"Abserver" vibration test

Test report

January 2008

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0.Introduction

We started development of a seismic isolation device for computer racks, cultural properties and precious assets in order to protect them from huge earthquakes.

Upon development, we firstly vibrated random waves with a simplex vibration trestle on one axis to grasp the characteristics of the device, and decided the final specification for mass production.
In order to investigate the actual behavior at the time of the earthquake, we simulated the seismic waves actually observed at the Kobe Marine Weather Valley in the 1995 Hyogo ken Nanbu Earthquake on the 3D vibration table.

1.Test date and time

Test date and time : Tuesday, September 19, 2007 8: 00 ~ 18: 00
Test location: Urban Renaissance Agency
Urban Housing Technology Institute
2683 - 3 Ishikawacho, Hachioji City, Tokyo
tel 042-644-3751
http://www.ur-net.go.jp/rd/vibrat/

写真１－１

写真１－２

2. Shaking Table Specification

The specifications of the vibration table are shown below.

- Vibration direction — Horizontal 2 axes, vertical 1 axis, rotation around each axis
- Shaking table dimensions — 4 m x 3 m
- Mounting load — 4 tf
- Maximum displacement — X = ± 250 mm, Y = ± 200 mm, Z = ± 100 mm
- Maximum speed — X = ± 75 cm / s, Y = ± 75 cm / s, Z = ± 75 cm / s
- Maximum acceleration — X = ± 1.2 G, Y = ± 1.2 G, Z = ± 1.2 G
- Measuring device — 64ch

写真２－１

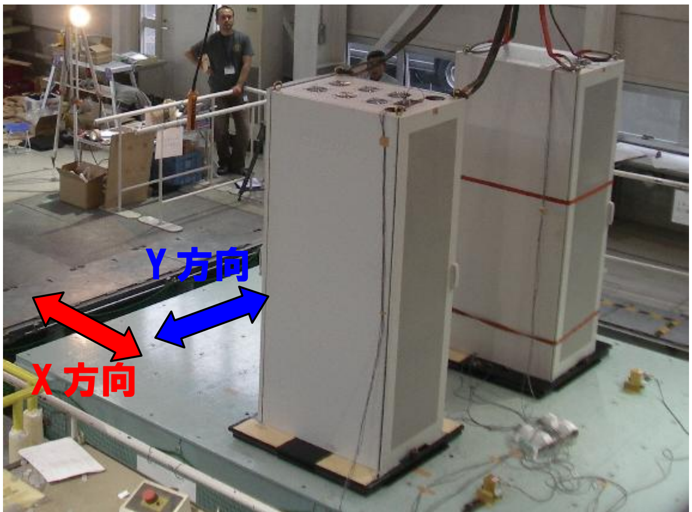


写真２－２

3. Simulated seismic wave

The seismic waves to be excited on the vibrating table are the seismic waves measured at the Kobe Maritime Atmosphere for the Hyogo ken Nanbu (Kobe) Earthquake (magnitude: 7.3, depth of epicenter: about 18 km) occurred on January 17, 1995.
The north-south direction is vibrated in the X direction of the shaking table, and the east-west direction is vibrated in the Y direction.
Figure 3-1 shows the time history waveform of the actual acceleration.

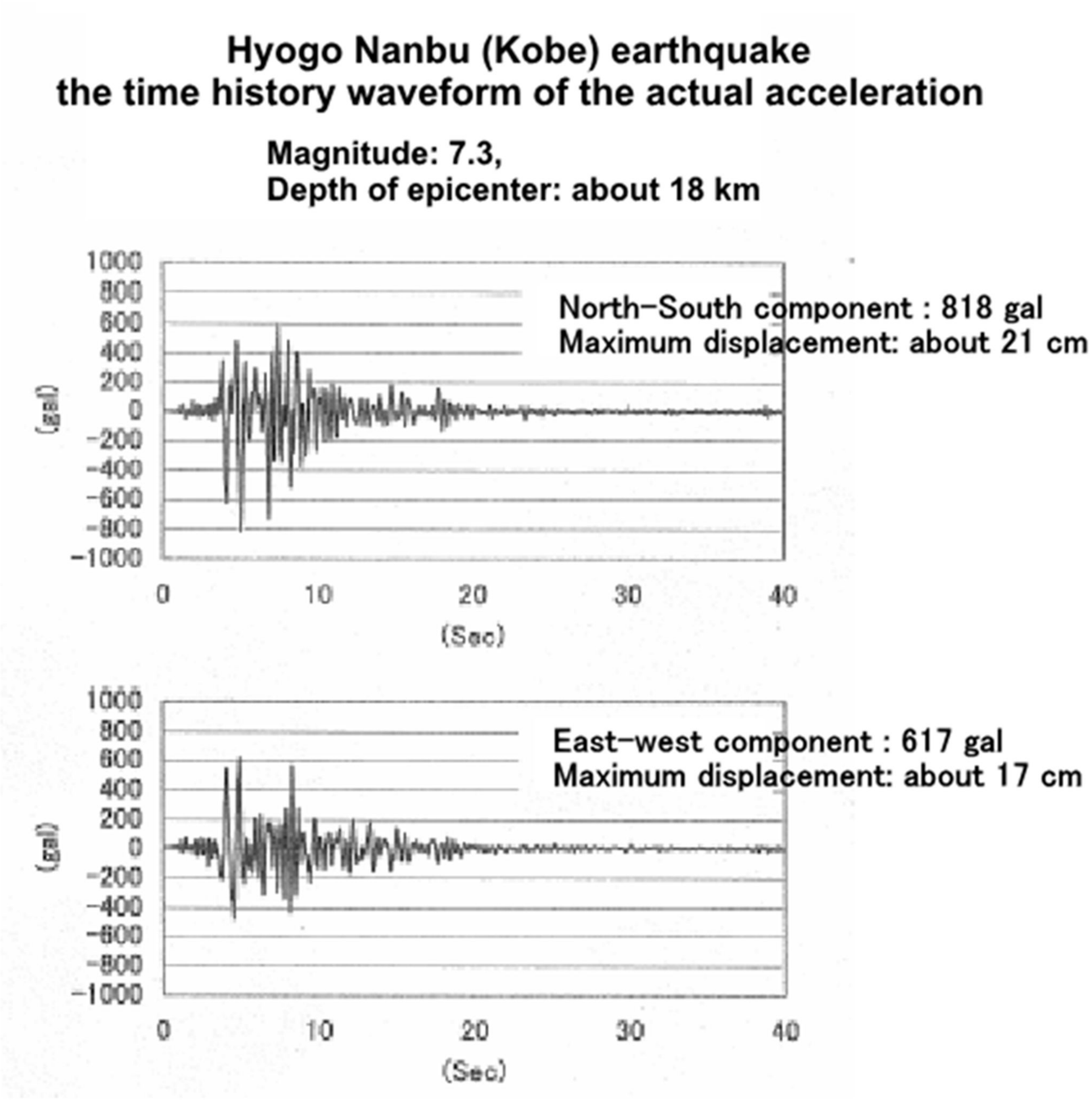
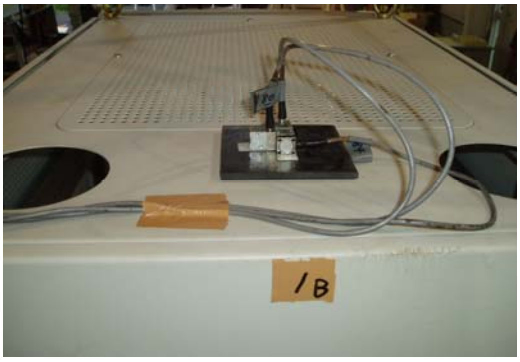


