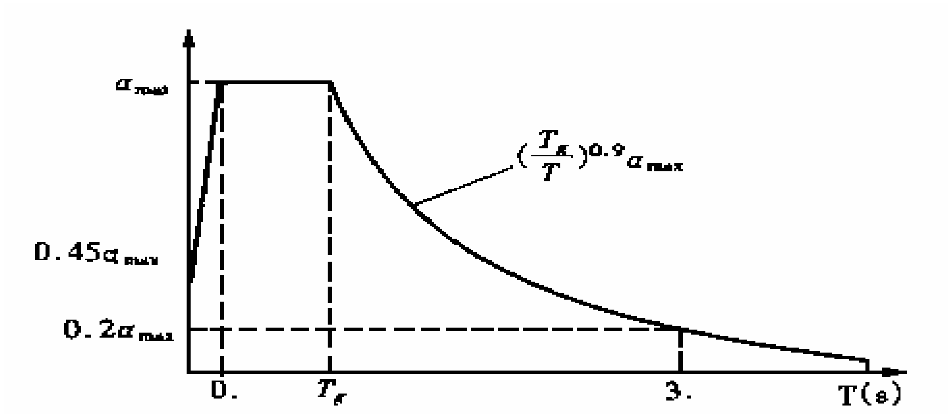


Fig 8 The earthquake response spectrum in the construction antiseismic criterion

Table 3 characteristic period T_g(s)

Ground-conditons	I	II	III	IV
Near earthquake	0.20	0.30	0.40	0.65
teleseism	0.25	0.40	0.55	0.85

Table 4 The maximum horizontal earthquake effecting value in the section antiseismic checking

intensity	I	II	III	IV
α_{max}	0.04	0.08	0.16	0.32

The ground categories in the table are hard, middle-hard, middle-soft, soft ground soil.

The structure damping ratio is an important parameter affects the acceleration response spectrum value. When the structure damping ratio is small, the variety will change the response spectrum value obviously, and then the earthquake force is affected. The earthquake response spectrum in the using antiseismic criterion takes a damping ratio of 0.05 as standard.

The soil type is taken with Type Ⅱ, close to the earthquake. Response chart adopts the standard response chart of Type Ⅱ soil as the chart analysis curve. The data points are in the Table 5, where ‘f’ is the frequency and ‘a’ is the corresponding acceleration.

Table 5 frequency—acceleration

frequency (Hz)									
No.	1	2	3	4	5	6	7	8	9
f	0.4	0.8	1.6	2.8	3.6	4.5	5.5	6.5	7.5

$a(m/s^2)$	0.091	0.179	0.355	0.179	0.267	0.355	0.441	0.527	0.615

Based on the free-vibration results, the x-direction acceleration is input in the 8 floors and 24 meters perforated concrete brick building model. The former 10 rank quake-patterns are piled up. In the calculation, the structure is regard to working in the elastic extent, the load is not discount.

By the response chart calculation, the last quake-pattern of the building is followed in Fig 9 to 11. The frequency of the model 1 is 0.533, the period is 1.876; the frequency of the model 2 is 1.601, the period is 0.625; the frequency of the model 3 is 2.707, the period is 0.369.

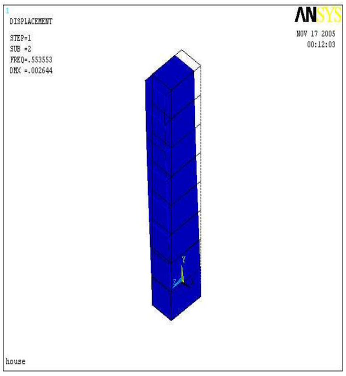


Fig 9 rank quake-pattern

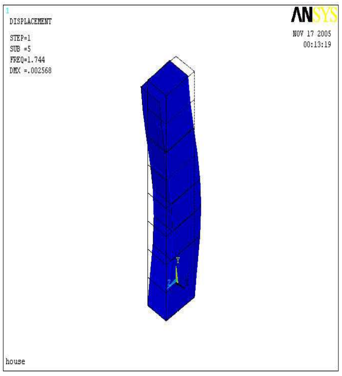


Fig 10 rank quake-pattern

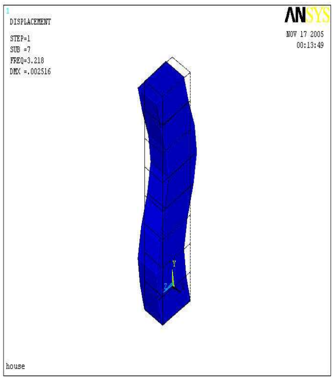


Fig 11 rank quake-pattern

ANALYSIS OF THE EARTHQUAKE DYNAMIC TIME-DEPENDING OF THE PERFORATED CONCRETE BRICK BUILDING

Compared with the dynamic experimental results, the earthquake acceleration is input with the El-CENTRO seismic waves 50gal, 100gal, 200gal, 300gal. Gal is the acceleration units, 1 gal equivalent to 0.01 m / s^2. The seismic waves have 500 data points, and the interval of the acceleration time is 0.01s.

