ONLY PUT ON !

Low cost base isolations by slide bearings without restoration mechanism

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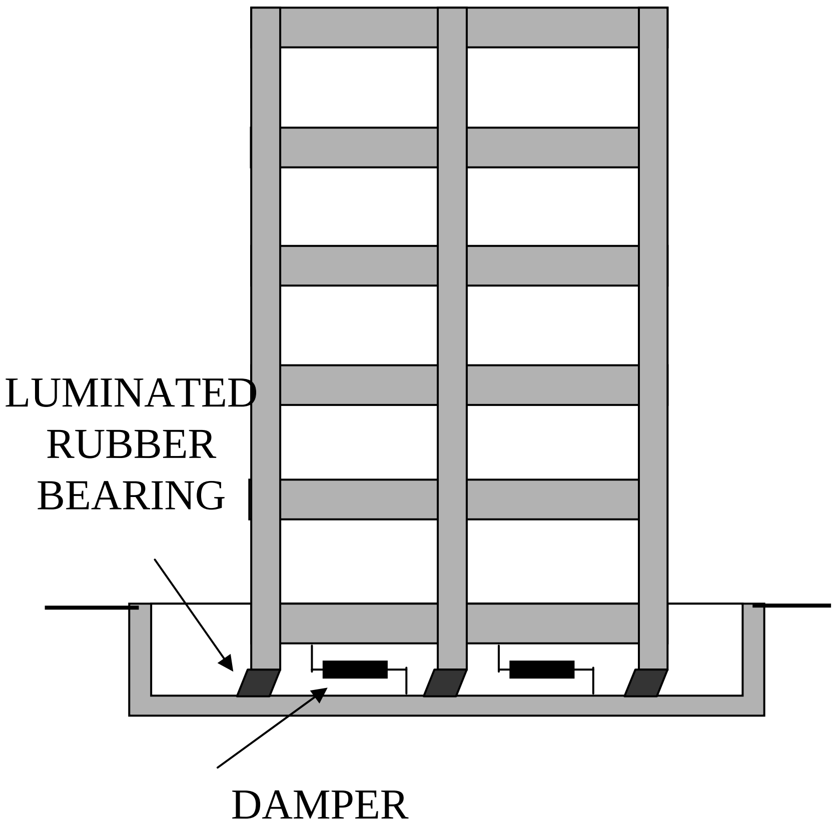
Motivation

Typical Isolator System



Problems

1) It's expensive.

2) The resonance arises if long cycle periods are included in earthquake.

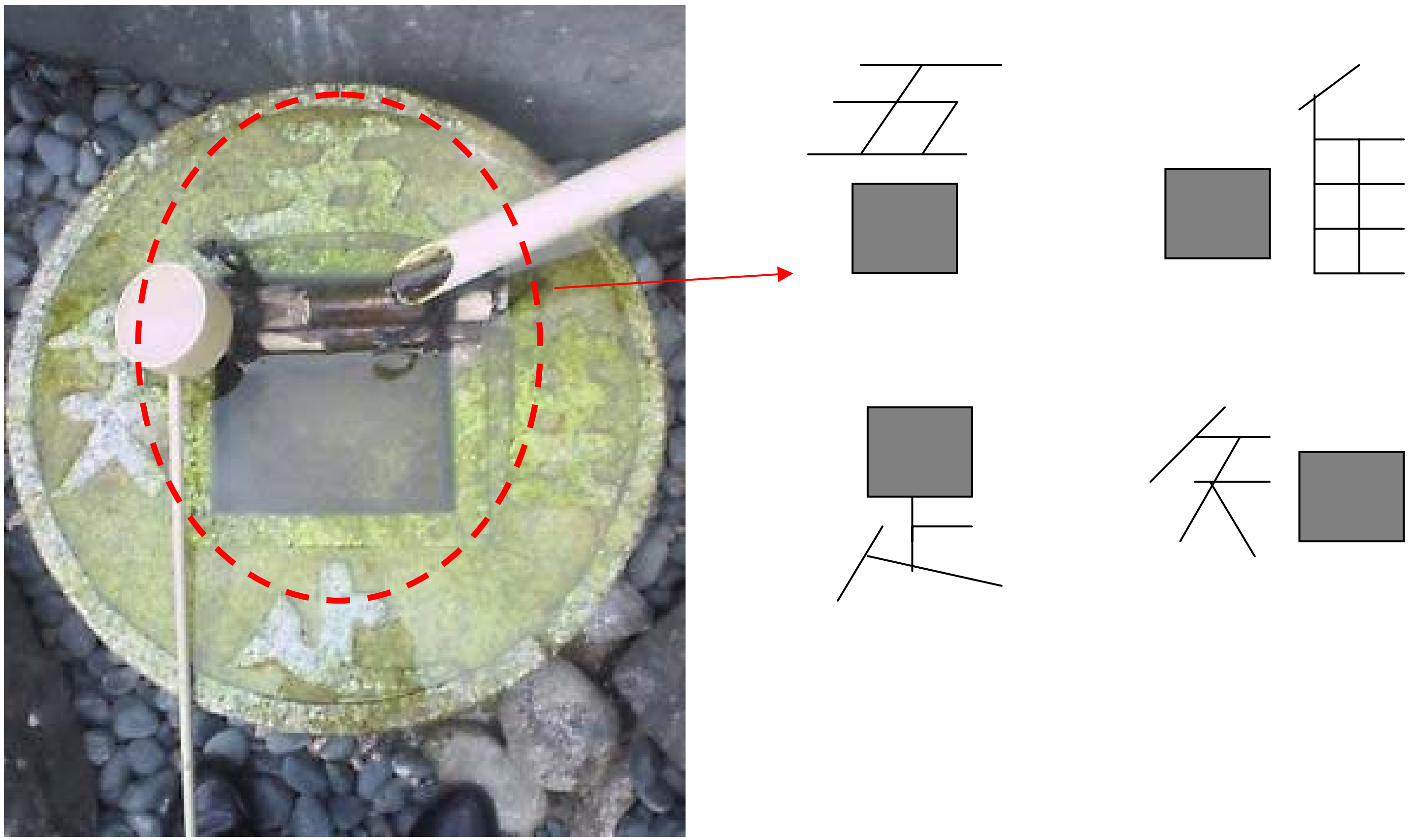
Let’s change of our mind.