Figure 3-1

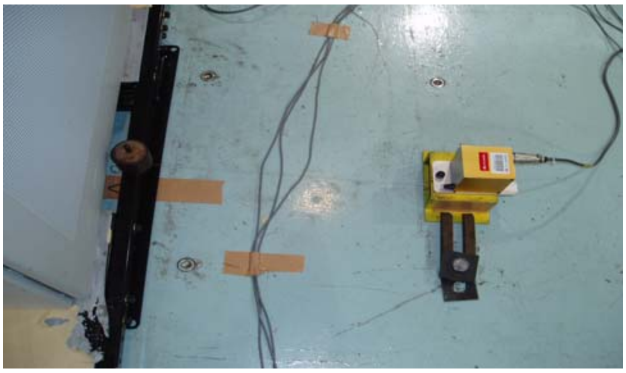
3.Test equipment

As shown in Photo 3-1, "Abserver" was placed on the oscillating table, and the server rack was placed on it. Installed an accelerometer on the vibration table, Abserver top, and server rack top, and a displacement meter between the vibration table and Abserver to measure Abserver displacement.(Photo 3-1, Photo 3-2, Photo 3-3)

Acceleration on server rack
Photo 3-1



Accelerometer on Abserver
Photo 3-2



Measure of displacement of Abserver
Photo 3-3

5-1. Test result (acceleration)

For the calculation of the test, a low pass filter was used which was zero from 10 Hz to 20 Hz for the following reasons.

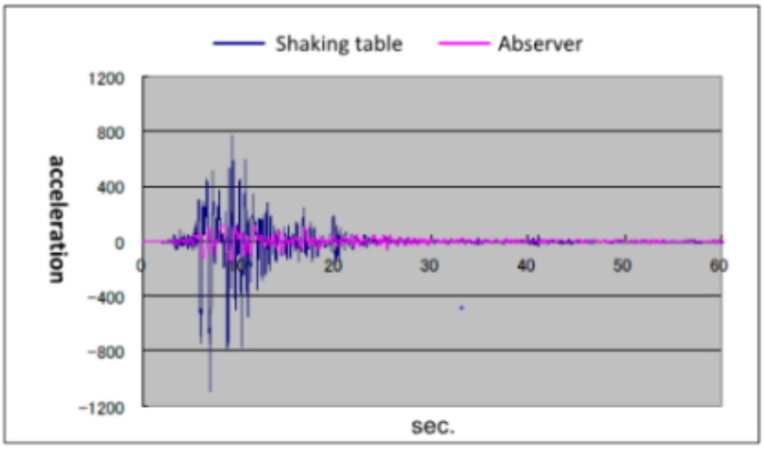
- For both X and Y directions, the numerical value of 10 Hz or more indicates an extremely small numerical value from the spectrum on the input side
- Accelerometer and displacement gauge Analogue value is A / D converted with Δt 0.005 sec (20 Hz)
- Consider the effect of the natural period of the rack loaded on Absever

The excitation acceleration, the acceleration on the Abserver, the acceleration on the server rack, and the relative displacement of the Abserver are shown in the X direction and the Y direction, respectively.