Analysis of the displacement time-depending results

The peak values of the displacement in every floor are listed in Table 6. The displacement time-depending curves in floor 1, 2 and top under the different acceleration peak value seismic waves are followed in Fig 12.

Table 6 The peak values of the displacement in every floor

floors	displacement (mm)							
	1 floor	2 floor	3 floor	4 floor	5 floor	6 floor	7 floor	8 floor

50gal	positive	0.310	0.504	0.644	0.765	0.826	1.047	1.188	1.287
	negative	-0.278	-0.469	-0.613	-0.656	-0.832	-0.938	-1.024	-1.028
100gal	positive	0.620	1.008	1.288	1.530	1.652	2.093	2.375	2.575
	negative	-0.556	-0.939	-1.226	-1.307	-1.664	-1.876	-2.048	-2.149
200gal	positive	1.241	2.017	2.576	3.061	3.305	4.188	4.752	5.151
	negative	-1.112	-1.878	-2.451	-2.613	-3.328	-3.752	-4.096	-4.298
300gal	positive	2.710	4.180	4.390	4.540	6.104	8.125	9.492	10.256
	negative	-2.600	-4.304	-5.350	-5.860	-6.889	-7.564	-7.577	-8.304
400gal	positive	5.030	6.590	6.807	7.837	9.374	12.241	14.049	15.196
	negative	-5.243	-5.921	-6.948	-8.247	8.951	10.620	13.350	14.019

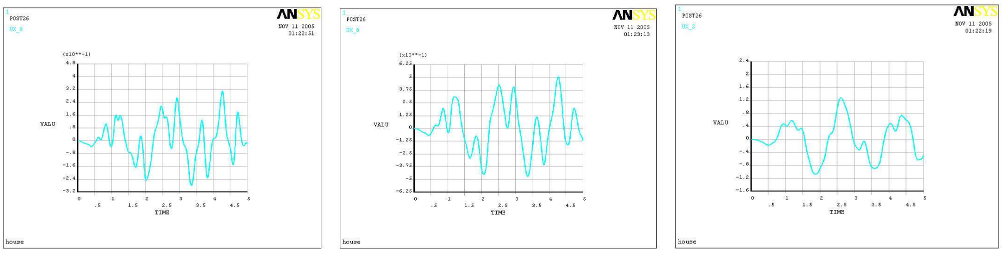
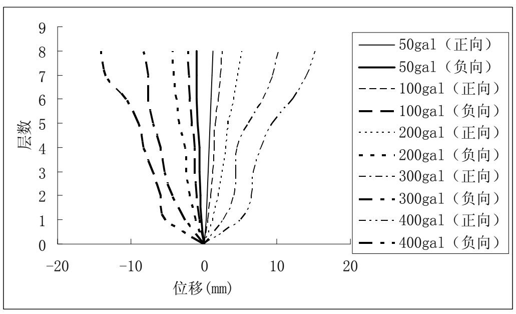


Fig 12 The displacement time-depending curves in floor 1, 2 and top under EL-CENTRO seismic waves 50gal

The change of the horizontal displacement with the height

According to the calculation results, the displaced shapes and the maximum displacement envelopes under the different acceleration peak value are shown in Fig 13, 14.

From Fig 13, the distortion of structure is mainly the cutting distortion. From Fig 14, the floor 1 is the most deformed.



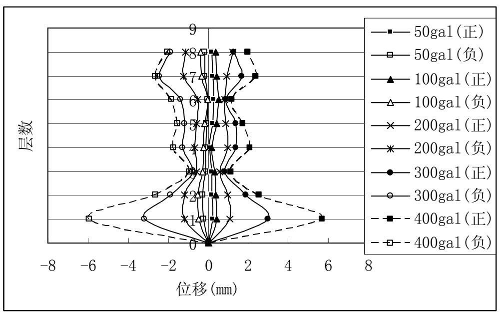


Fig 13 side-move curves in every state Fig 14 maximum displacement curves in every state

Comparison between the finite element results and the dynamic experiments

The comparison of the displacement breadth value

The displacement values of every floor and experimented results are listed in Table 7.