Then how to change?

We should be satisfied if the acceleration of the building can be decreased to the 50%.

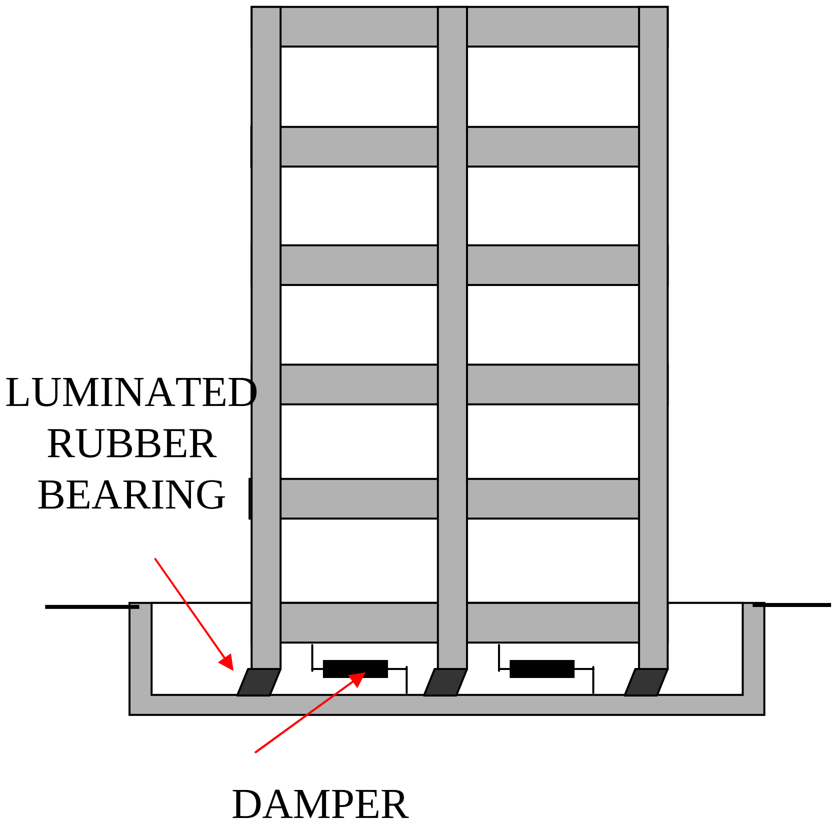
We should allow the remaining gap of the building after the earthquake.

We should not devour.