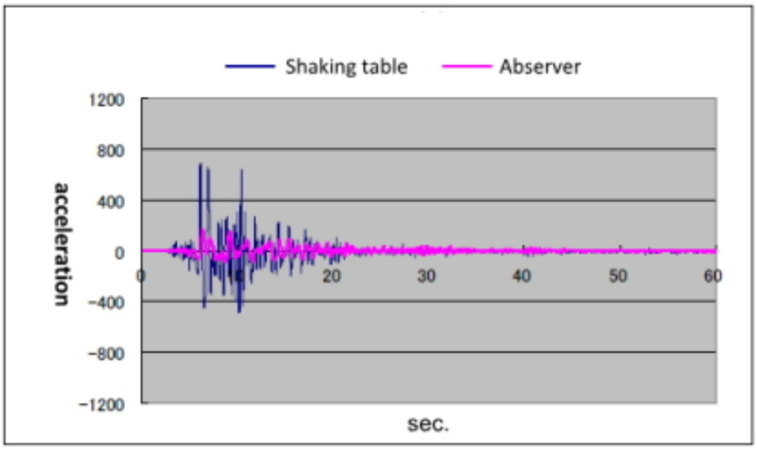
	X direction (North-South)	Y direction (East-West)
Max. acceleration on Shaking table	1100 (gal)	692 (gal)
Max. acceleration on Abserver	156(gal) (1/7.1)	166(gal) （1/4.2）
Max. acceleration on the top of server rack	455(gal) （1/2.4）	532(gal) （1/1.3）
Max. displacement of Abserver	13.6 (cm)	11.1 （cm）

Table 5-1 Test results

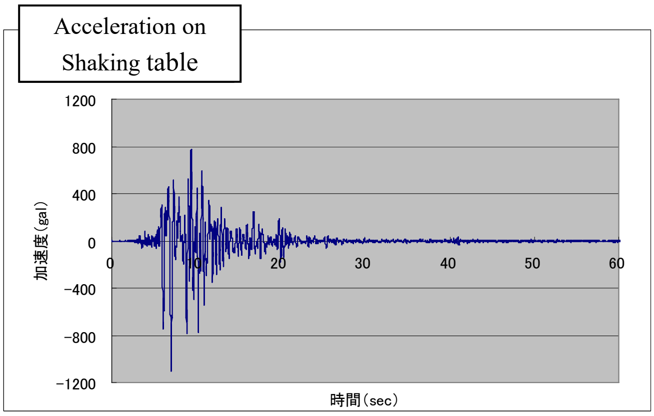
X direction



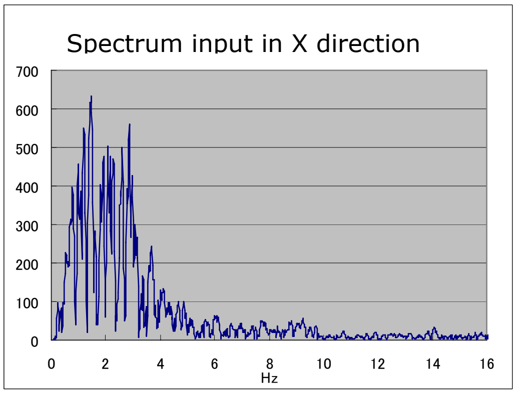
Y direction



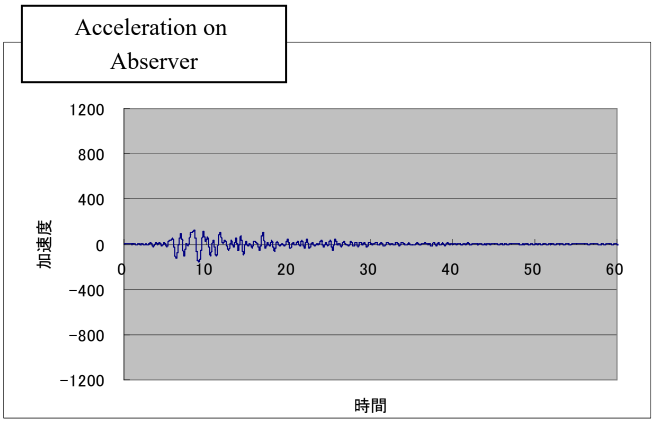
X direction



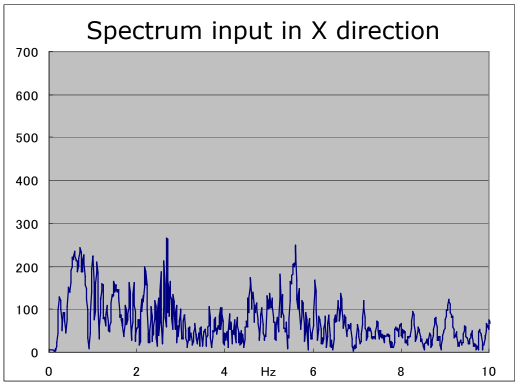
Acceleration on Shaking table
加速度(gal)
時間(sec)