It can be seen that:

(a) The biggest inter-floor displacement is increasing with the increase of acceleration breadth. It is linear relation between 50gal to 100gal. The reason is that the increase of the inter-floor displacement is basically linear relationship with the acceleration.

(b) The structure is in the yielding stage after 200gal, the inter-floor displacement increases more rapidly. The dropping stage comes in 400gal. The inter-floor shearing force decreases, while the inter-floor displacement increases. It indicates that the structure is beyond terminal stage.

(c) The calculated displacement is bigger than the experimental result. The reasons are followed: the first is that the mortar strength of the model building is higher than the designed one. So the elastic modulus of the mortar is much bigger. The analysis adopts the designed one, so the difference is big according to the equation in reference1. The second reason is that the bearing area in experiment is 1 opening room and 2 half opening room on the two sides. However, in the finite element analysis, the effect of the half opening room mass on the two sides is not considered.

Table 7. The displacement values of every floor and imitate-dynamic experiment results under the different acceleration peak value

seismic waves	type	displacement（mm）					
		1 floor		2floor		top floor	
		positive	negative	Positive	negative	positive	negative
ELwave50gal	finite element	0.225	-0.228	0.407	-0.502	1.545	-1.237
	experiment	0.15	-0.19	0.27	-0.295	0.611	-0.56
ELwave100gal	finite element	0.449	-0.456	0.815	-1.004	3.090	-2.474
	experiment	0.425	-0.829	0.72	-1.351	1.383	-1.885
ELwave200gal	finite element	1.099	-1.158	2.067	-2.313	7.497	-7.032
	experiment	1.681	-1.725	2.95	-3.742	4.612	-4.971
ELwave300gal	finite element	2.985	-3.172	4.847	-5.049	13.275	-14.699
	experiment	3.67	-4.70	6.32	-9.23	8.158	-10.538
ELwave400gal	finite element	5.671	-5.962	8.211	-8.573	19.753	-20.295
	experiment	6.99	-11.33	10.77	-17.57	12.738	-19.058

The comparison of the based shearing force

From Table 8, the calculated shearing force is bigger than the experimental result. The reasons are: The finite element model is established by 24 walls, and the dimension is

not reduced. So the self-mass is 48 times than the one in the imitate-dynamic experiment. As a result, the shearing force in the finite element analysis is bigger than the experimental result. But the former is basically 48 times than the last one. So the calculate value is correspond to the experimental one.
However, the difference exists, especially in 50gal. The reasons are: The nonlinear constitutive relationship of the wall is different to the actual situation. On the other hand, the experimental result is effected by many external factors, like the date-reading error, accumulative error, the slippage of the soleplate, the change of the vertical load and so on.

Table 8 Comparison of the base shear force in finite element analysis and experiment under different peak value acceleration

seismic waves peak value acceleration	Maximum base shear force（kN）			
	finite element analysis		imitate-dynamic experiment	
	Positive(push)	Negative(pull)	Positive(push)	Negative(pull)
EL-50gal	6.16	-6.28	21	-26
EL-100gal	41.09	-41.88	108	-106
EL-200gal	125.07	-118.12	189	-184
EL-300gal	252.64	-238.32	486	-439
EL-400gal	316.96	-298.97	562	-530

Hysteresis curve of structure

Because the structure hysteresis curve can reflect the bearing load, stiffness,ductility, energy-consuming and so on, the hysteresis curves of floor 1 and 2 under different peak value acceleration are drawn in Fig 15. And Fig 16 is the corresponding one in the dynamic experiments.

It can be known:
The hysteresis curve between 50 gal and 100 gal is basically beeline. So the structure is in elastis stage.
The load of hysteresis curve increases in 200gal, but the slope reduces relatively. The structure is coming into plastic stage.
The hysteresis curve of floor 2 is reverse S type. The distortion is mainly shearing one.
The structure is in terminal stage in 400gal. The bearing load reduces with the increasing of the load, while the displacement is increasing.
The imitate-dynamic experiment results show that structure is in still in elastic stage

between 50gal to 100gal, yielding stage in 200gal, cracking in 300gal, terminal stage in 400gal. It is likely the situation of the finite element analysis. So the veracity of the analysied result is known.

