Evaluation of effects of recent strong motion records on water supply facilities

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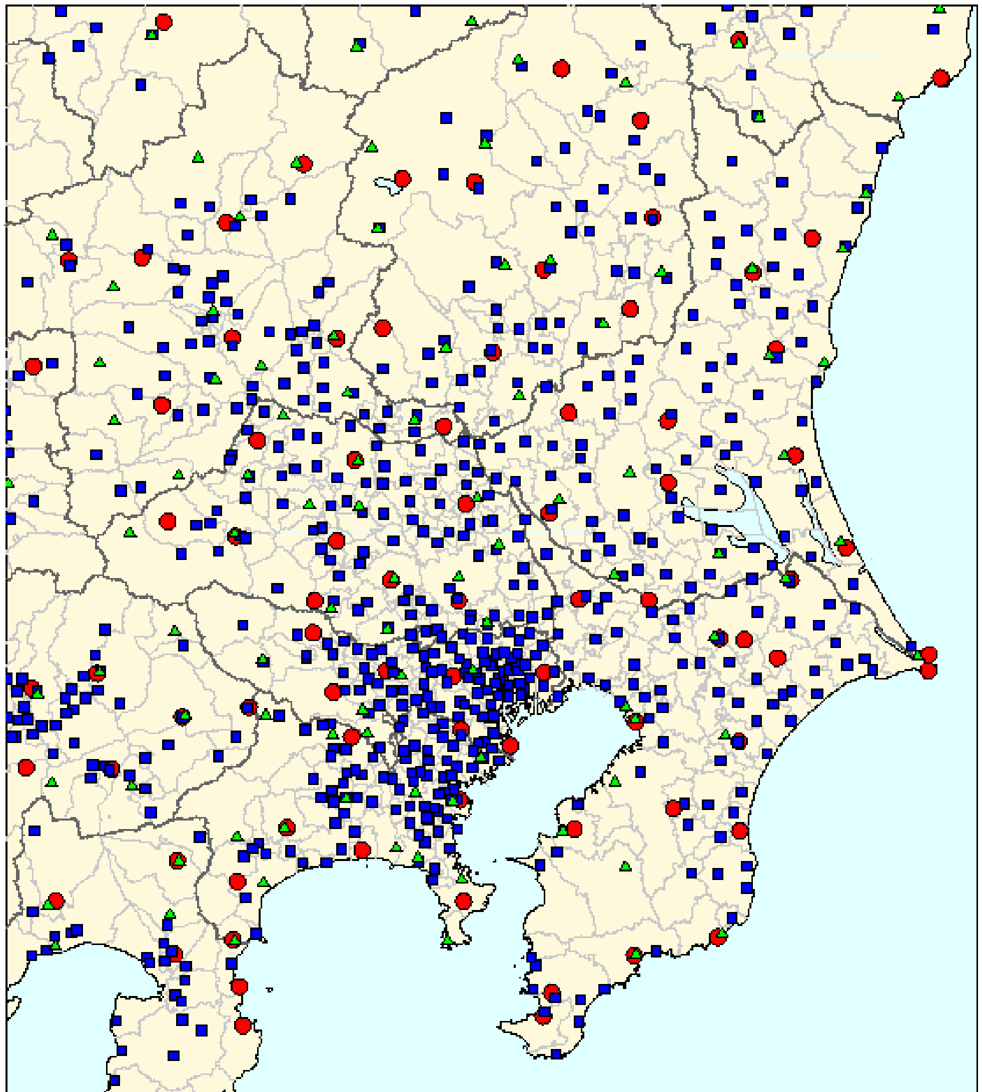
INTRODUCTION



- After the 1995 KOBE earthquake, seismograph networks have been deployed by JMA , NIED and local governments.
- About 4200 seismometers for seismic intensity observation.
- Several records of ground surface acceleration exceeded the design earthquake motion (L2) of the 1997 seismic design code for water supply facilities.

PURPOSE OF THIS STUDY

Evaluate of effects of the recent strong motion records on water supply facilities

STUDY1

Design response spectrum (L2) of the 1997 seismic design code

Comparison

Response acceleration spectrum of strong motion observations

(JMA seismic intensity 6 after the 1995 KOBE earthquake)

STUDY2

Using the recent strong motion records, response of the reinforced concrete reservoir tank has been simulated with the dynamic nonlinear analysis.

STUDY1

COMPARISON OF THE DESIGN RESPONSE SPECTRUM WITH THE RESPONSE ACCELERATION SPECTRUM OF OBSERVATION

Earthquake data used in this study

Using strong motion records from inland earthquakes with JMA seismic intensity more than 6 after the 1995 Kobe earthquake.

1. The Western Tottori Prefecture Earthquake in 2000 (M_J=7.3)
2. The Mid Niigata Prefecture Earthquake in 2004 (M_J=6.8)
3. The Noto Hanto Earthquake in 2007 (MJ=6.9)
4. The Niigataken Chuetsu-oki Earthquake in 2007 (MJ=6.8)
5. The Iwate-Miyagi Nairiku Earthquake in 2008 (MJ=7.2)

JMA Seismic Intensity

JMA Seismic Intensity	Situations	JMA Seismic Intensity	Situations
4 	■Many people are frightened. ■Most sleeping people awake.	6- 	Some houses with low earthquake resistance become tilted.
5- 	Most people try to escape from a danger.	6+ 	Many houses with low earthquake resistance become tilted or collapse
5+ 	■Many people find it difficult to move. ■In many cases, un-reinforced concrete-block walls collapse.	7 	■Many buildings with low earthquake resistance become tilted or collapse. ■Occasionally, houses with high earthquake resistance become tilted.