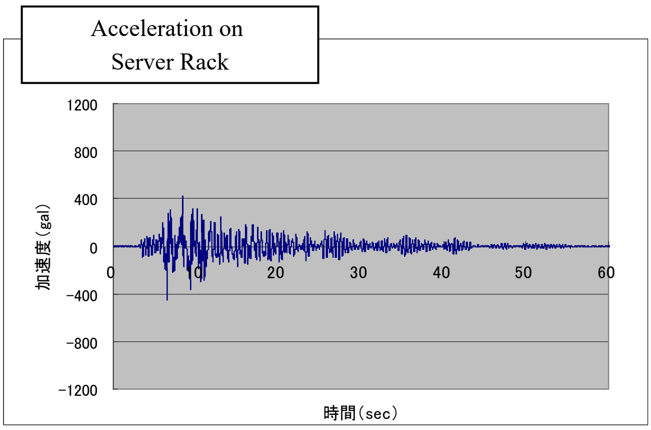
Spectrum input in X direction
Hz



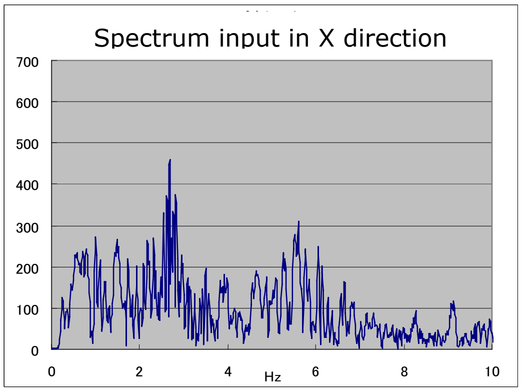
Acceleration on Abserver
加速度
時間



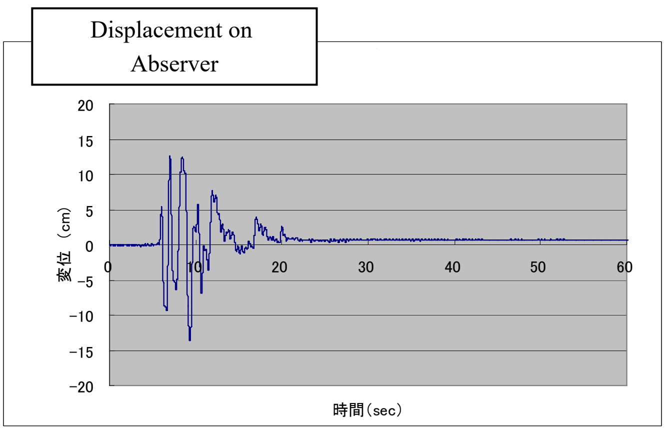
Spectrum input in X direction
Hz



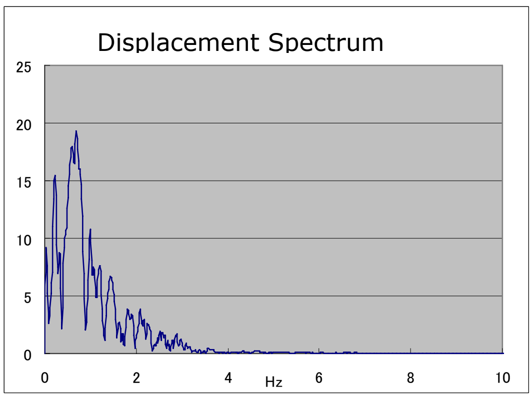
Acceleration on Server Rack
加速度(gal)
時間(sec)



Spectrum input in X direction
Hz

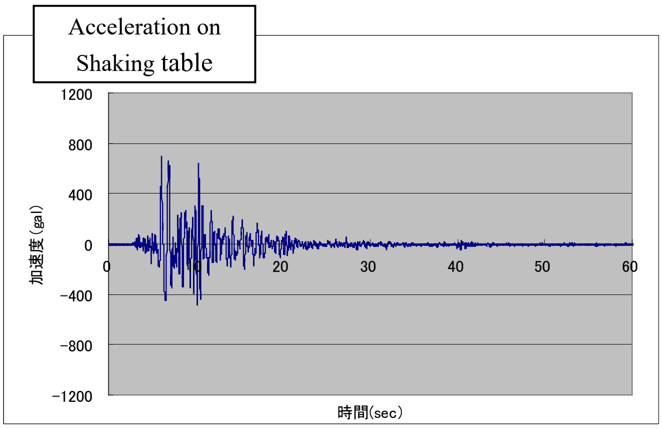


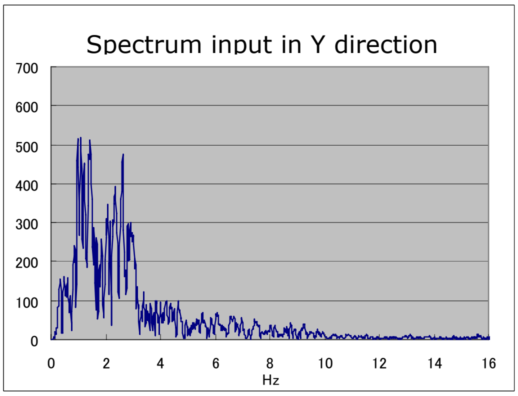
Displacement on Abserver
変位 (cm)
時間(sec)