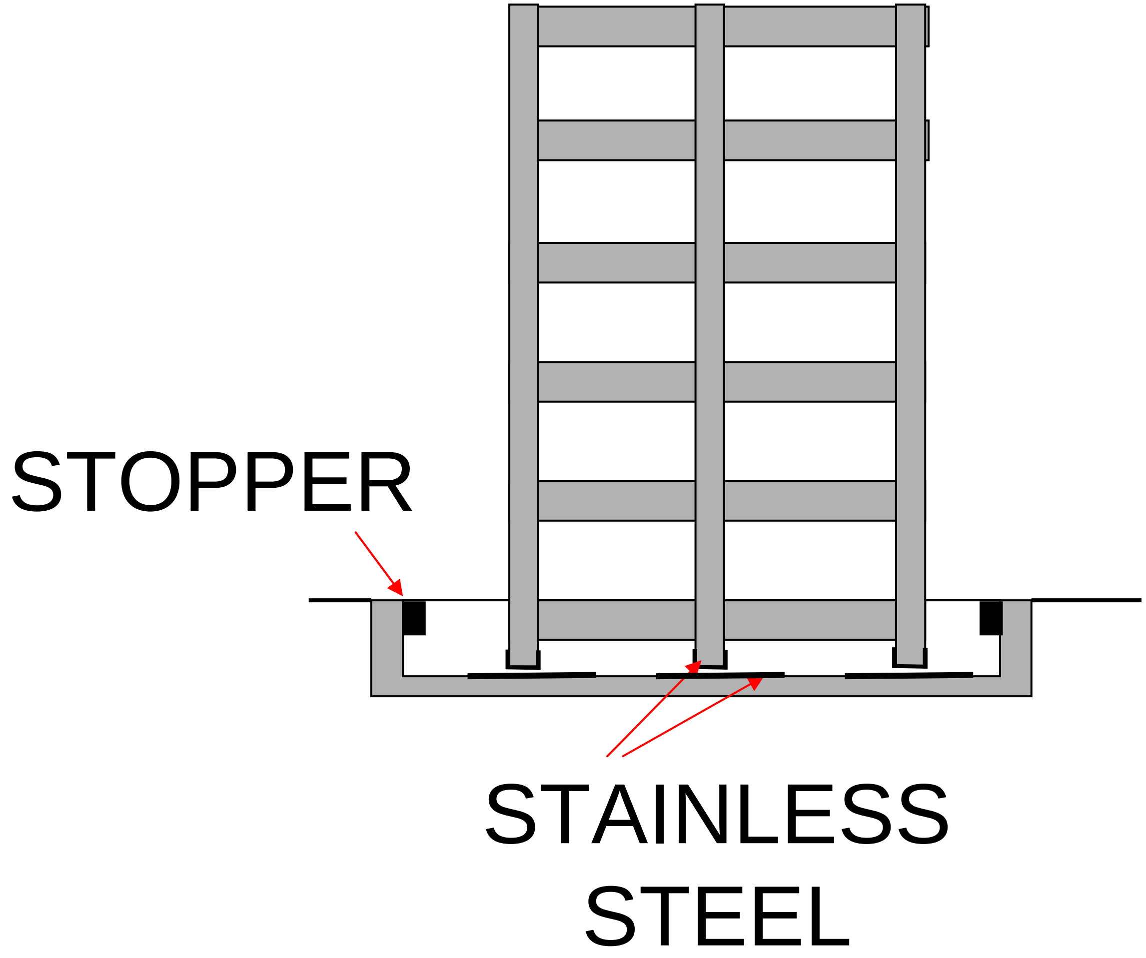


Washing water at ZEN temple

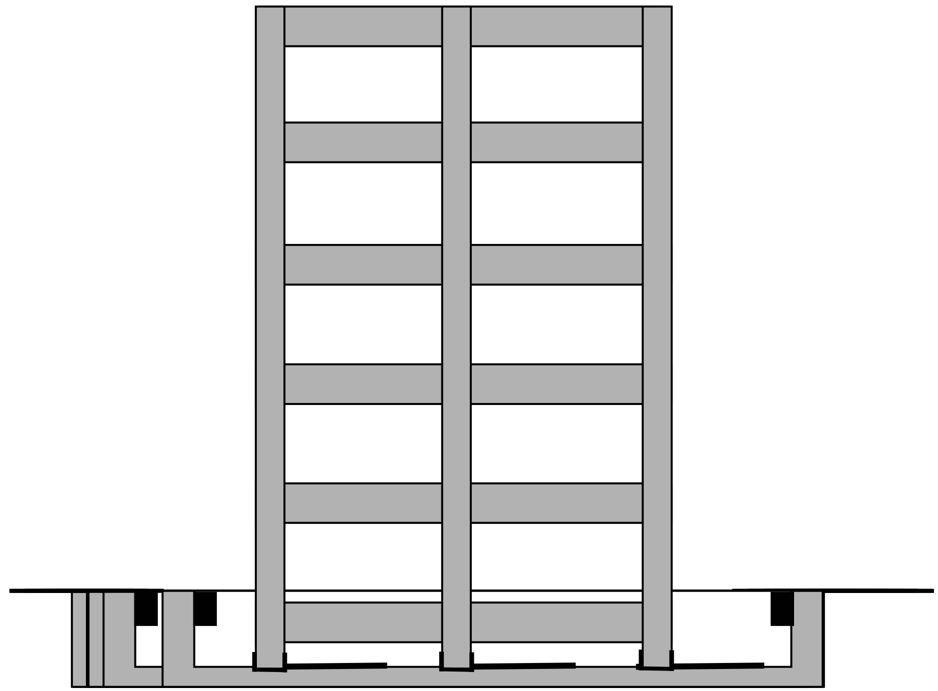
So, let's remove all devices



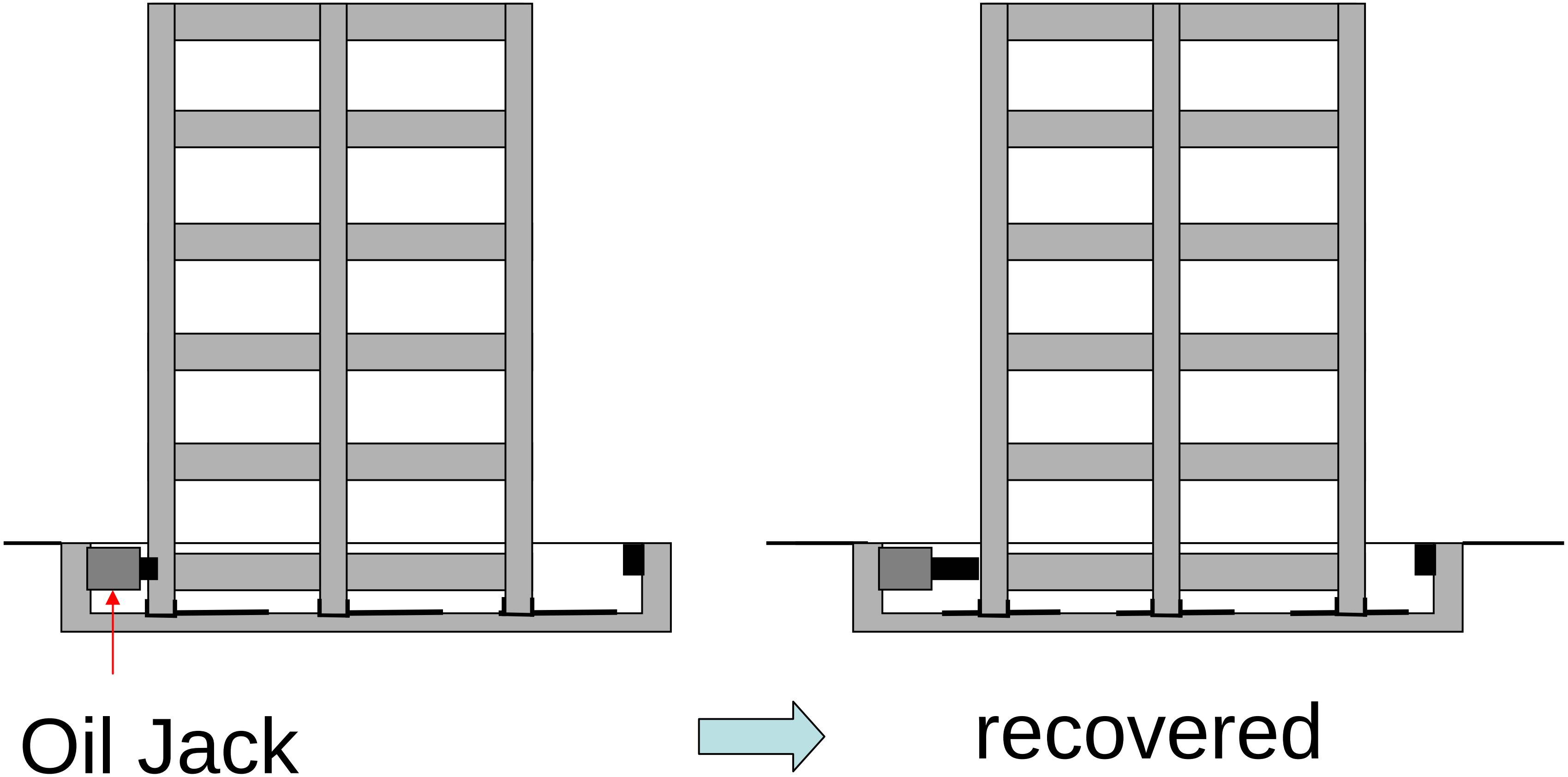
ONLY PUT ON Concept