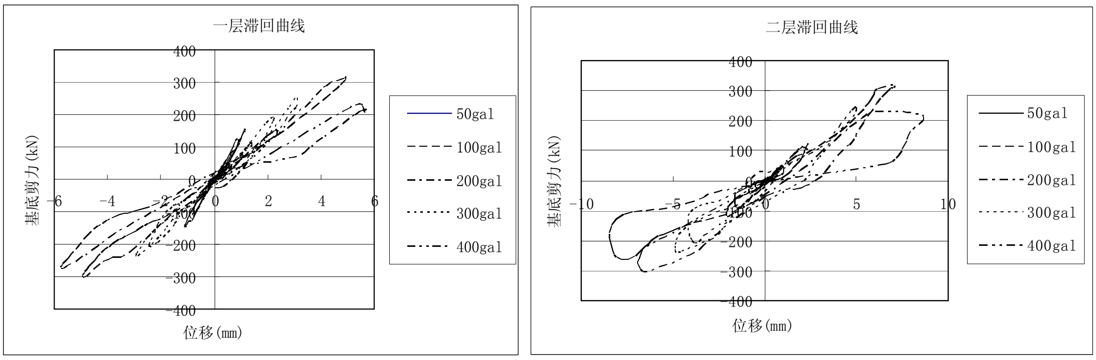


Fig 15 the structure hysteresis curves in floor 1 and 2

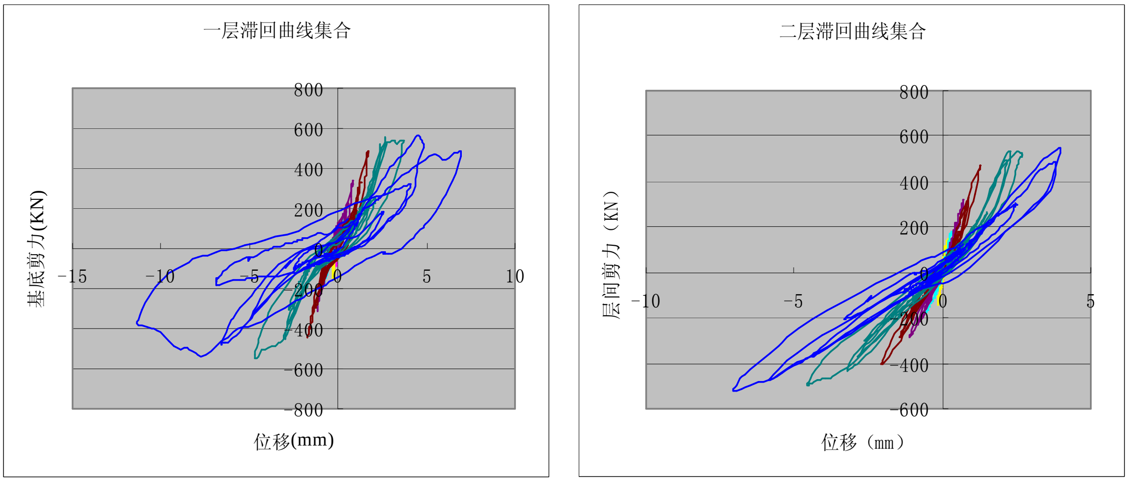


Fig 16 the structure hysteresis curves in floor 1 and 2 by imitate-dynamic experiment

CONCLUSION

The paper establishes the 8 floors and 24 meters (3 opening rooms) nonlinear finite element model with ANSYS, adopts the grider elment and shell element to establish the grider, floor board and wall, selects the proper constitutive relationship of the wall.

By mode analysis, the former 10 model frequency and periods is known. The first, second, and third model are gained by inputting the horizontal response chart. Based on the analysis, the vertical displacement and base shear force is known by inputting the El-CENTRO seismic waves 50gal, 100gal, 200gal, 300gal. The results are compared to the experimental results.

The results show that it is possible to establish the finite element model in this way. Under the El-CENTRO seismic waves 200gal, the 8 floor 24 meters perforated concrete brick building is in yielding stage. While it isn't in terminal stage in 300gal, the terminal load comes in 400gal. It indicates that the structure can endure 7-degree middle

earthquake, and can bear load in a big earthquake. A 24 meter tall perforated concrete brick structures with 8 floors in 6-degree section is safe. The finite element analysis also proves the veracity of the dynamic experiments.

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