Performance of Buildings under the Coming Mid-size Earthquake beneath Tokyo Metropolitan Area

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We had very severe earthquakes in East Japan last year and suffered a lot of damages not only in the district near the epicenter but in the distant area. Especially those damages around Tokyo area were mainly not to main structure but to non-structural components. Furthermore, another mid-size earthquake will be forecasted beneath Tokyo metropolitan area near future. Here, we tried to simulate the response of many types of buildings under the artificial ground-motions of a coming earthquake.

the Coming Mid-size Earthquake beneath Tokyo metropolitan area

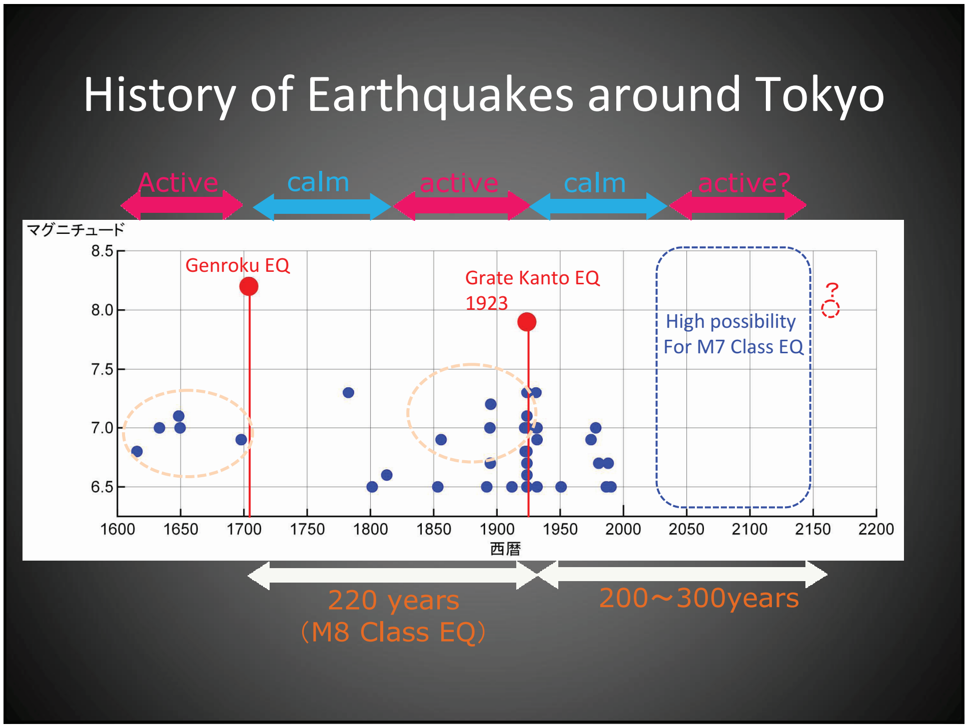
Since two plates have sunk beneath Tokyo area, the occurring earthquake can consider various types. The Central Disaster Prevention Council 2004 (like FEAMA) is performing assessment of damage by each earthquake supposing 18 kinds of earthquakes.
This study has done based on the northern Tokyo Bay earthquake which is expected to have the largest number of victims or the greatest economic impact among 18 scenarios.

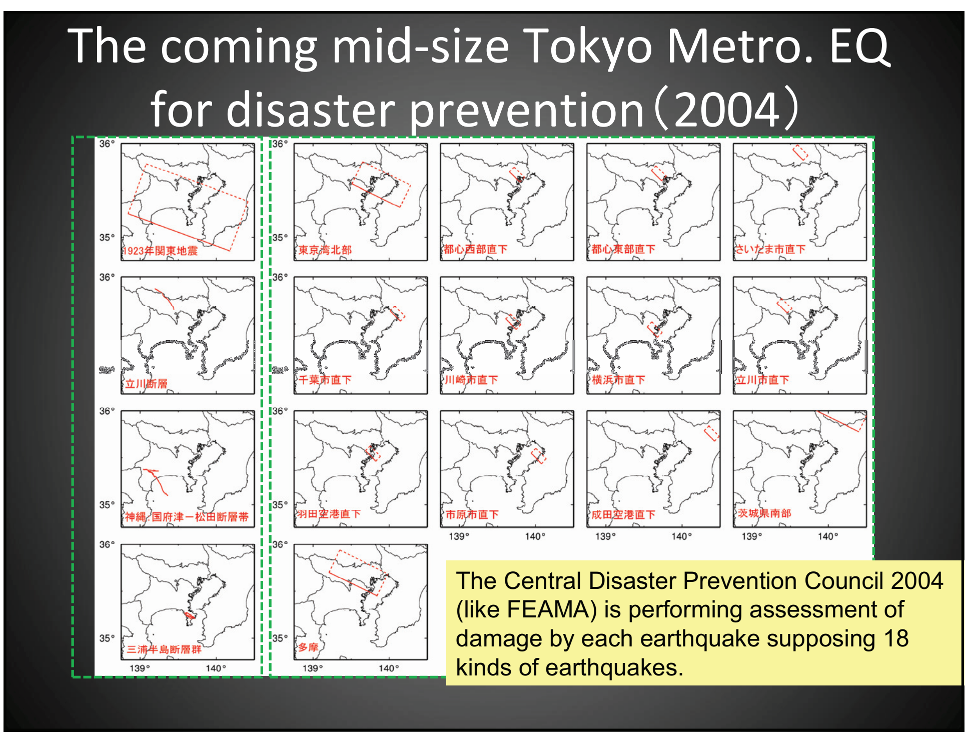
Selection of Examination Point, and Feature of Subsurface Layer

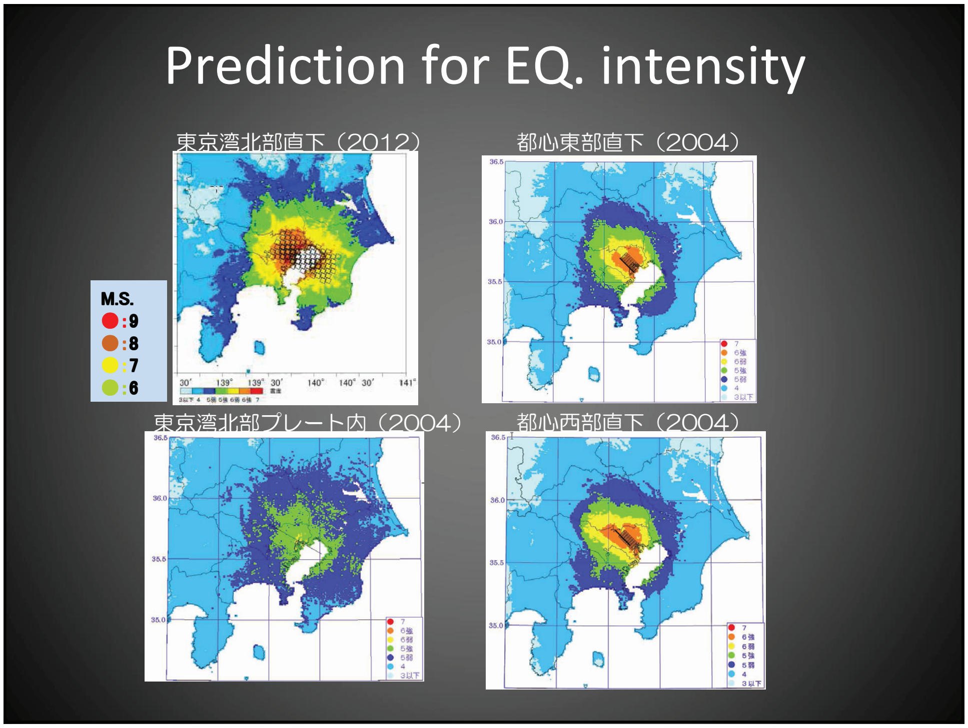
Based on the assumed position and earthquake size of the northern Tokyo Bay fault, the subsurface layer was assumed in every five points.
Five points are Shinjuku (following SITE-S), Kasumigaseki (following SITE-K), Urayasu (following SITE-U), Makuhari (following SITE-M), and Yokohama (following SITE-Y).
The artificial ground motion was generated using hybrid procedure that combines finite difference modeling at low frequencies with stochastic modeling at high frequencies.