Using strong motion record

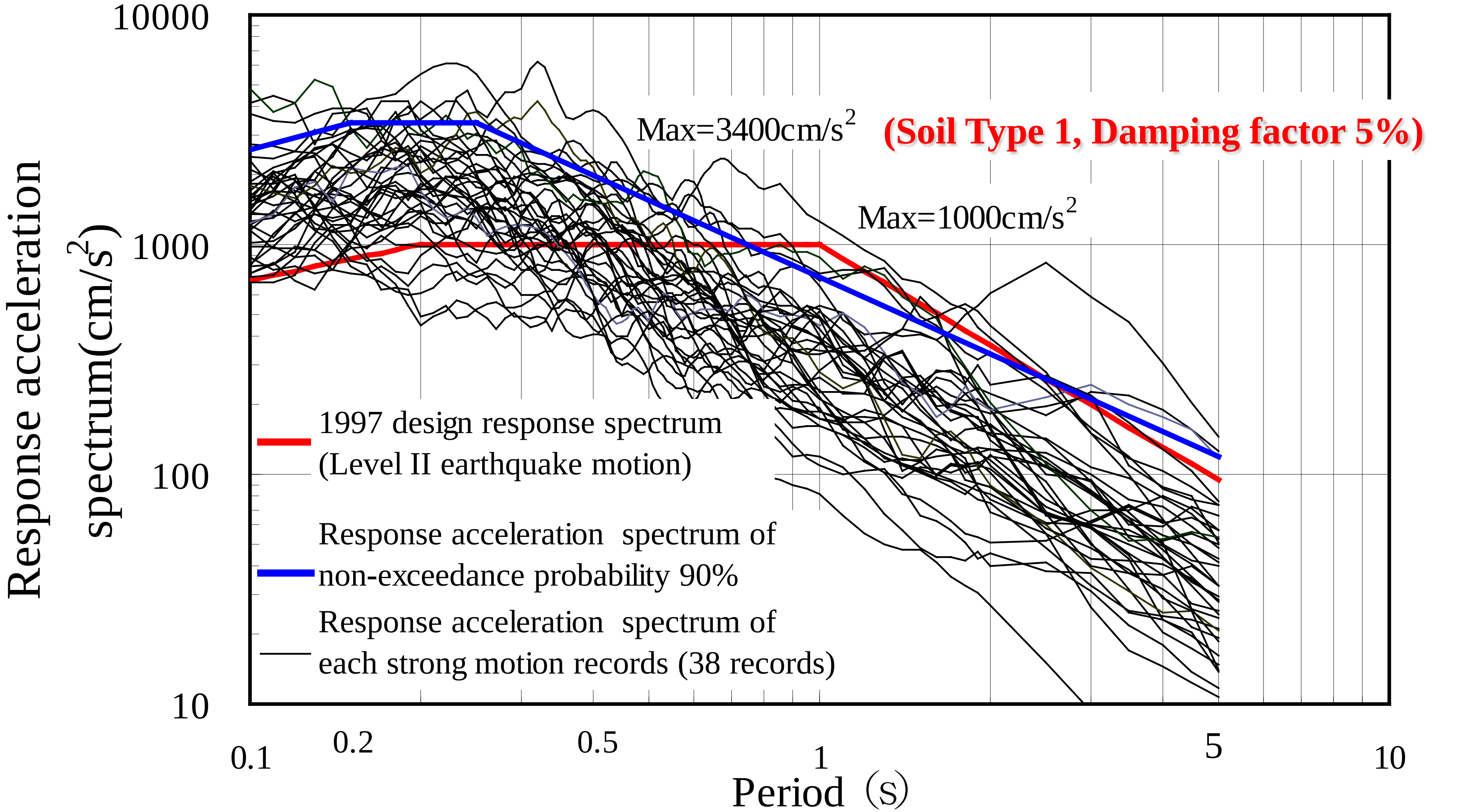
Strong motion records used in this study

- The strong motion records were obtained from the database of the Kyoshin Network (K-Net), the Kiban-Kyoshin Network(KiK-Net) and JMA database.
- K-net and KiK-net data maintained by NIED of Japan have online records of earthquakes occurred in all over Japan since 1996.

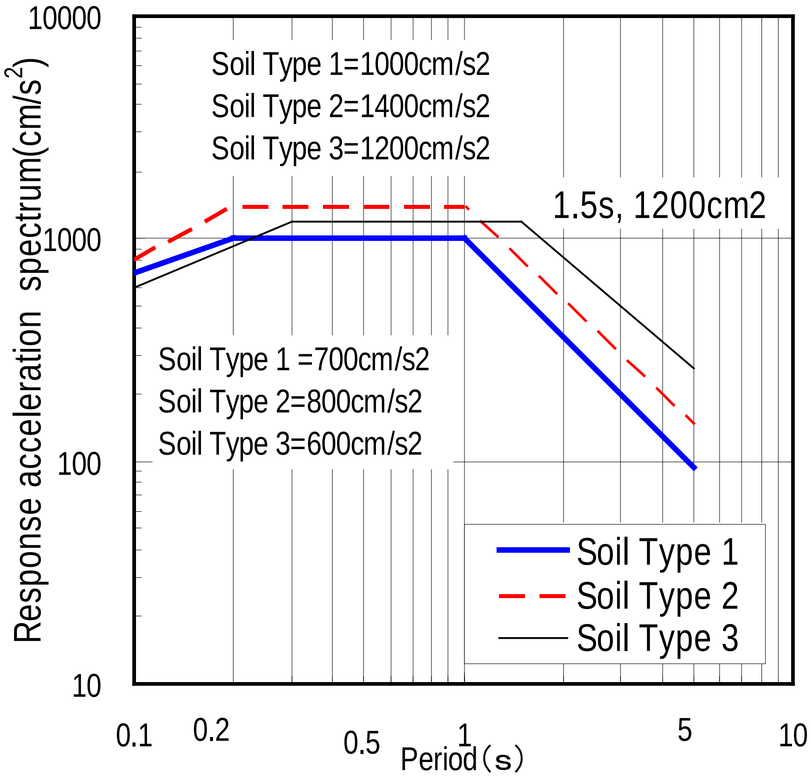
Strong motion records used in this study