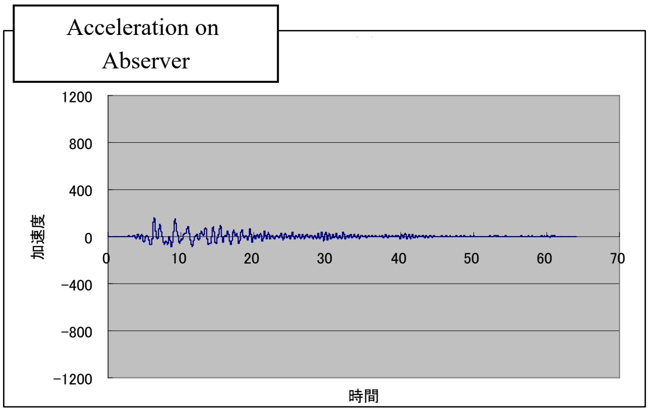


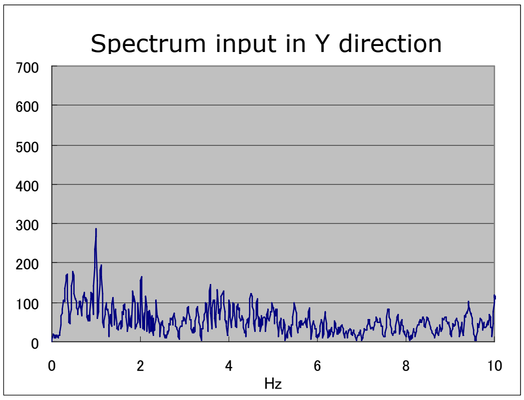
Displacement Spectrum
Hz

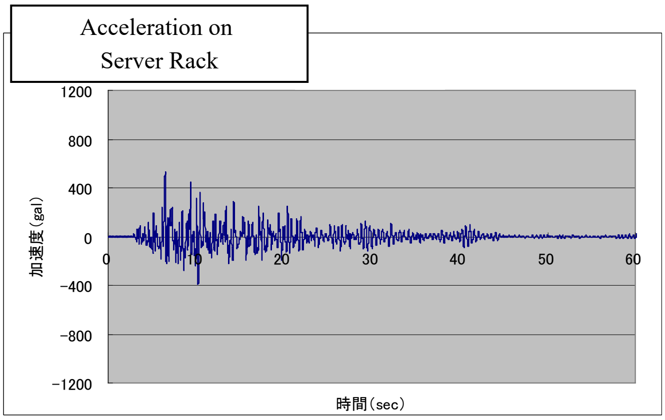
Y direction

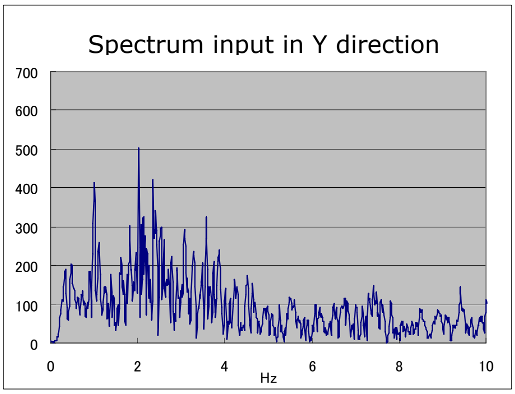

Acceleration on Shaking table
加速度(gal)
1200
800
400
0
-400
-800
-1200
0
10
20
30
40
50
60
時間(sec)

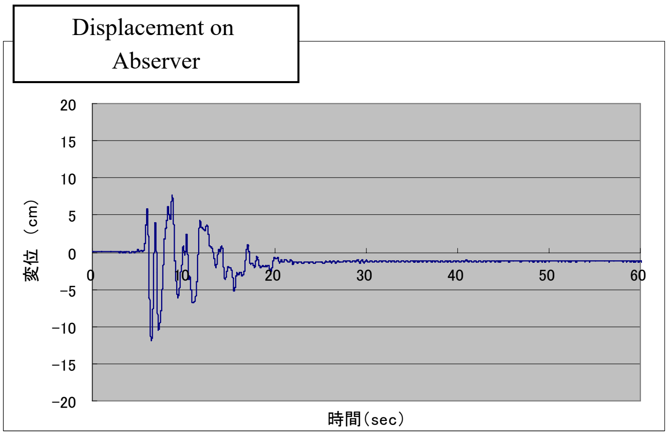

Spectrum input in Y direction
700
600
500
400
300
200
100
0
0
2
4
6
8
10
12
14
16
Hz

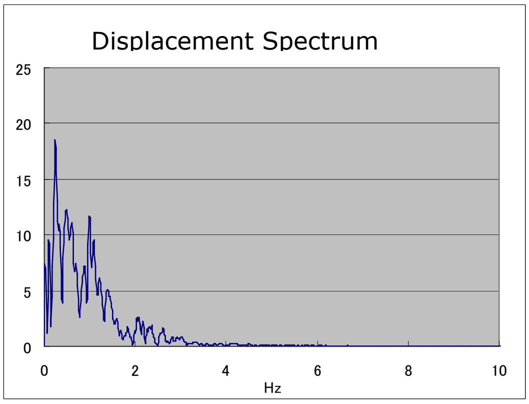

Acceleration on Absorver
加速度
1200
800
400
0
-400
-800
-1200
0
10
20
30
40
50
60
70
時間