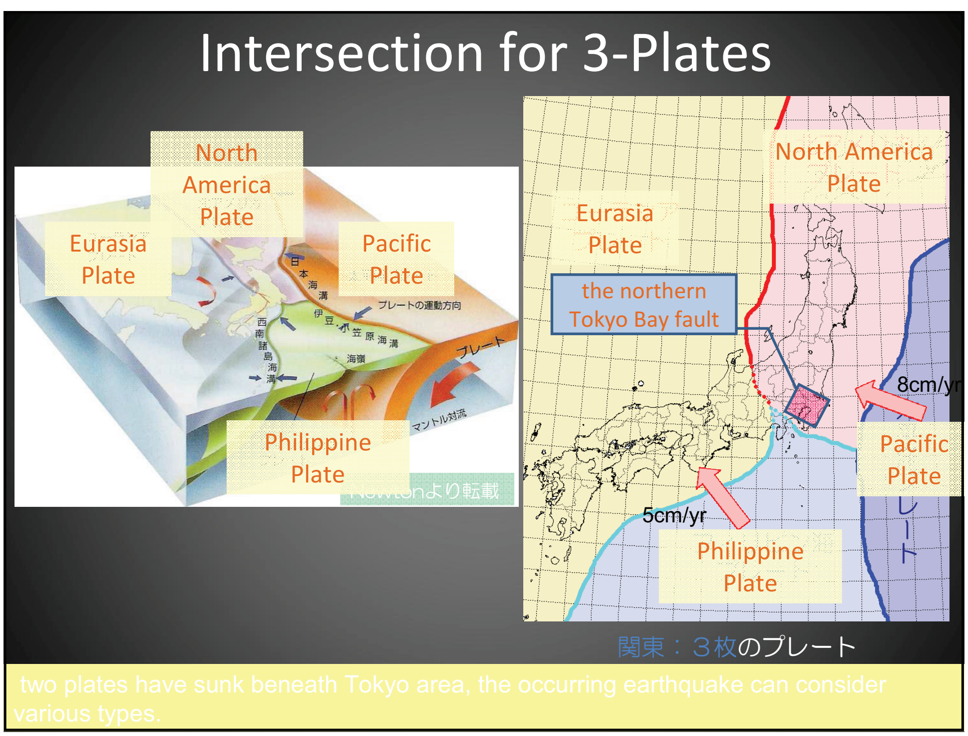
Response of buildings on the site

・Although the influence by the difference in the starting point of the rupture is not so great, influence may be great in the direction of the point away from the fault (SITE-Y, 1~2 s).
・According to the response spectra on surface, high cycle components prominent at SITE-S,K(good subsurface) and low cycle components(1~2s) prominent at SITE-U,Y (deep subsurface).
・The response of the low-mid rise building may become larger than the design force depending on a site, while the response for high rise buildings may be smaller.
・The influence of fault modeling is great for response of buildings, and even if a fault and a scale are specified, it is difficult to predict the response of a building in a certain degree of accuracy.
・The accuracy of the response prediction from a fault to a building is still not sufficient, and the full-scale dynamic experiments of building are very effective.


History of Earthquakes around Tokyo
Active
calm
active
calm
active?
マグニチュード
8.5
8.0
7.5
7.0
6.5
Genroku EQ
Grate Kanto EQ
1923
High possibility
For M7 Class EQ
?
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050
2100
2150
2200
西暦
220 years
（M8 Class EQ）
200～300years


The coming mid-size Tokyo Metro. EQ
for disaster prevention（2004）
1923年関東地震
東京湾北部
都心西部直下
都心東部直下
さいたま市直下
立川断層
千葉市直下
川崎市直下
横浜市直下
立川市直下
神縄.国府津一松田断層帯
羽田空港直下
市原市直下
成田空港直下
茨城県南部
三浦半島断層群
多摩
36°
35°
139°
140°
The Central Disaster Prevention Council 2004
(like FEAMA) is performing assessment of
damage by each earthquake supposing 18
kinds of earthquakes.


Prediction for EQ. intensity
東京湾北部直下（2012）
都心東部直下（2004）
M.S.
:9
:8
:7
:6
東京湾北部プレート内（2004）
都心西部直下（2004）

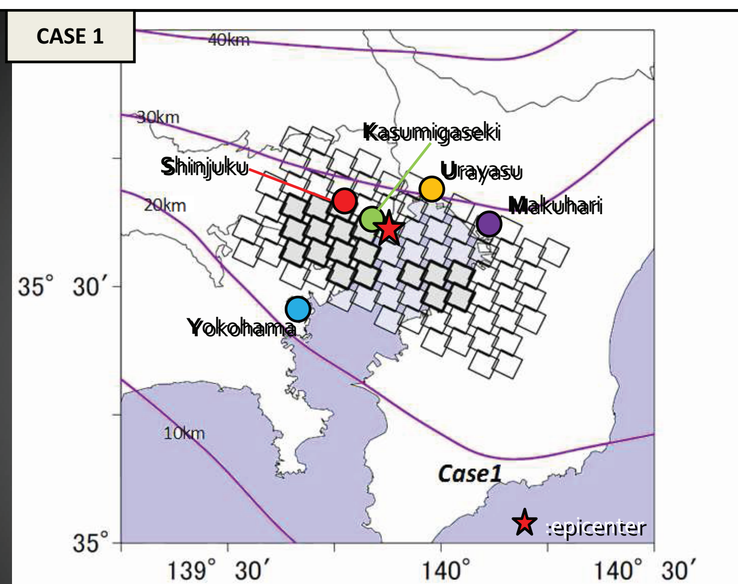

Intersection for 3-Plates
North America Plate
Eurasia Plate
Pacific Plate
Philippine Plate
プレートの運動方向
マントル対流
North America Plate
Eurasia Plate
the northern Tokyo Bay fault
8cm/yr
Pacific Plate
5cm/yr
Philippine Plate
関東：３枚のプレート
two plates have sunk beneath Tokyo area, the occurring earthquake can consider various types.