Soil Type	Soil Name	Number of strong motion records
Soil Type 1	Bed rock, Diluvium	19 stations × 2components = 38
Soil Type 2	Alluvium	15 stations × 2components = 30
Soil Type 3	Soft soil	12 stations × 2components = 24
Total		46 stations × 2components = 92

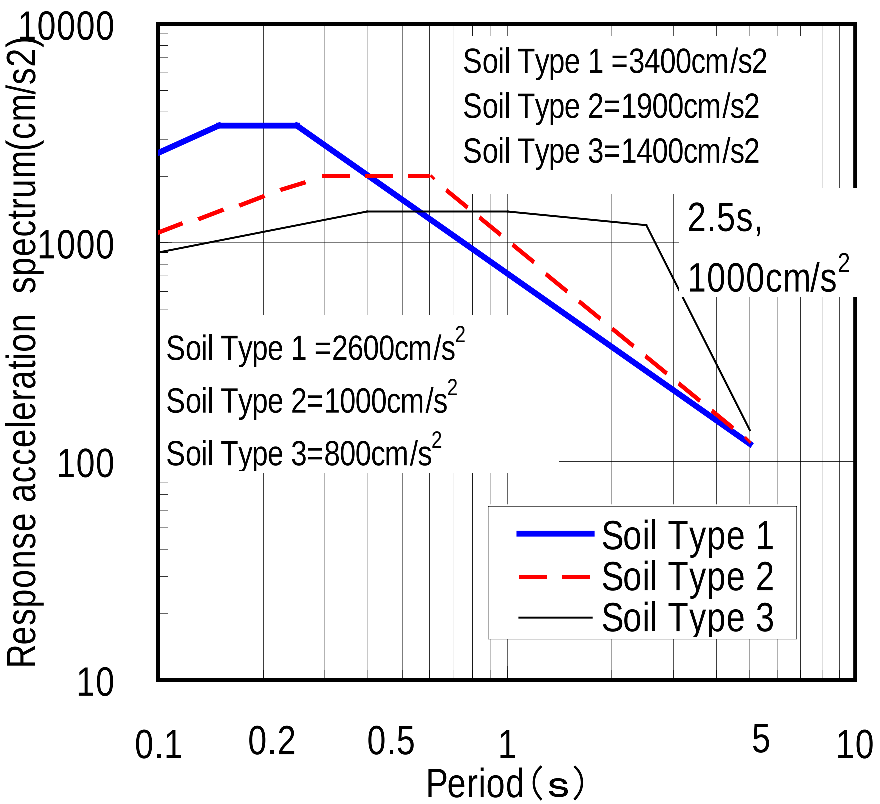
Response acceleration spectrum of strong motions recorded at JMA seismic intensity more than 6 after the 1995 Kobe earthquake



Design response spectrum of the 1997 seismic design code (Level II earthquake motion)



Non-exceedance probability value of 90% from the response acceleration spectrum of strong motion records



- The design response spectrum was set based on the strong motion observations recorded during the 1995 Kobe earthquake.
- The 90% non-exceedance probability value of records is **larger than the 1997 seismic design code.**

STUDY2

EFFECTS OF LEVELII EARTHQUAKE MOTION ON RESORVOIR TANKS USING DYNAMIC ANALYSIS

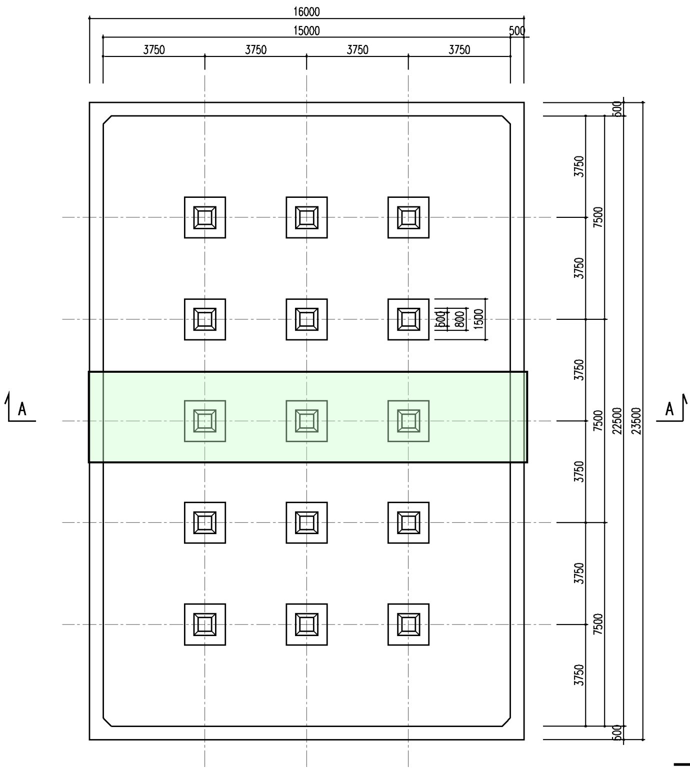
Analysis conditions

- Construction: the reinforced concrete reservoir tank
- Simulation method: the dynamic nonlinear analysis
- Input seismic motion: the recent strong motion records and the accelerogram consistent with the design response spectrum

CASE OF THE DYNAMIC NONLINEAR ANALYSIS

No.	Soil type	Input seismic motion	Max.ACC (cm/s^2)
Ⅰ-1	Soil Type1	Accelerogram consistent with design response spectrum (Level II ,Soil type 1)	538
Ⅰ-2	Soil type 1	K-net Tokamachi-NS (Observation record during the Mid Niigata Prefecture Earthquake)	1,715
Ⅱ-1	Soil type 2	Accelerogram consistent with design response spectrum (Level II ,Soil type 2)	680
Ⅱ-2	Soil type 2	JMA Kawaguchimachi-EW (Observation record during the Mid Niigata Prefecture Earthquake)	1,676
Ⅱ-3	Soil type 2	Takatori Station –NS (Observation record during the Kobe Earthquake)	604

