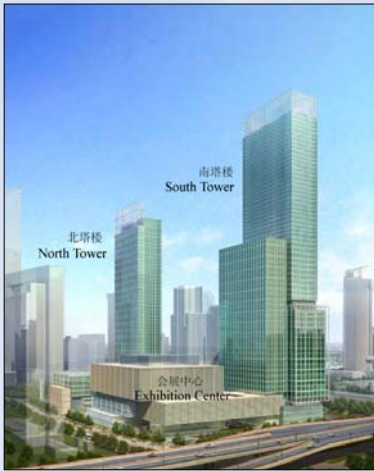




# Shaking table model test of a super high-rise building with setbacks in elevation

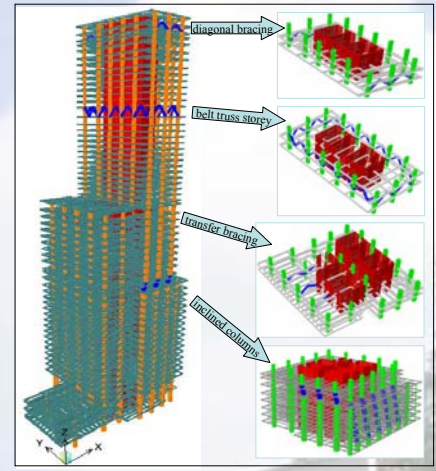


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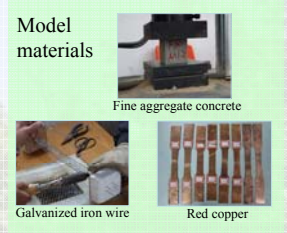


## Introduction

Storey: 58 above the ground and a 4-storey basement  
 Height: 244.8m (top of roof)  
 260.0m (top of steel frame)  
 Function: office building and hotel  
 Structural system: SRC frame and RC core  
 Characteristics: setbacks  
 inclined columns  
 belt truss storey  
 transfer bracing  
 Seismic design intensity: 7 (0.1g)  
 Code: Chinese code for seismic design of buildings (GB 50011-2001)  
 Technical specification for concrete structures of tall building (JGJ 3-2002)



## Model design and construction



### Similitude relationship

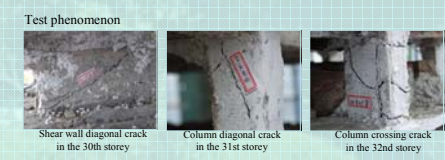
Parameters	Relationships	Model/prototype
Length	$S_L$	1/35
Elastic modulus	$S_E$	0.30
Stress	$S_\sigma$	0.30
Strain	$S_\epsilon/S_{\epsilon E}$	1.00
Density	$S_\rho$	3.50
Force	$S_F$	2.45E-04
Frequency	$S_f$	10.25
Acceleration	$S_a$	3.00