Fault model spec.

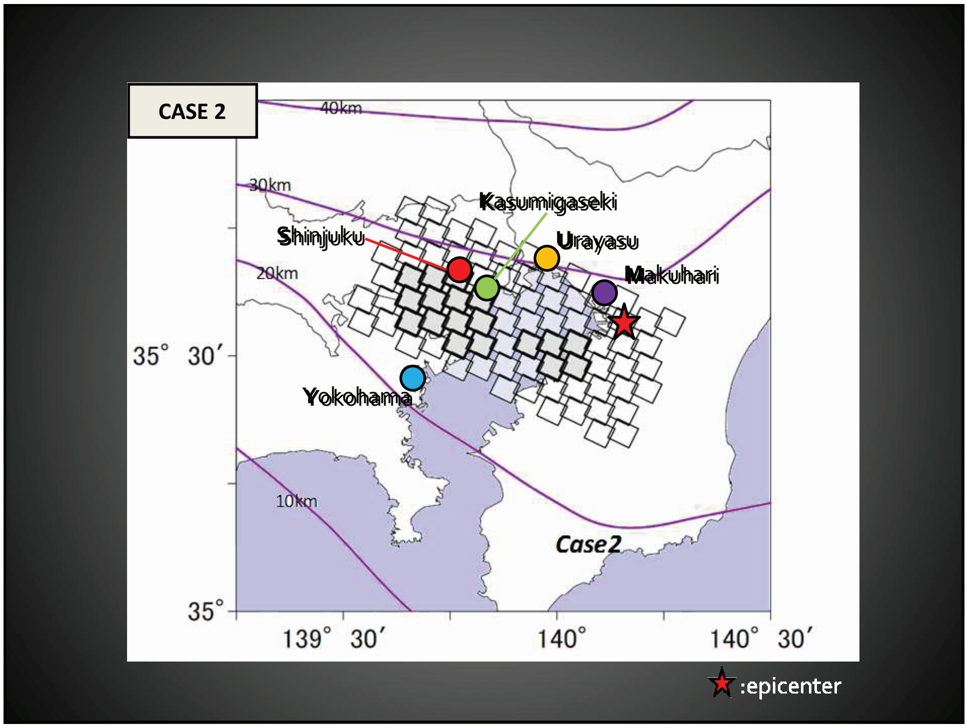
The main specifications of the set-up fault model are shown below.

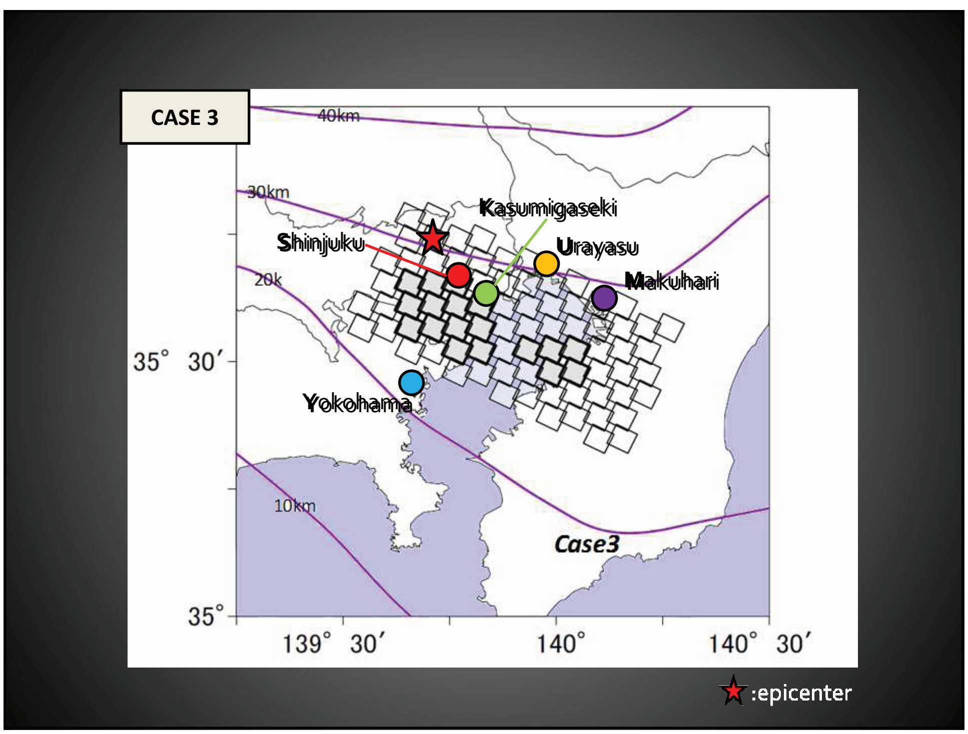
Earthquake size: Mw7.3
Tomographic-layer product: 63 km x 32 km
Strike of a fault: 296 degrees
Inclination of a fault: 23 degrees
Slide angle: 138 degrees
Mean-stress descent: 3MPa
fmax: 6Hz
Rupture-propagation speed: 2.5 km/s

This study has done based on the northern Tokyo Bay earthquake which is expected to have the largest number of victims or the greatest economic impact among 18 scenarios.

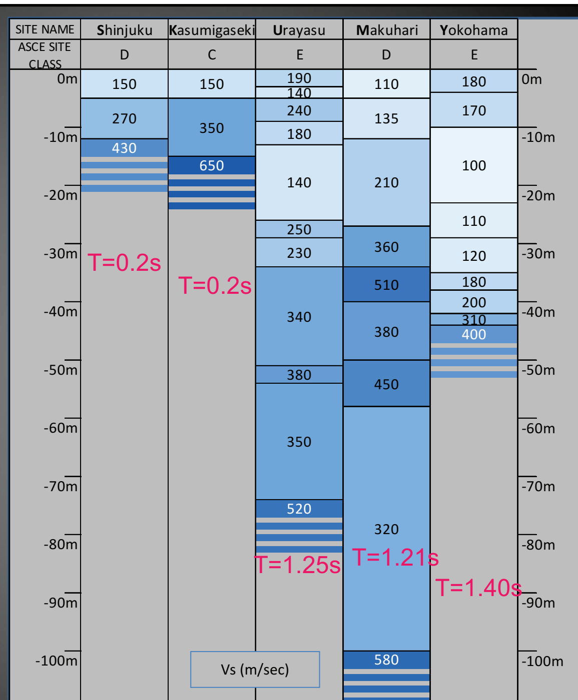


About the rupture starting point, Three different type were considered.
Case-1:from center of the fault, Case-2:from east part of the fault and Case-3:from west part of the fault

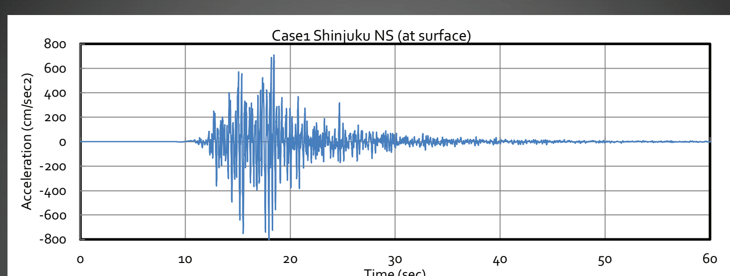

CASE 2
40km
30km
20km
10km
Kasumigaseki
Shinjuku
Urayasu
Makuhari
Yokohama
Case2
35° 30′
35°
139° 30′
140°
140° 30′
:epicenter