Construction conditions



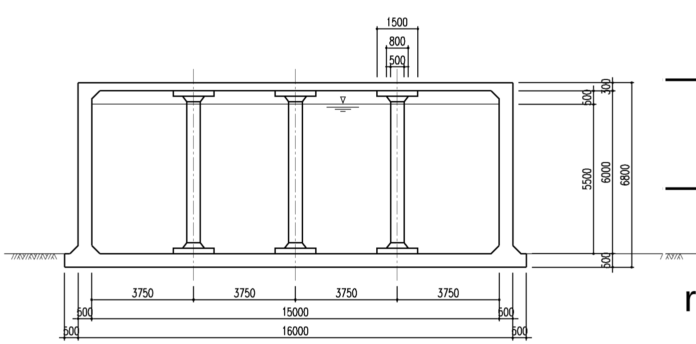


Fig. Over View of structure

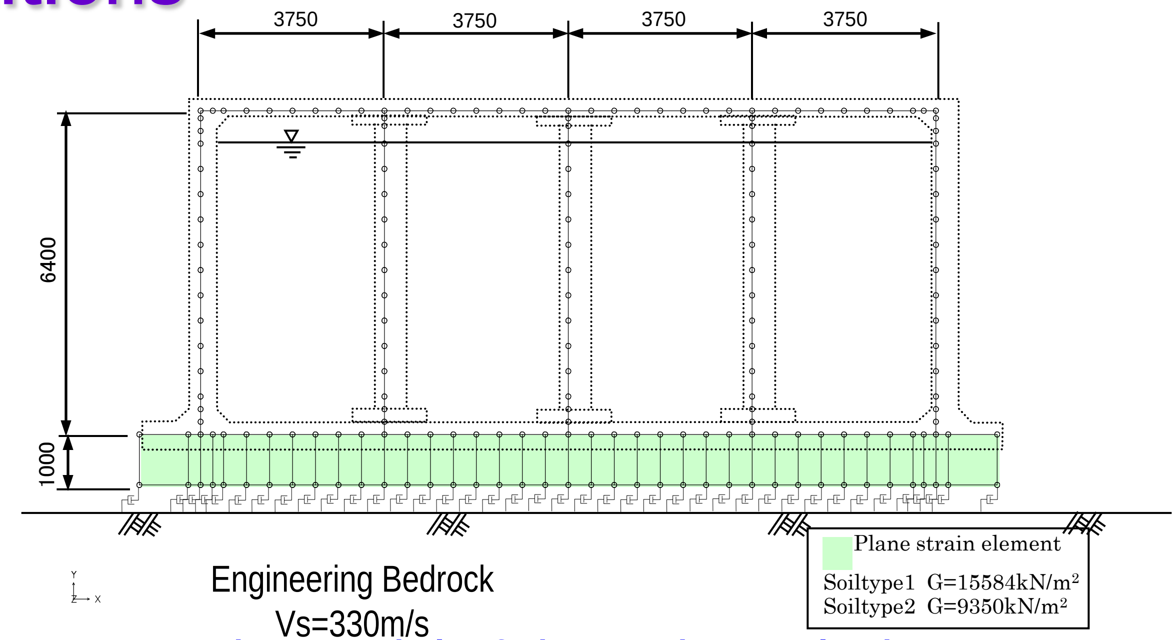
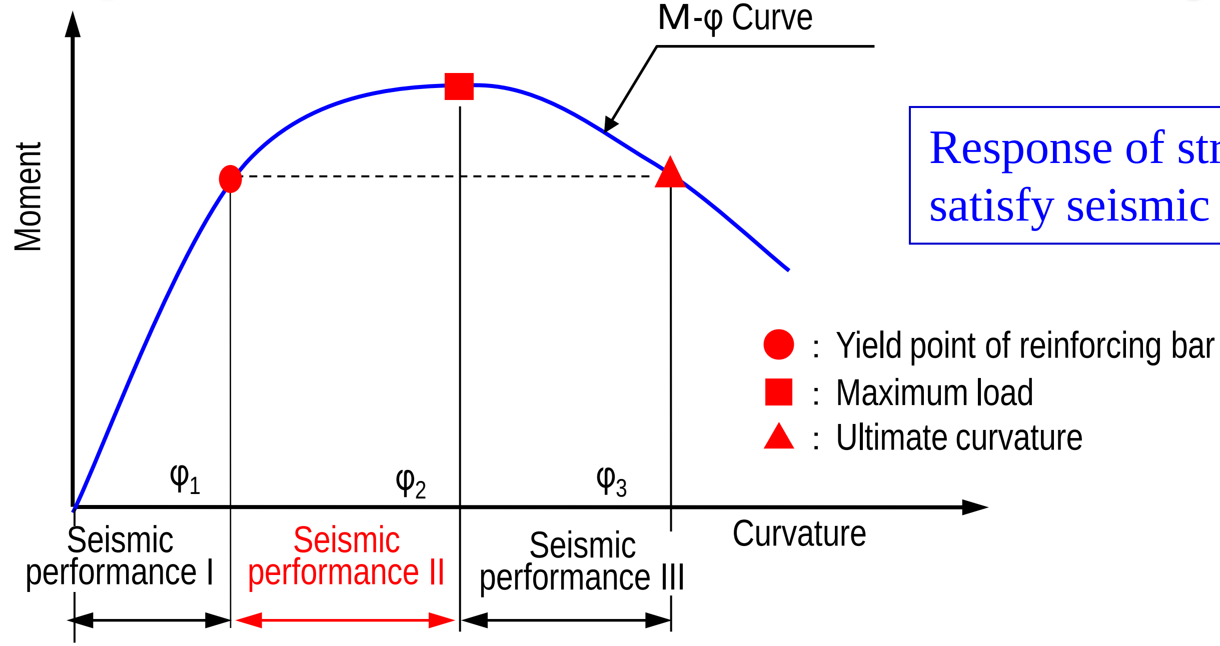