It’s very simple idea



Remaining gap can be recovered by oil jack



We can find it at old temples

Matters of weight for put on type bearings

? Desirable frictional coefficient μ

? Maximum gap δ_{max} and remained gap δ_{rem} after the earthquake

The necessary condition of μ

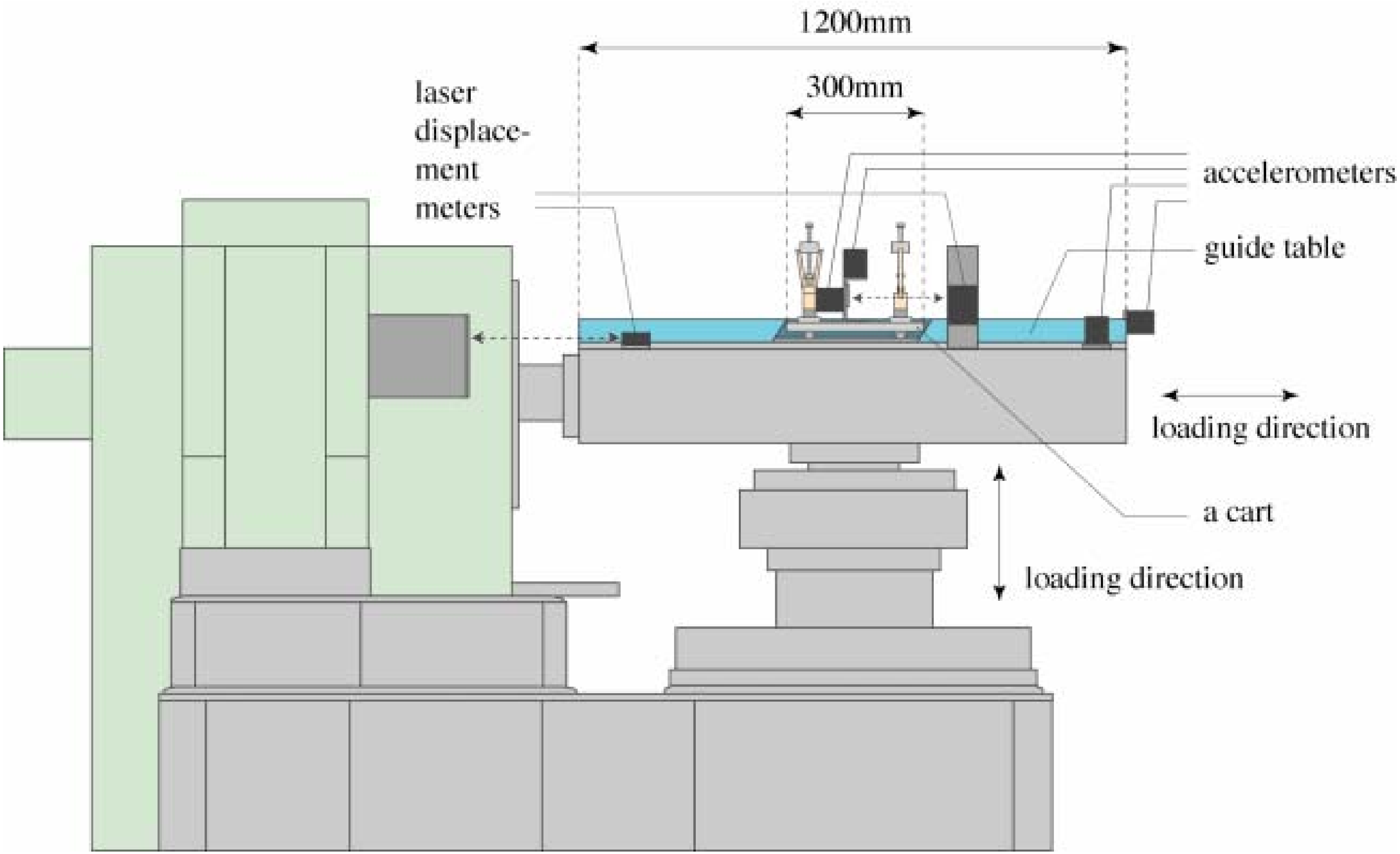
a) Do not slide due to wind force or small earthquakes

b) Must slide by big earthquake (Max acceleration>200cm/sec^2)