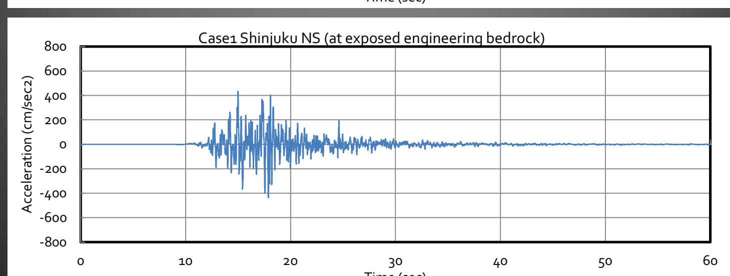

CASE 3
40km
30km
20k
10km
Kasumigaseki
Shinjuku
Urayasu
Makuhari
Yokohama
Case3
35° 30′
35°
139° 30′
140°
140° 30′
:epicenter

Site Spec.



Example of Acceleration on the ground level & at the level of the seismic bedrock at SITE-S





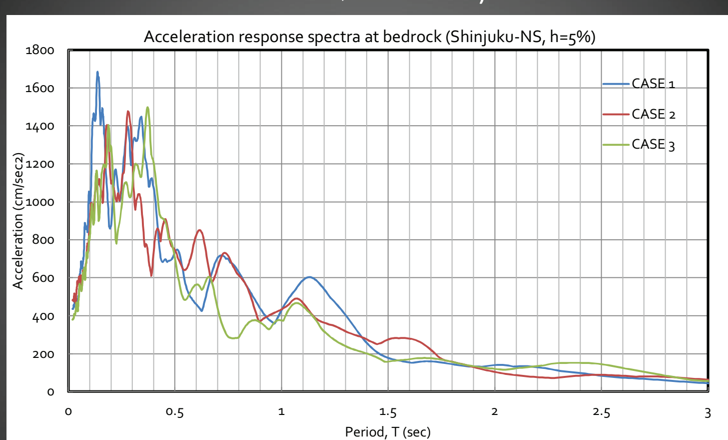
1）Comparison of ACC. Response spectra (h=5%)
on bed-rock (Vs>400m/s） for 5-site
- depend on Case-1,2,3
- including design-earthquake force

2) Comparison of ACC. Response spectra (h=5%)
on the ground level
- h=5% & 20%

3) Comparison of VELOCITY Response spectra (h=5%)
- bed-rock & on the ground level

4) Responses of 15 sample buildings
by results of non-linear time history analysis
with the effect of dissipation damping for 5-site

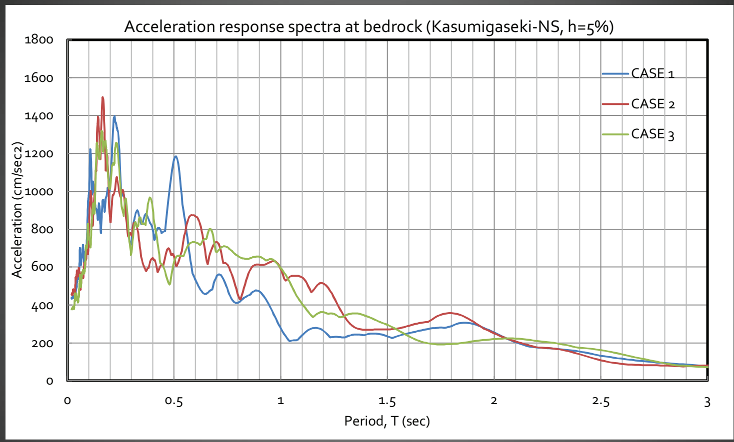
Response spectra for Acceleration on bedrock h=5%
SITE-S（SHINJUKU)



Basically there are not so much differences for CASE-1,2,3.
Response for period of 1~1.5 exceed in CASE-1.

Response spectra for Acceleration on bedrock h=5%

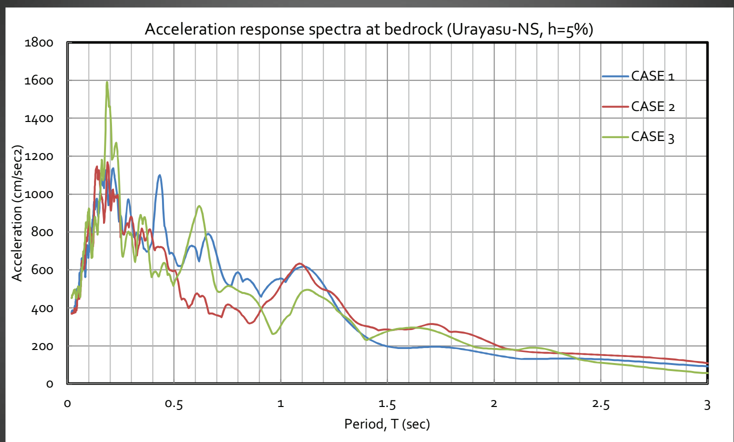
SITE-K（KASUMIGASEKI)



Basically there are not so much differences for CASE-1,2,3.
Response for period of 1~1.5 exceed in CASE-2 than CASE-1.

Response spectra for Acceleration on bedrock h=5%

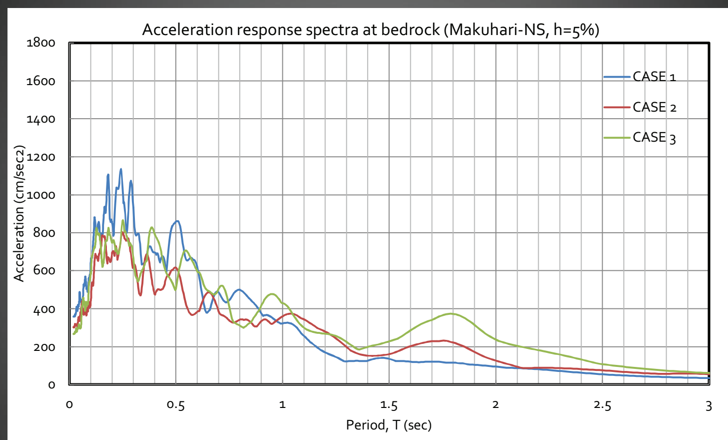
SITE-U（URAYASU)



Response for period of 0.5~1.5 exceed in CASE-1,3 than CASE-2.