Spectrum input in Y direction
700
600
500
400
300
200
100
0
0
2
4
6
8
10
Hz

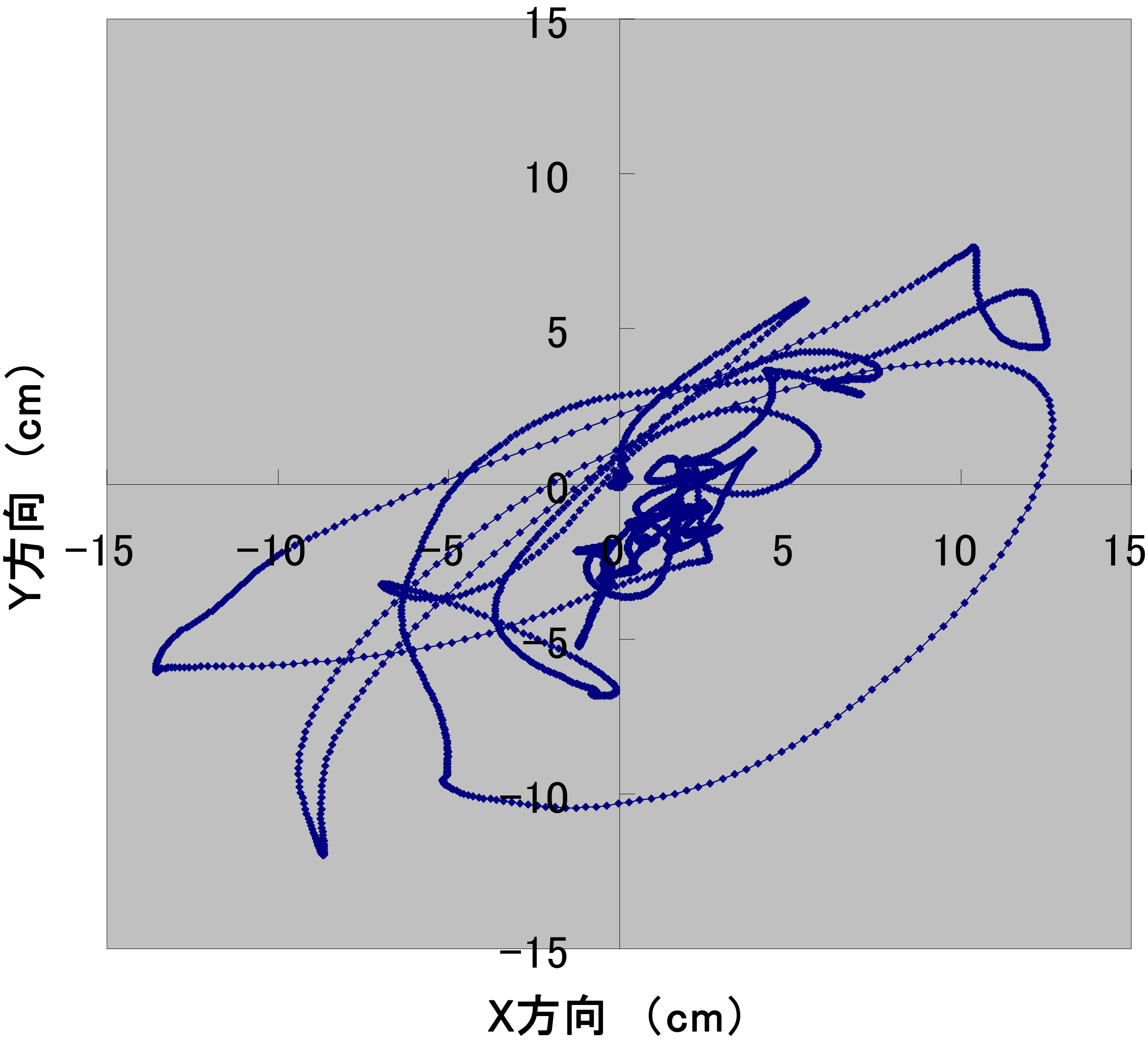

Acceleration on Server Rack
加速度(gal)
1200
800
400
0
-400
-800
-1200
0
10
20
30
40
50
60
時間(sec)


Spectrum input in Y direction
700
600
500
400
300
200
100
0
0
2
4
6
8
10
Hz


Displacement on Absorver
変位 (cm)
20
15
10
5
0
-5
-10
-15
-20
0
10
20
30
40
50
60
時間(sec)


Displacement Spectrum
25
20
15
10
5
0
0
2
4
6
8
10
Hz

Displacement Orbit



5-2 Consideration

The Absorver used for this vibration shaking test was made of two bearings of marble and two ball bearings, but standard should be used in combination with two ball bearings as ball bearing as shown in Photo 5-3 , It was confirmed that the response acceleration decreased from the free vibration experiment result, so we chose this combination as the standard.

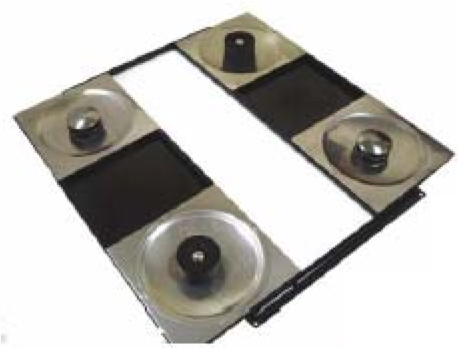


Photo 5-3

Also, from the vibration table test results, we will infer the response acceleration by the following method.
Figure 5-4 shows the results of the vibration with the same specification as the shaking table test, and Figure 5-5 shows the addition of the vibration reduction pad in Figure 5-4.

When comparing the acceleration of the initial wave and the acceleration of the second wave in free vibration
In Figure 5-4
  First time 105/132 = 0.80   Second time 165/218 = 0.76   Average 0.78
In Figure 5-5
  First time 70/100 = 0.70   Second time 88/126 = 0.70   Average 0.7

Although the average reduction in free vibration was about 10%, the results of reflecting the results in the shaking table test are added in Table 5-1.

2 marbles + 2 ball bearings

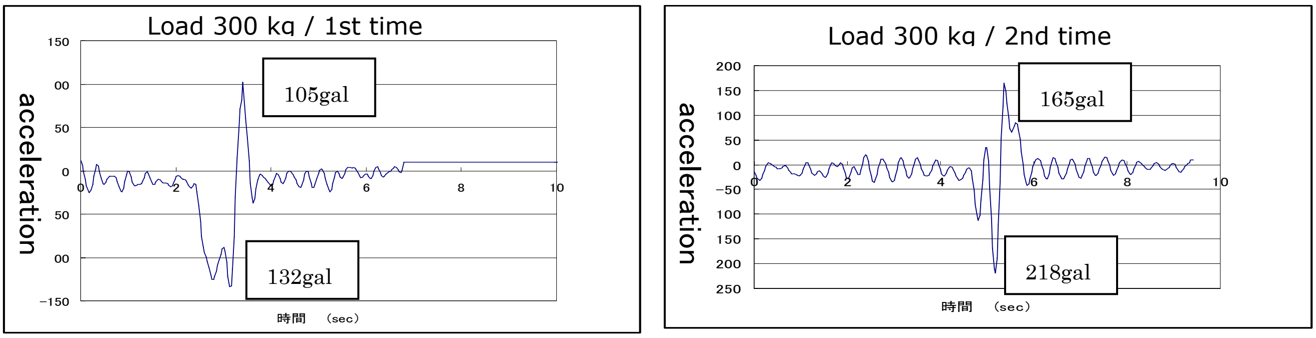


Fig. 5-4

2 marbles + 2 ball bearings with vibration reduction pad

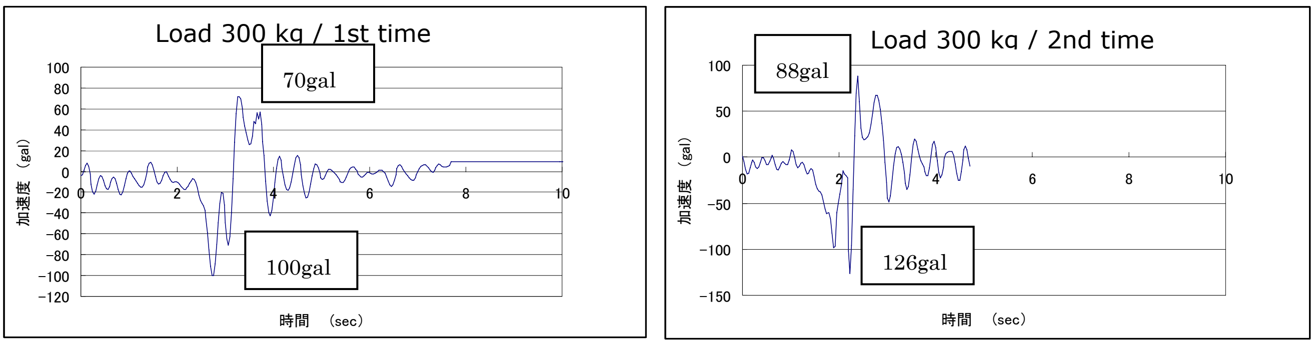


Fig. 5-5

6. Displacement Analysis by Building

Based on the test at Urban Renaissance Agency, the maximum displacement amount of the building and the seismic isolation device was obtained by our original analysis program.