μ 0. 2 → Stainless Steel

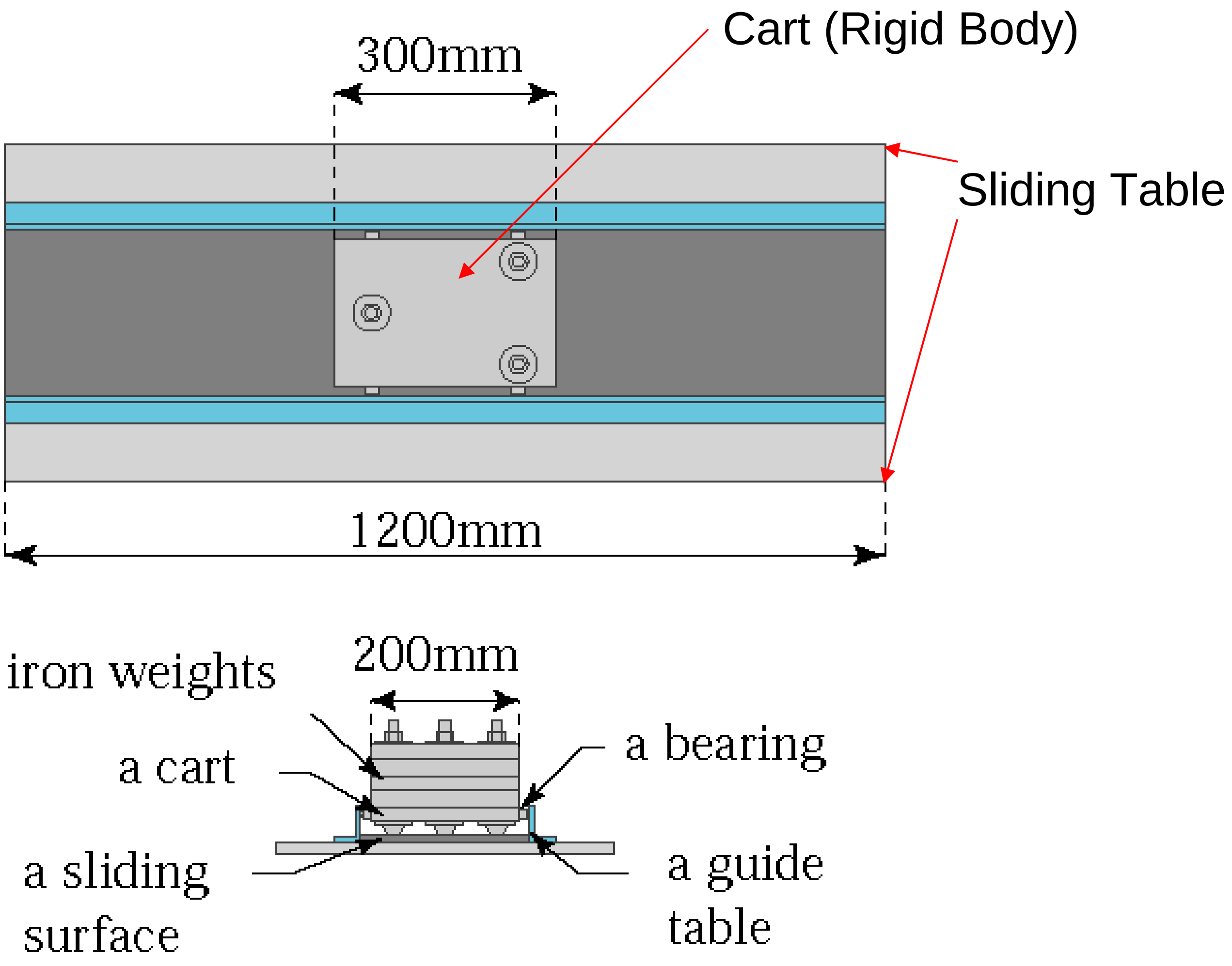
Let’s verify it by experiment

Magnetic Shaking Table (Elev.)



Magnetic Shaking Table (Photo)