Response spectra for Acceleration on bedrock h=5%

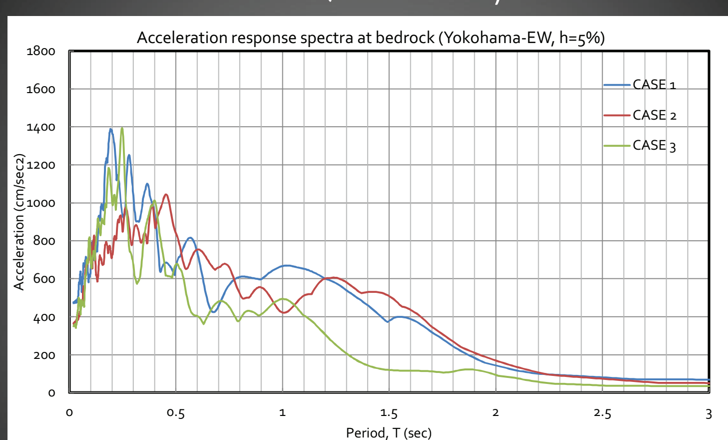
SITE-M（MAKUHARI）



Response for period of 1.0~2.0 exceed in CASE-2,3 than CASE-1.

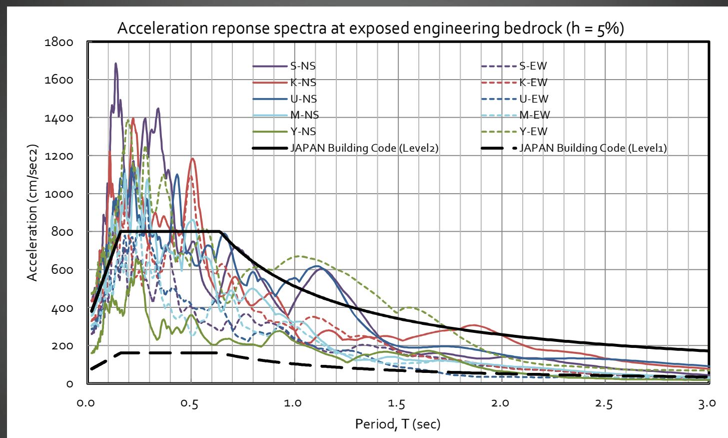
Response spectra for Acceleration on bedrock h=5%

SITE-Y（YOKOHAMA）



Response for period of 1.0~2.0 exceed in CASE-1,2 than CASE-3.

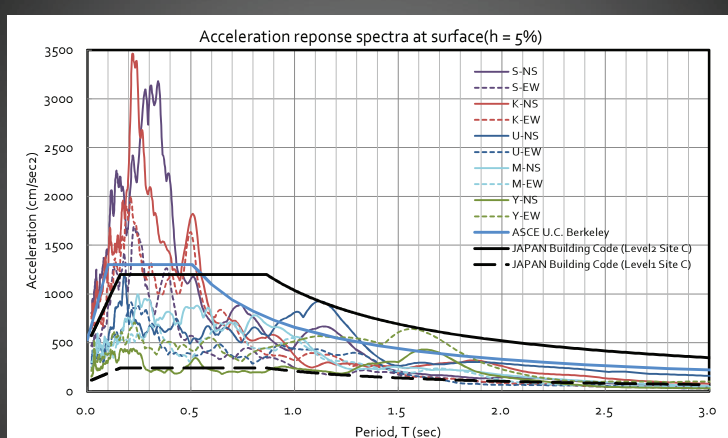
Response spectra for Acceleration on the bedrock level h=5%



Response for period of 1.0~1.5 exceed in SITE-Y than others.

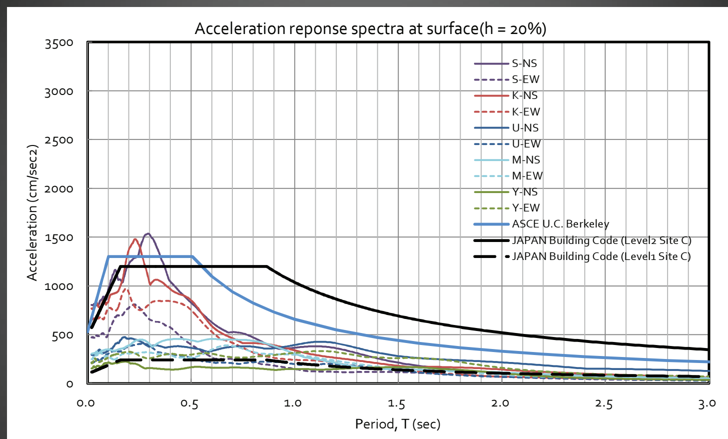
工学的基盤 加速度応答スペクトル 5%減衰

Response spectra for Acceleration on the ground level h=5%



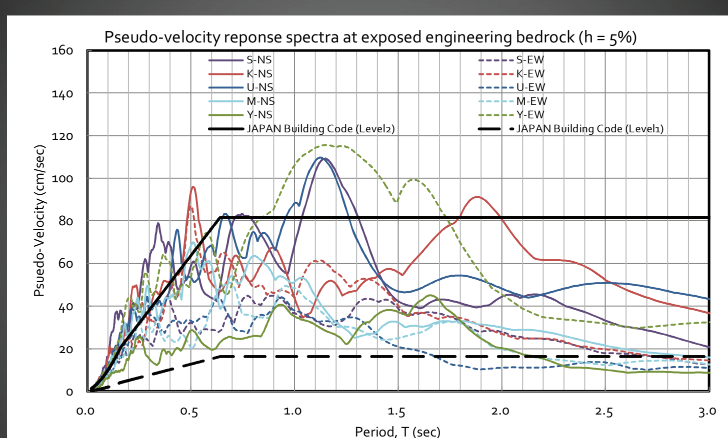
Response for period of 0~0.5 exceed in SITE-S,K than others.
For period of 1.0~2.0, SITE-U,Y than others.

Response spectra for Acceleration on the ground level h=20%



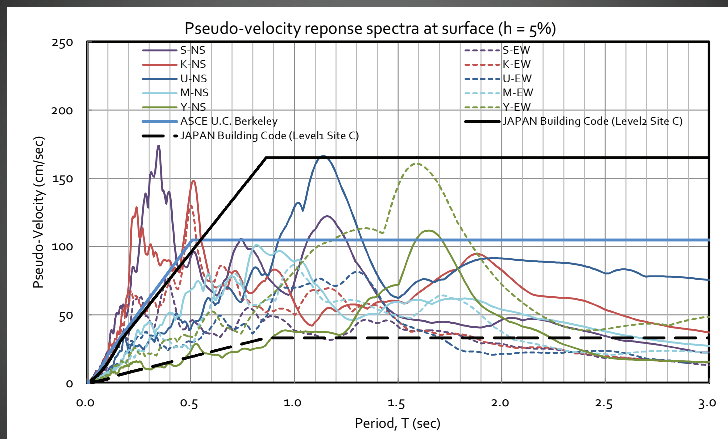
Taking into consideration about dissipation damping, The response of buildings will not so large.