6-1. Analysis method

As shown in Fig. 6-1, the building was made a vibration model of one mass point by rigidity and damping elements.
We calculated the response acceleration when the ground was forcibly excited with seismic waves measured by the Kobe Marine Weather Valley during the Hyogo ken Nanbu Earthquake and calculated again as the input wave.

In Fig. 6-1, the stiffness is determined so that the mass point M is the effective vibration mass of the building and the natural period calculated from the height of the building matches the natural period calculated from the following formula.

Reinforced Concrete construction : $T = 0.02 \times H$
Steel construction : $T = 0.03 \times H$

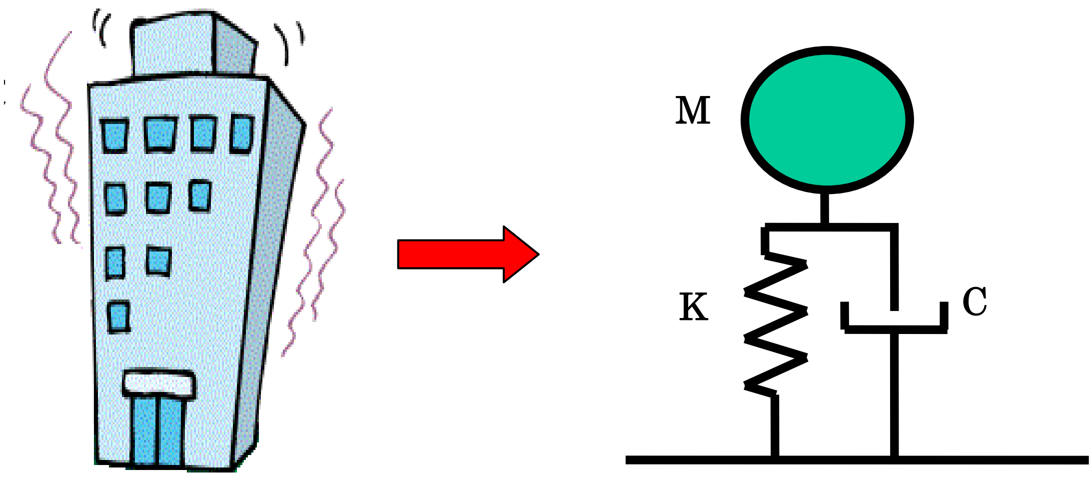


Fig. 6-1 One mass vibration model

H: Overall height of building (m)
T: Primary natural period (sec)
M: Vibration mass (weight)
K: Stiffness (restoring force, spring constant)
C: Damping coefficient (braking force)

6-2. Analysis parameters

The details of the building used for this analysis are decided as follows, S-construction is shown in Table 6-1 and RC-construction is summarized in Table 6-2.

・Building height is calculated assuming that the height of the first floor is 3.5 m.

・2/3 of the building height shall be effective height.

・Determine the weight of the entire building with the plan dimension of the building set to 50 m × 50 m and the weight to 1 tonf / m 2 to the rank multiple

・S-construction is 0.6 times, R- construction is 0.7 times to the total weight to be the vibration weight.

・Structural attenuation is set so that the response displacement with respect to effective height is 1/100 in S structure and 0.7 / 100 in RC construction.

Table 6-1 Analytical terms of S-construction model

	Building height(m)	Effective height(m)	Weight (tonf)	Primary natural period(s)	Structural decay(％)
10F	３５	２３．３	１５０００	１．０５	１９
15F	５２．５	３５	２２５００	１．５７５	9
20F	７０	４６．７	３００００	２．１	2
30F	１０５	６８	４５０００	３．１５	2
40F	１４０	９３．３	６００００	４．２	2

Table 6-2 Analytical terms of RC-construction model

	Building height(m)	Effective height(m)	Weight (tonf)	Primary natural period(s)	Structural decay(％)
10F	３５	２３．３	１７５００	０．７	１２
15F	５２．５	３５	２６２５０	１．０５	１８
20F	７０	４６．７	３５０００	１．４	1
30F	１０５	６８	５２５００	２．１	1
40F	１４０	９３．３	７００００	２．８	1

The following three types of Abserver bearibgs are used for this analysis.

・Standard type
　2 marbles + 2 steel balls with earthquake resistant pad
・Earthquake pad change type
　Size change of standard earthquake resistant pad
・Marble type
　4 marbles

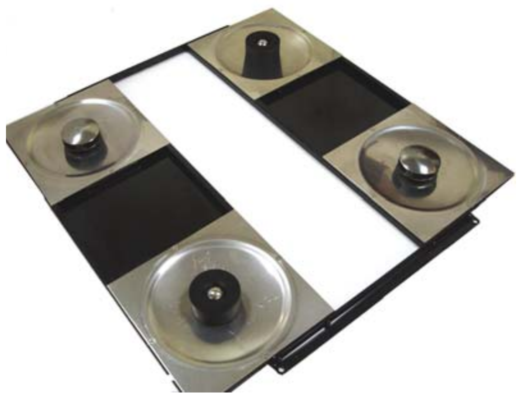


Fig. 6-2 Standard type of Abserver

6-3. Analysis result

For each relative displacement due to building response at the time of earthquake, select a combination of bearings that optimizes the characteristics of Abserver.
The analysis results are shown in the table below.