Fig. Model of dynamic analysis

TABLE. Element conditions

Element		Base	Slab	Wall	Column
Thickness(mm)		t=500	t=300	t=500	500 × 500
Axial reinforcing bar	Diameter and Pitch(Inside)	D16@300	D16@300	D22 @ 300	4-D19
	Diameter and Pitch(Outside)	D16@300	D16@300	D22 @ 300	4-D19

Seismic performance, Evaluation of safety



Response of structure should satisfy seismic performance 2

Fig. Relationship between seismic performance and resistance status of the element

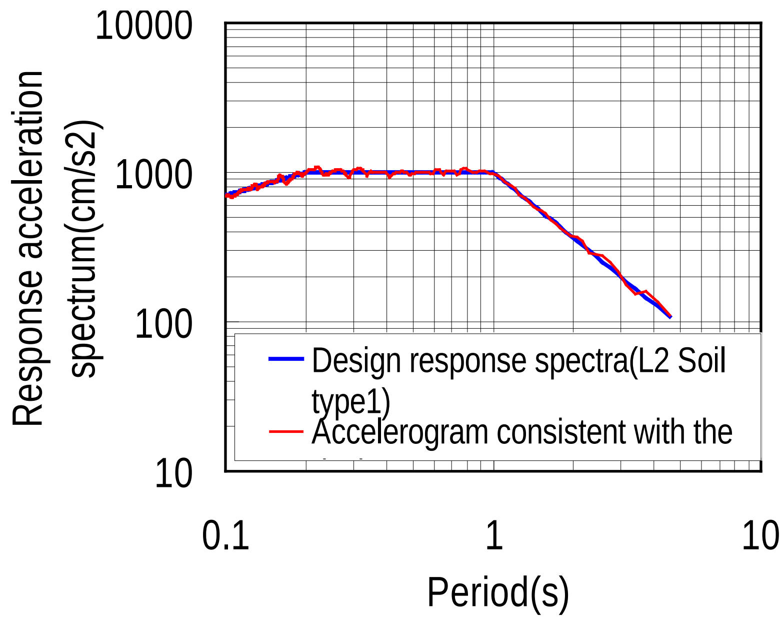
Evaluation of safety

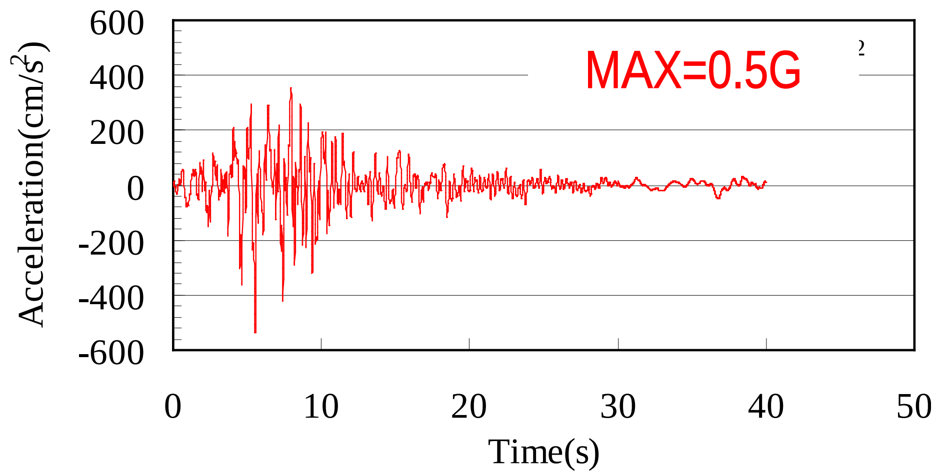
$$\boxed{\gamma_i \cdot \frac{S_d}{R_d} \leq 1.0}$$

$S_d = \gamma_a \cdot S$: Design response (response curvature)

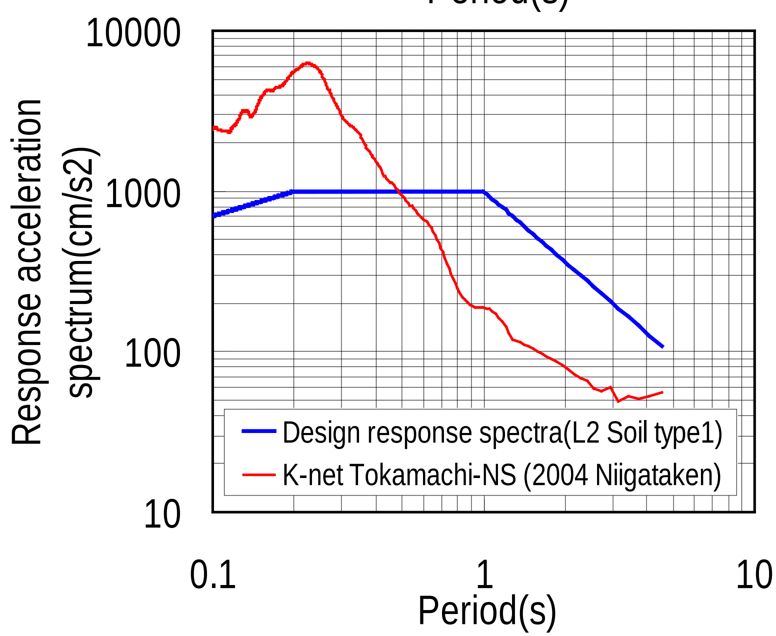
$R_d = \dfrac{R}{\gamma_b}$: Design resistance (Curvature at maximum load)