Response spectra for velocity on the bedrock level h=5%



工学的基盤 疑似速度応答スペクトル 5%減衰

Response spectra for velocity on the ground level h=5%



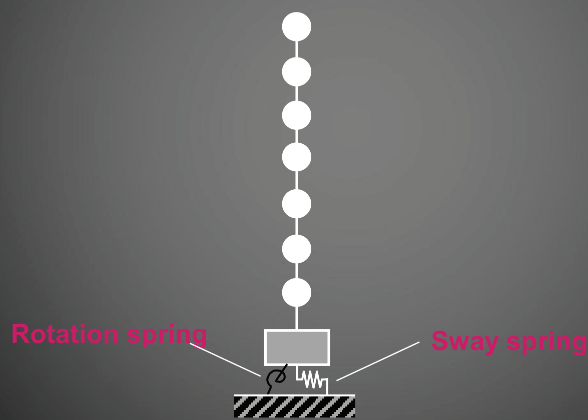
地表面 疑似速度応答スペクトル 5%減衰

15 sample buildings

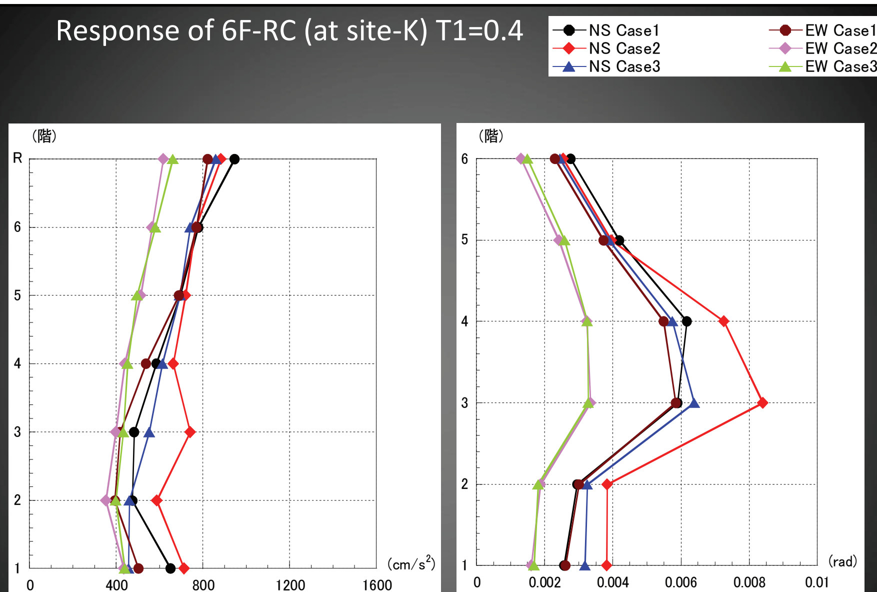
		Story			Height	Length	Width
		Basement	Ground	Rooftop	(m)	(m)	(m)
HIGH-RISE	Steel 1	4	35	3	163.0	61.6	51.6
	Steel 2	3	31	1	139.9	70.5	45.7
	RC	—	30	—	93.1	31.8	27.6
	Base Isolation	1	42	2	144.1	39.5	39.5
MIDDLE-RISE	Steel 1	—	10	1	40.3	32.6	20.2
	Steel 2	1	14	1	58.0	32.0	18.6
	RC	—	15	—	43.9	45.0	14.0
	SRC	1	9	2	30.5	31.5	23.5
	Base Isolation	1	8	1	29.9	72.3	29.9
LOW-RISE	Steel 1	—	5	1	20.5	33.6	20.2
	RC 1	1	6	1	20.2	18.4	13.5
	RC 2	1	2	—	10.3	18.8	13.8
	SRC	1	5	1	19.9	36.0	27.0
	Base Isolation 1	—	4	1	12.3	24.8	14.0
	Base Isolation 2	2	3	—	9.5	32.9	30.8

non-linear time history analysis

with the effect of dissipation damping for 5-site

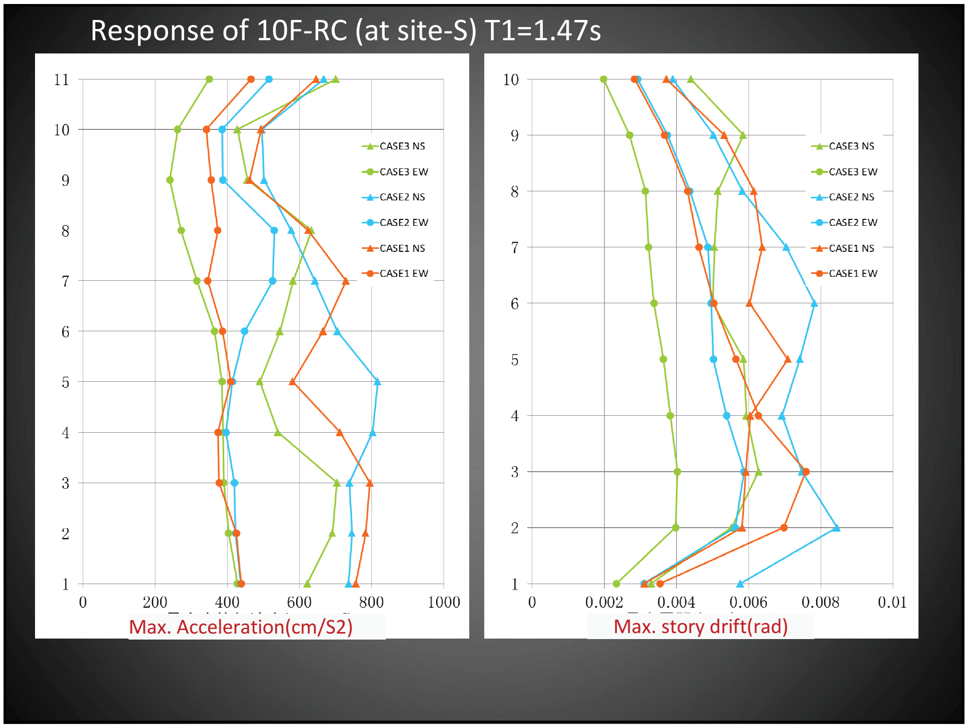


Response of 6F-RC (at site-K) T1=0.4

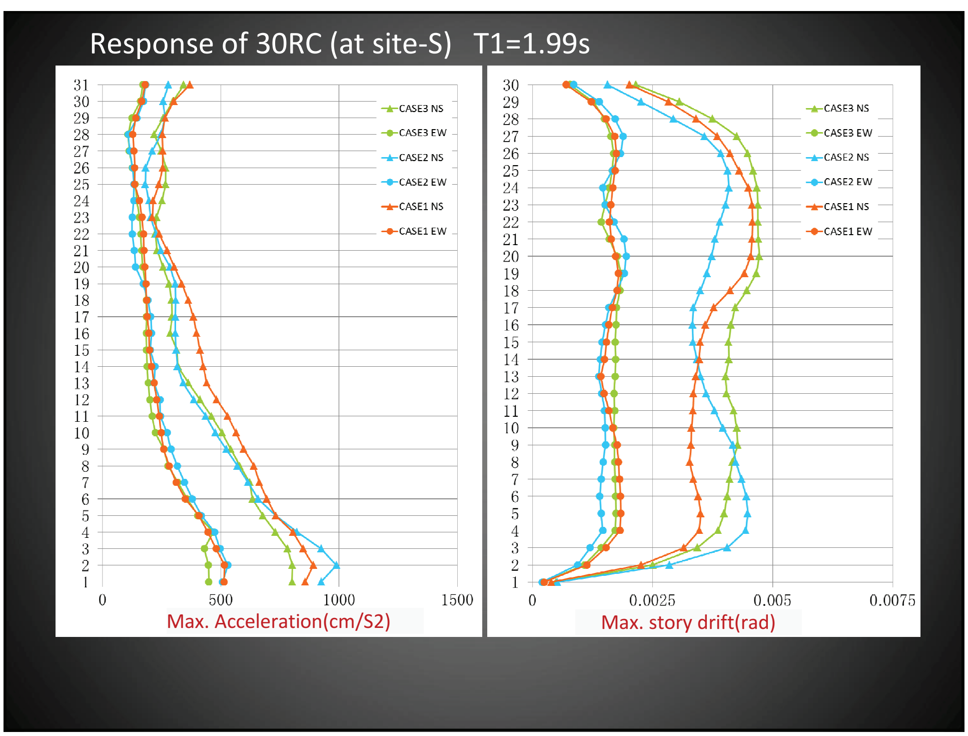


Max. Acceleration(cm/S2)