Rigid Body Tests



Parameter

Earthquake

1) JMA KOBE NS *
2) JMA KOBE EW *
3) El Centro NS **

Slide Surface

1) Without Lubrication
2) With Lubrication

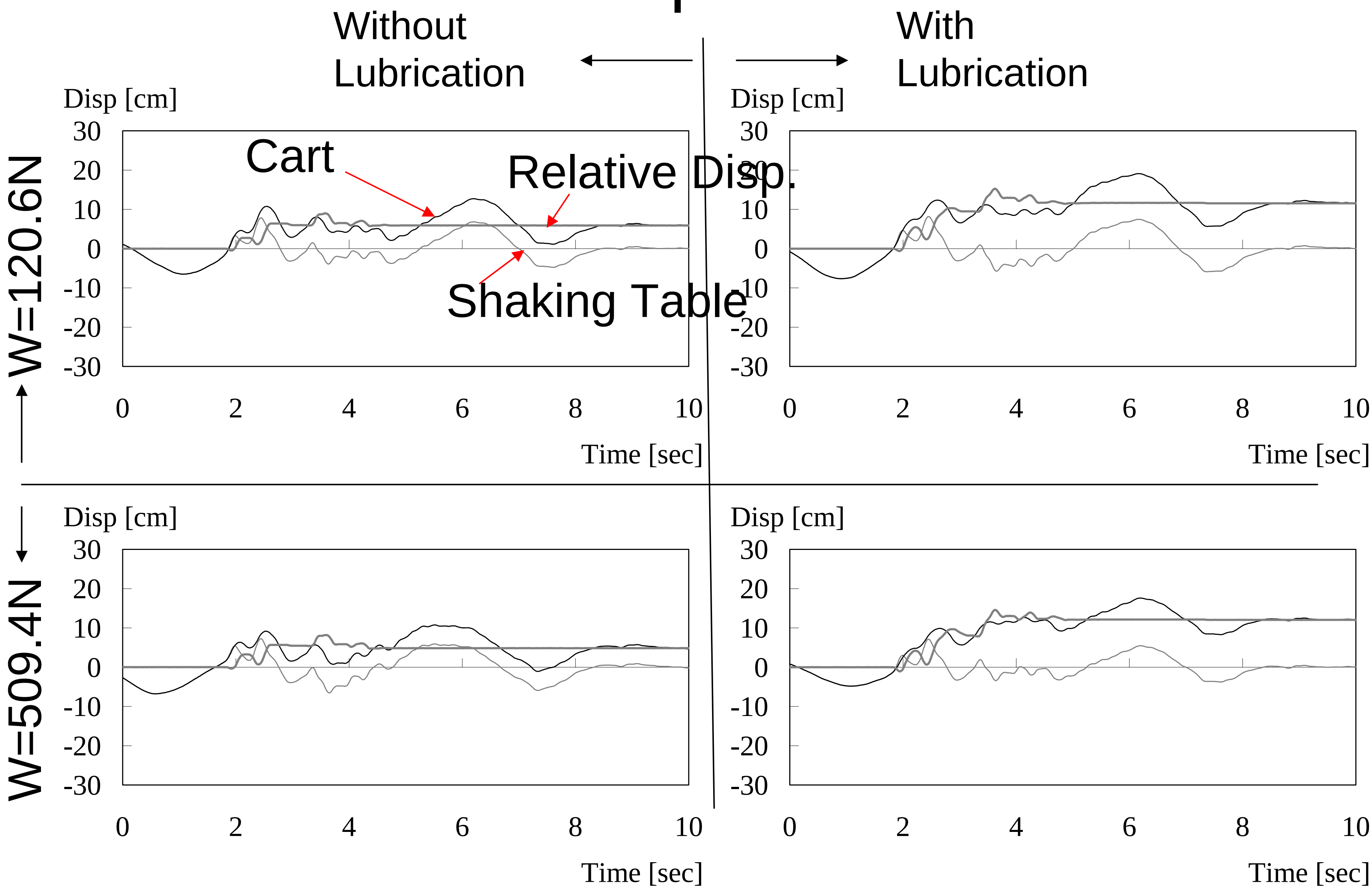
- Change time increments from Δt to $\Delta t/2$