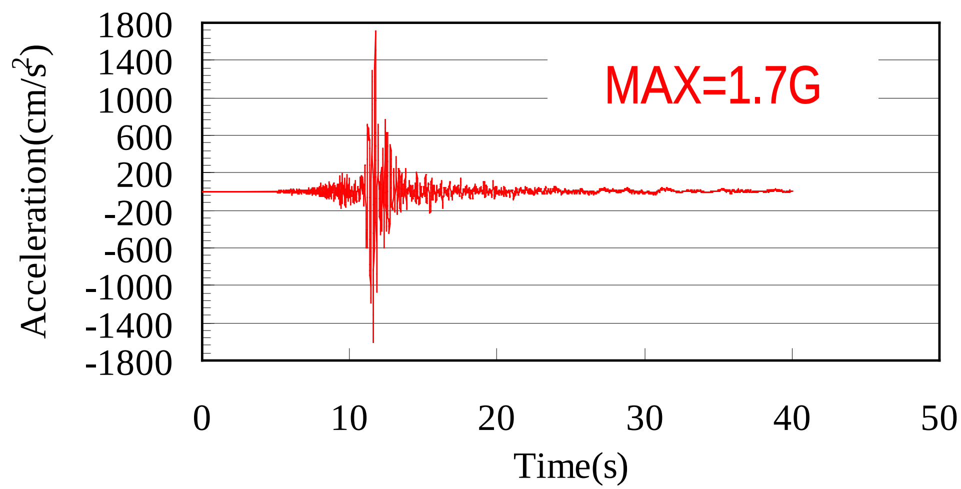
Input seismic motion for soil type 1 model





Accelerogram consistent with the design response spectrum for Soil type 1

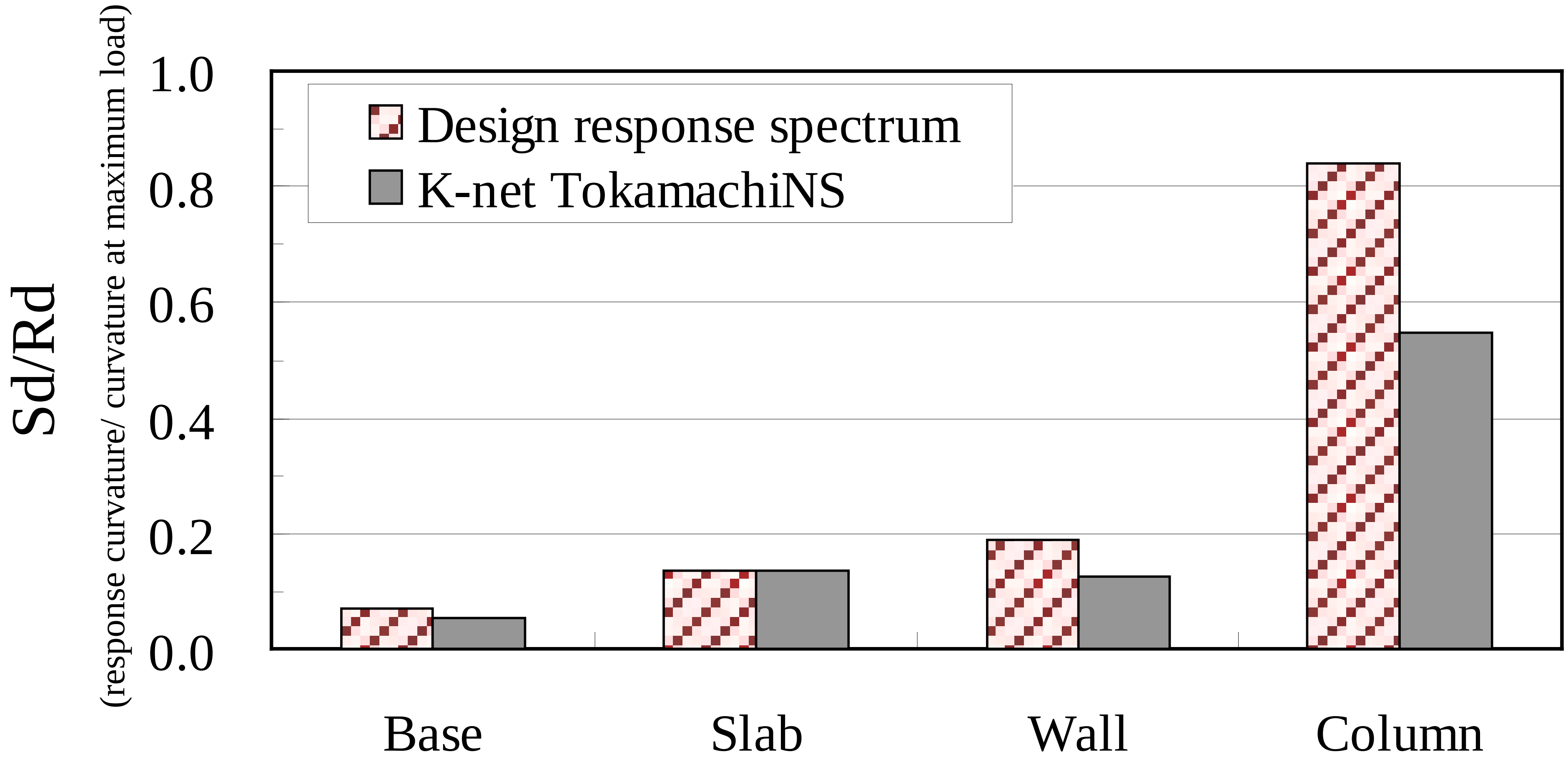




Observations record

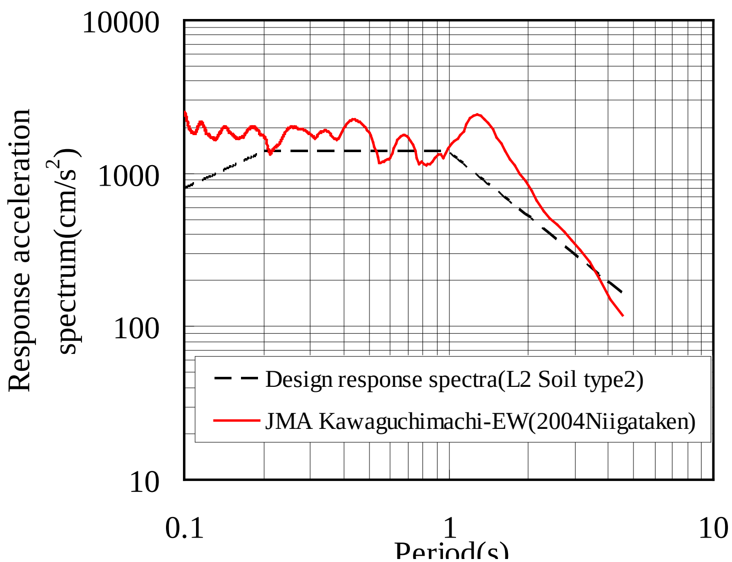
(K-net Tokamachi-NS, 2004 Niigata Earthquake)