## Test program

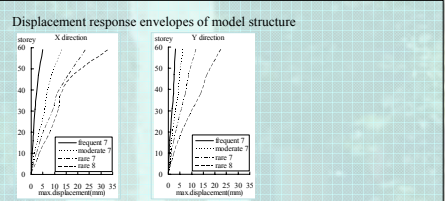
Test case	Case name	Earthquake Frequency	Input Signal	Peak value of input acceleration (g)						Note
				Direction X		Direction Y		Direction Z		
1	W1	Frequency 7	White noise 1	0.05	0.05	0.05	0.05	0.05	0.05	3D
2	F1EYX		El Centro	0.11	0.128	0.09	0.097			2D
3	F1EYX		El Centro	0.09	0.101	0.11	0.152			2D
4	F1PYX		El Centro	0.11	0.129	0.09	0.073			2D
5	F1PYX		El Centro	0.09	0.126	0.11	0.143			2D
6	F1SHX		SHW1	0.11	0.123					1D
7	F1SHY		SHW1			0.11	0.152			1D
8	W2	White noise 2	White noise 2	0.05	0.05	0.05	0.05	0.05	0.05	3D
9	B1EYX		El Centro	0.30	0.342	0.26	0.276			2D
10	B1EYX		El Centro	0.26	0.261	0.30	0.264			2D
11	B1PYX	El Centro	0.30	0.349	0.26	0.281			2D	
12	B1PYX	El Centro	0.26	0.299	0.30	0.348			2D	
13	B1SHX	SHW1	0.30	0.436					1D	
14	B1SHY	SHW1			0.30	0.304			1D	
15	W3	White noise 3	White noise 3	0.05	0.05	0.05	0.05	0.05	0.05	3D
16	R1EYX		El Centro	0.60	0.713	0.51	0.418			2D
17	R1EYX	El Centro	0.51	0.526	0.60	0.508			2D	
18	R1PYX	El Centro	0.60	0.741	0.51	0.573			2D	
19	R1PYX	El Centro	0.51	0.552	0.60	0.593			2D	
20	R1SHX	SHW1	0.60	0.803					1D	
21	R1SHY	SHW1			0.60	0.471			1D	
22	W4	White noise 4	White noise 4	0.05	0.05	0.05	0.05	0.05	0.05	3D
23	R2EYX		El Centro	1.08	1.407	0.92	0.803	0.70	0.716	3D
24	R2EYX	El Centro	0.92	1.227	1.08	1.33	0.70	0.654	3D	
25	R2PYX	El Centro	1.08	1.716	0.92	1.139	0.70	1.032	3D	
26	W5	White noise 5	White noise 5	0.05	0.05	0.05	0.05	0.05	0.05	3D

## Test results



### The first three frequencies and modal shapes

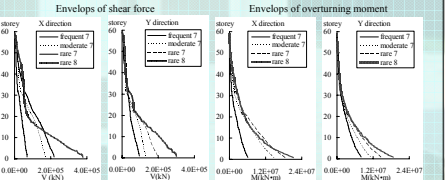
Structure	Model structure			Prototype structure			
	No.	1	2	3	1	2	3
White noise 1	Frequency	3.418Hz	3.418Hz	6.347Hz	0.333Hz	0.333Hz	0.619Hz
	Modal shape	X	Y	T	X	Y	T
White noise 2	Frequency	3.418Hz	3.418Hz	6.347Hz	0.333Hz	0.333Hz	0.619Hz
	Modal shape	X	Y	T	X	Y	T
White noise 3	Frequency	2.930Hz	2.930Hz	—	0.286Hz	0.286Hz	—
	Modal shape	X	Y	T	X	Y	T
White noise 4	Frequency	2.930Hz	2.930Hz	5.371Hz	0.286Hz	0.286Hz	0.524Hz
	Modal shape	X	Y	T	X	Y	T
White noise 5	Frequency	2.441Hz	2.441Hz	—	0.238Hz	0.238Hz	—
	Modal shape	X	Y	T	X	Y	T



### Dynamic response of prototype structure

Inter-story drift angle of prototype structure

Test phase	Frequency 7		Moderate 7		Rare 7		Rare 8		
	Direction	X	Y	X	Y	X	Y	X	Y
Max. inter-storey drift angle	1/838	1/1611	1/352	1/801	1/207	1/308	1/138	1/218	
Code value	1/500	1/500			1/100	1/100			



## Conclusions and suggestions

- Under frequent occurrence of seismic design intensity 7, no visible damage can be observed. The natural frequency remained unchanged. Under moderate occurrence of seismic design intensity 7, the natural frequency decreased very slightly, which indicates that the prototype structure can behave elastically when attacked by those levels of earthquakes. Under rare occurrence of seismic design intensity 7 and 8, the structure damaged locally but still could survive and keep stable, which indicates that the target high-rise building could meet the design criteria of no damage under frequent earthquake and no collapse under rare earthquake;
- The maximum inter-storey drift angles under frequent earthquake 7 and rare earthquake 7 satisfy the limitations of Chinese code;
- Under rare earthquake 8, the setback storey damaged severely which may leads to the weak point of the structure. It is suggested that appropriate improvement on ductility should be made to the stories adjacent the setbacks;
- The angle of inclined columns to the vertical direction should be decreased to improve the seismic performance of the structure.

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