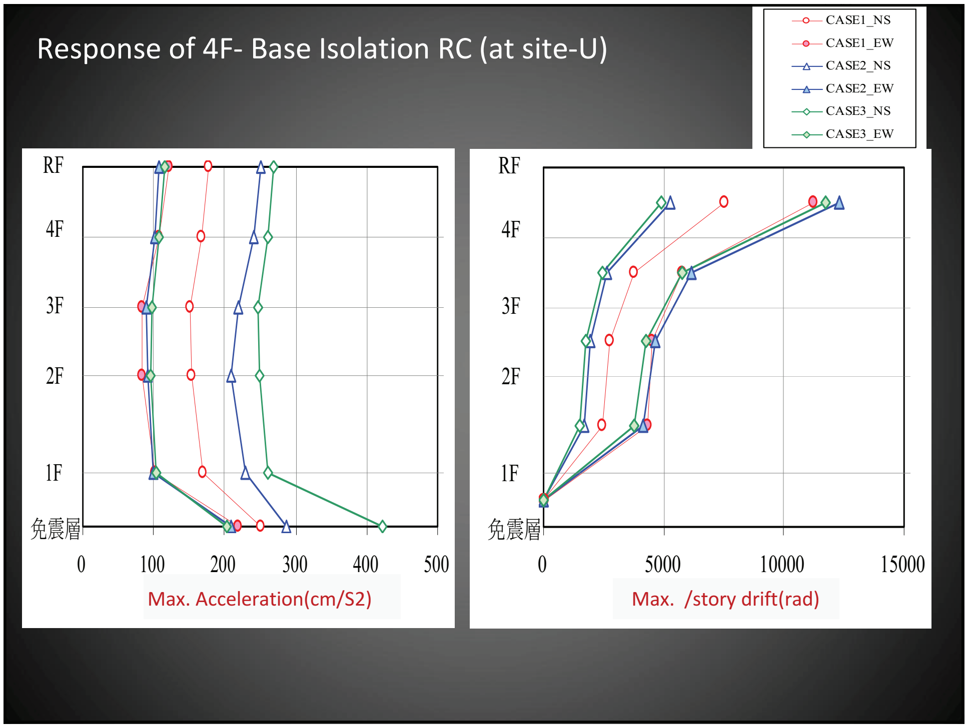
Max. story drift(rad)

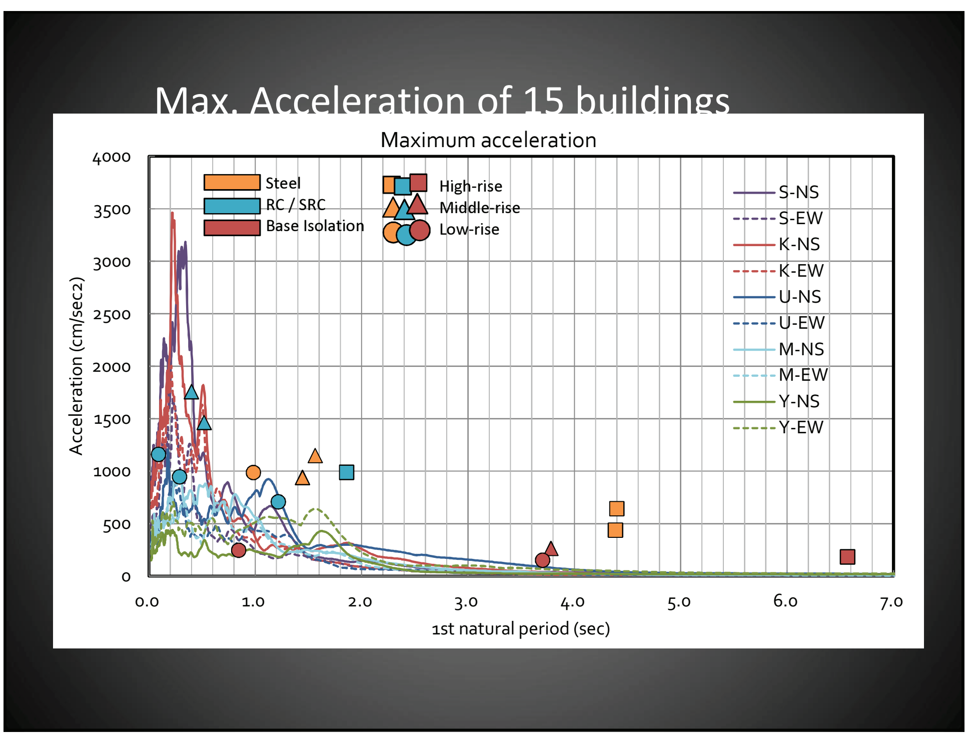


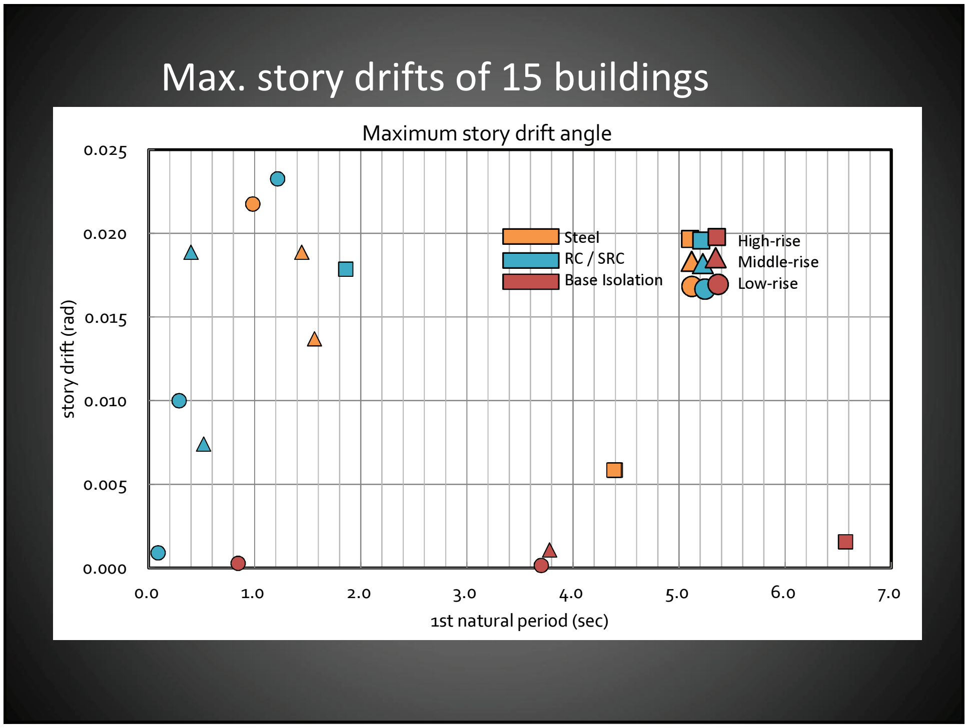
Response of 10F-RC (at site-S) T1=1.47s
CASE3 NS
CASE3 EW
CASE2 NS
CASE2 EW
CASE1 NS
CASE1 EW
Max. Acceleration(cm/S2)
Max. story drift(rad)