Table 6-3 Response displacement of S-construction

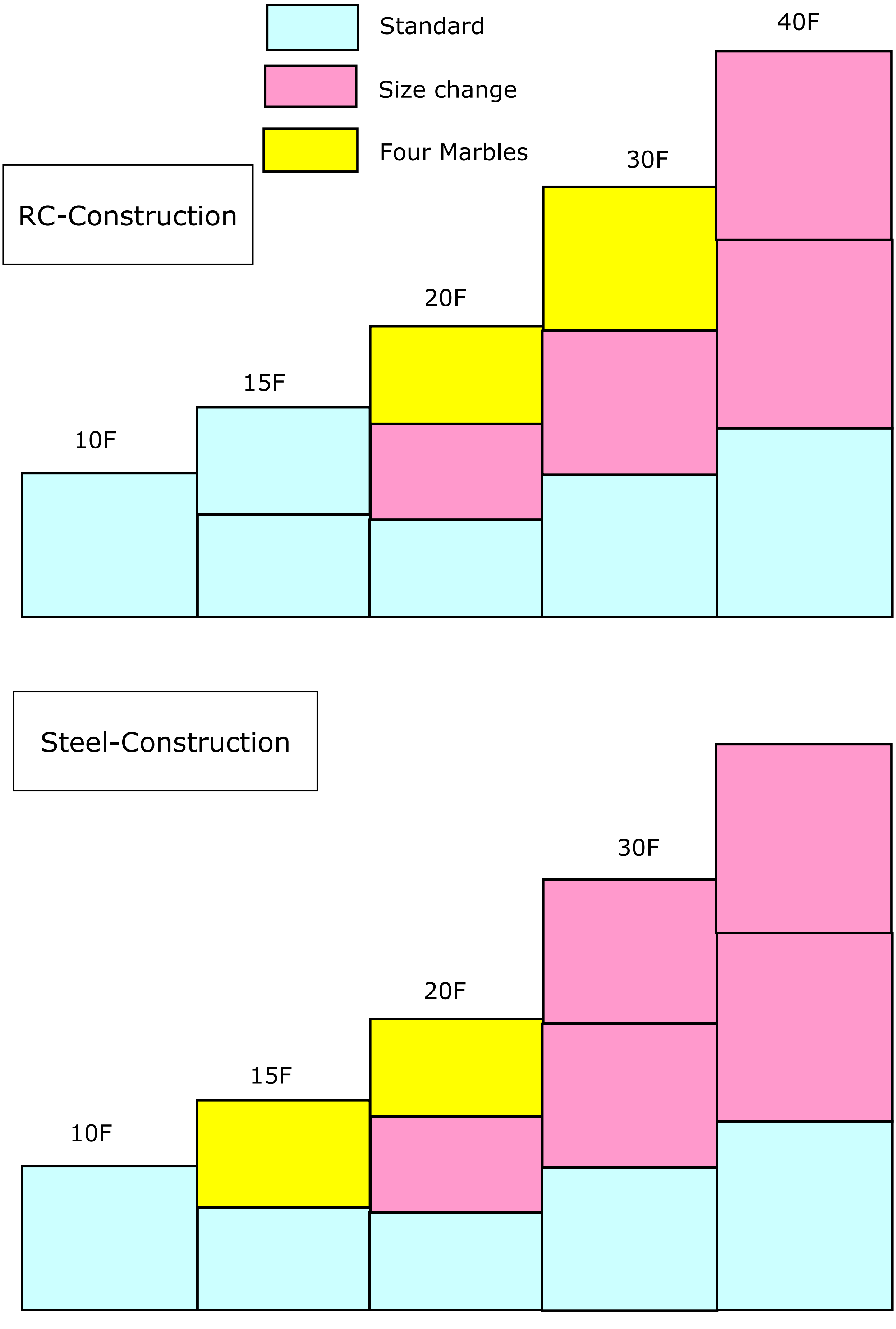
		Maxi.disp. of building (cm)	Disp. of Abserver (cm)
10F	High floor	23.2	26.3
	Low floor	16.6	13.1
15F	High floor	34.1	30.0
	Low floor	17.1	17.7
20F	High floor	41.0	30
	Mid. floor	27.3	23.8
	Low floor	13.7	10.9
30F	High floor	39.4	13.9
	Mid. floor	26.3	9.3
	Low floor	13.1	5.0
40F	High floor	53.3	14.0
	Mid. floor	35.5	9.3
	Low floor	17.6	4.8

Table 6-4 Response displacement of RC-construction

		Maxi.disp. of building (cm)	Disp. of Abserver (cm)
10F	High floor	16.1	27.2
	Low floor	8.1	13.6
15F	High floor	24.0	27.1
	Low floor	12.0	13.6
20F	High floor	21.5	30
	Mid. floor	11.7	30.0
	Low floor	10.8	12.9
30F	High floor	38.7	26.8
	Mid. floor	25.8	19.3
	Low floor	12.9	10.5
40F	High floor	41.3	18.6
	Mid. floor	27.5	12.4
	Low floor	13.8	6.6

6-4. Summary

We conducted performance evaluation of Abserver with building structure type and installation floor, but in this experiment various assumptions are used to set the building as vibration model of one mass point.
For actual installation, it is desirable to analyze using seismic waves considering ground characteristics etc.
For buildings with heights of 60 m or more, high-rise evaluation is essential and it is necessary to conduct vibration analysis.


Standard
Size change
Four Marbles
RC-Construction
40F
30F
20F
15F
10F
Steel-Construction
30F
20F
15F
10F