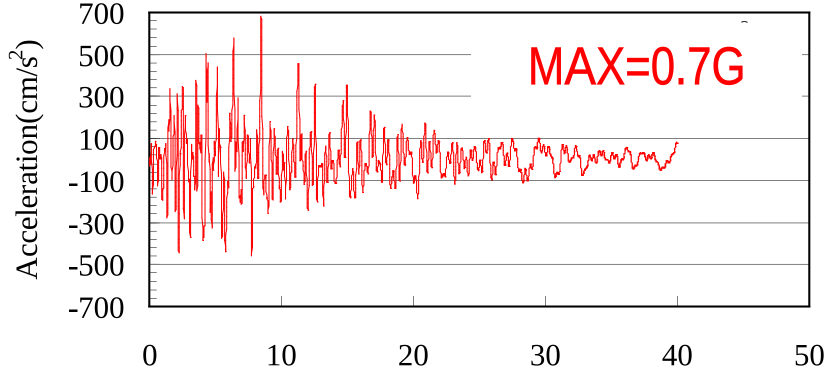
Analysis results for soil type 1 model



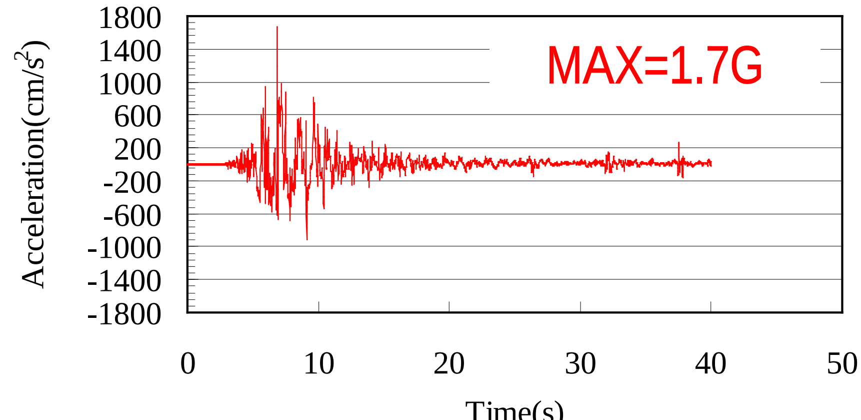
- For both types of input seismic motion, Sd/Rd shows a maximum at the column, and a minimum at the base.
- For Tokamachi-NS record, Sd/Rd was 40% smaller than other case at column