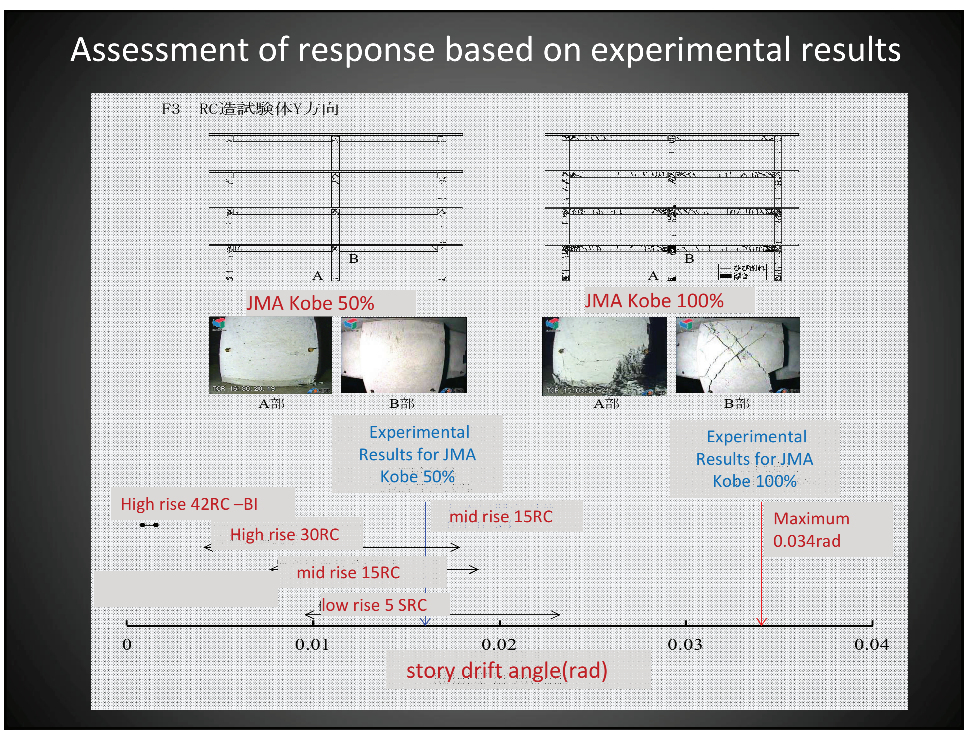
Response of 30RC (at site-S) T1=1.99s
CASE3 NS
CASE3 EW
CASE2 NS
CASE2 EW
CASE1 NS
CASE1 EW
Max. Acceleration(cm/S2)
Max. story drift(rad)


Response of 4F- Base Isolation RC (at site-U)
CASE1_NS
CASE1_EW
CASE2_NS
CASE2_EW
CASE3_NS
CASE3_EW
RF
4F
3F
2F
1F
免震層
0
100
200
300
400
500
Max. Acceleration(cm/S2)
0
5000
10000
15000
Max. /story drift(rad)


Max. Acceleration of 15 buildings
Maximum acceleration
Steel
RC / SRC
Base Isolation
High-rise
Middle-rise
Low-rise
S-NS
S-EW
K-NS
K-EW
U-NS
U-EW
M-NS
M-EW
Y-NS
Y-EW
Acceleration (cm/sec2)
4000
3500
3000
2500
2000
1500
1000
500
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
1st natural period (sec)

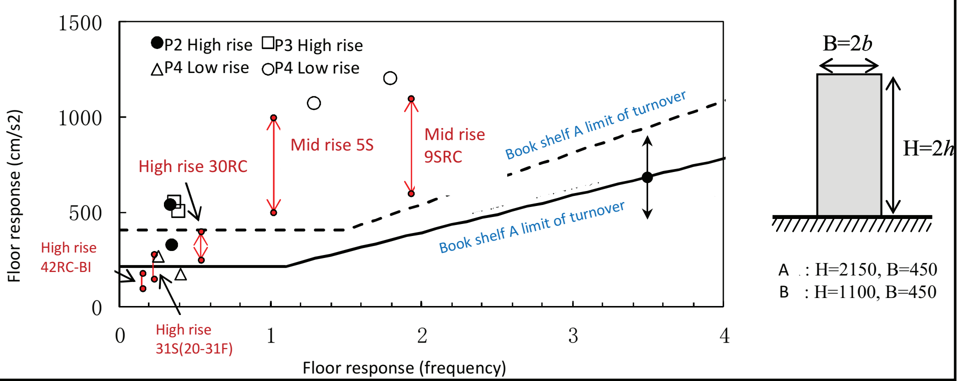


Max. story drifts of 15 buildings
Maximum story drift angle
0.025
0.020
0.015
0.010
0.005
0.000
story drift (rad)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
1st natural period (sec)
Steel
RC / SRC
Base Isolation
High-rise
Middle-rise
Low-rise



Assessment of response based on experimental results
F3 RC造試験体Y方向
JMA Kobe 50%
JMA Kobe 100%
A部
B部
A部
B部
Experimental Results for JMA Kobe 50%
Experimental Results for JMA Kobe 100%
High rise 42RC –BI
High rise 30RC
mid rise 15RC
mid rise 15RC
low rise 5 SRC
Maximum 0.034rad
0
0.01
0.02
0.03
0.04
story drift angle(rad)

Assessment of response based on experimental results



conclusion

- The response of the low-mid rise building may become larger than the design force depending on a site, while the response for high rise buildings may be smaller.
- The simulation for the ground motion at particular earthquake still have indefinite uncertainty.
- Structural engineers should understand there are still the uncertainties for artificial ground motion.
- Earthquake motion prediction and earthquake motion input evaluation are the information which should be made the big ground of a designer's judgment in the proper design of a building, and the designer needs to judge those information humbly and needs to make it reflected in a design.

ACKNOWLEDGEMENT

The contents of this paper summarize the details of research of the exchange meeting for the Ministry of Education, Culture, Sports, Science and Technology “task force about the promotion of utilization of Mid-size Earthquake ground motion beneath Tokyo metropolitan area." Gratitude is expressed here at the researchers concerned.