Input seismic motion for soil type 2 model

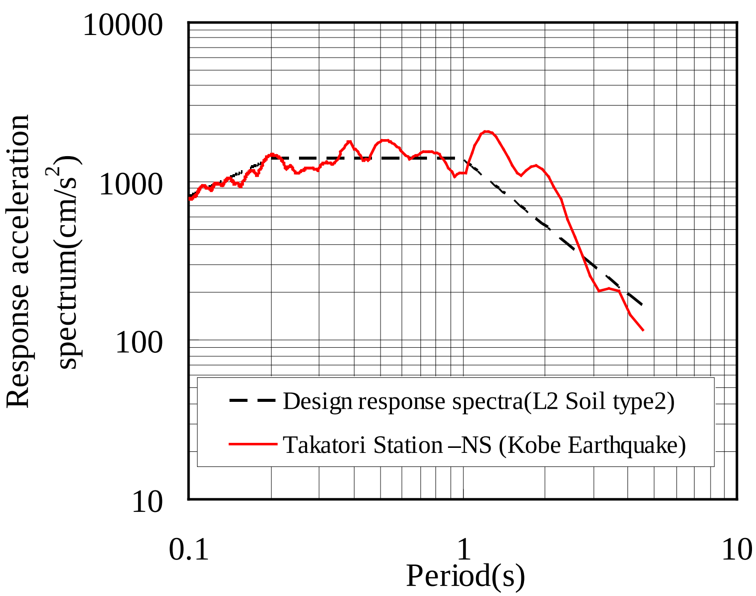


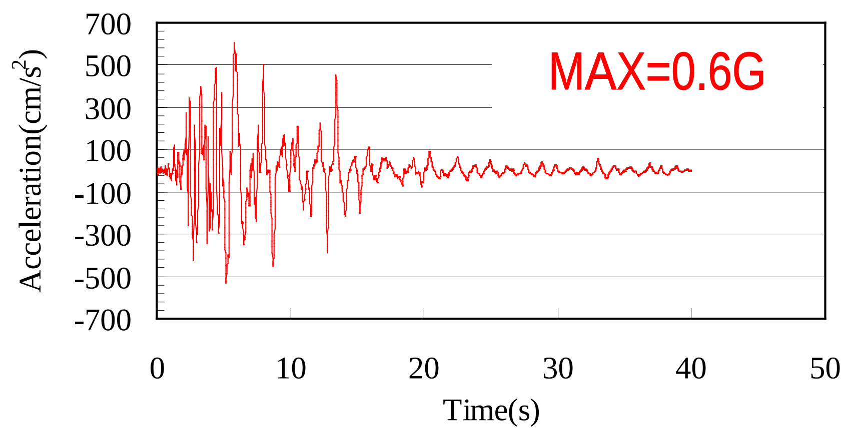


Accelerogram consistent with the design response spectrum for Soil type 2



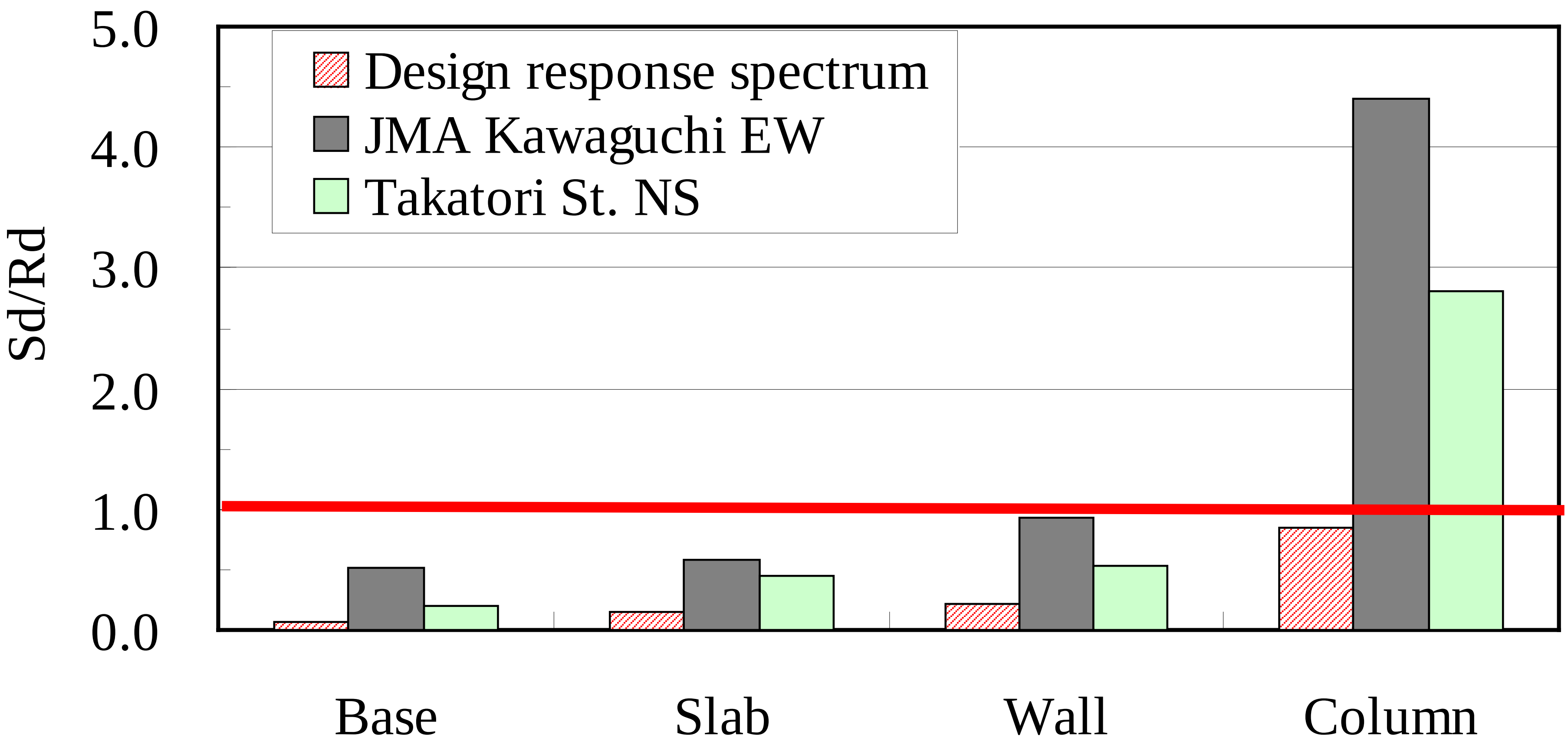
Observations record (Kawaguchimachi, 2004 Niigata earthquake)





Observations record (Takatori)

Analysis results for soil type 2 model



- The minimum Sd/Rd values were calculated with the design response spectrum.
- For the Kawaguchi EW and Takatori NS seismic motions, Sd/Rd was larger than 1.0 at the column, and the seismic performance 2 could not be ensured.

OVERVIEW OF RESULTS

Soil type	Comparison of response spectrum	Calculations for reservoir tank using non-linear dynamic analysis
Soil type 1	The response spectrum of strong motion records was more than three times lager than the 1997 design response spectrum.	• Both cases ensured seismic performance II. • In case of using accelerogram consistent with design response spectrum, the response value was slightly larger than other case.
Soil type 2	The response spectrum of strong motion records was approximately 1.3 times lager than the 1997 design response spectrum.	• In cases of using the strong motion records, the results could not ensure seismic performance II (column). • In case of using accelerogram consistent with design response spectrum, the response value was smaller than other cases.
Soil type 3	The response spectrum of strong motion records was approximately 1.1 times lager than the 1997 design response spectrum.	—

CONCLUSIONS

- The important findings in this study
  1. The recent strong motion records exceeded the design response spectrum.
  2. Results of dynamic analysis was different depending on the soil type.
- Facilities damage
  1. No significant damage due to earthquake motions to water supply facilities (except pipelines) since 1995 KOBE earthquake (using the 1997 design response spectrum) .
  2. In this study, the evaluation using dynamic non-linear analysis were conducted only reservoir tanks. The other type structures have not been calculated.
- A revision to the 1997 design response spectrum should be closely checked.

FUTURE STUDY

- It will be necessary to continue studies on the design response spectrum, paying full attention to the following issues:
  1. Effects of construction type and status on response characteristics.
  2. Evaluation of seismic performance of real structures, in term of experienced strong motion records.
  3. Evaluation of effects of significant long period components on water supply facilities.

Thank you, Kind attention.