** Change time increments from Dt to Dt/2 and the acceleration is amplified to twice.

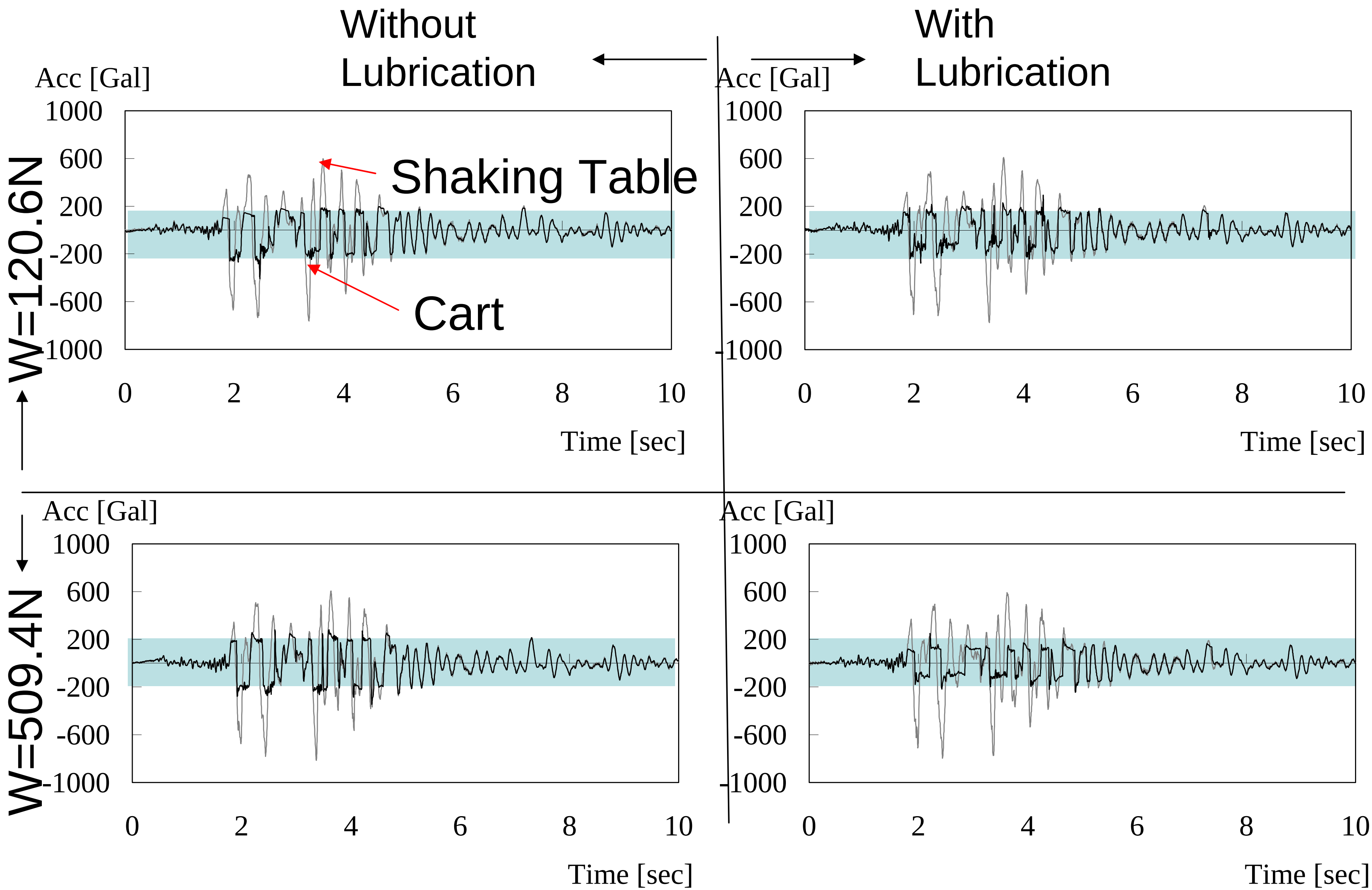
Weight of Cart [N]

1) 120.6
2) 217.4
3) 310.7
4) 410.1
5) 509.4

Time-Displacement



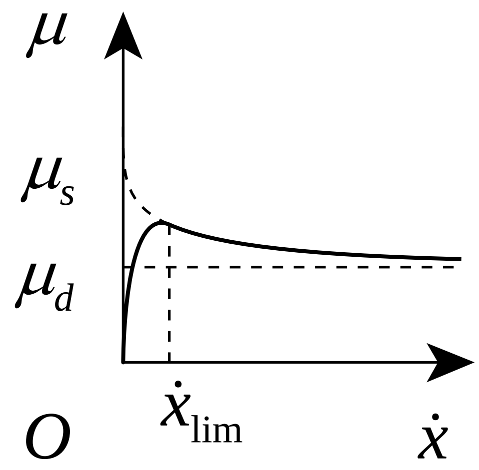
Time-Acceleration



Identification of frictional coefficients

Expression of Frictional Coefficients

$$\mu = \begin{cases} \mu^* & \dot{x} < -\dot{x}_{\lim}, \dot{x}_{\lim} \le \dot{x} \\ \left|\dfrac{\dot{x}}{\dot{x}_{\lim}}\right| \mu^* & -\dot{x}_{\lim} \le \dot{x} < \dot{x}_{\lim} \end{cases}$$



$\dot{x}$: Relative velocity

$\dot{x}_{\lim}$: Smoothing parameter

$\dot{x} = 0$

$$\mu^* = \mu_d + (\mu_s - \mu_d)\exp\left(-c\left|\dot{x}\right|\right)$$

μ_s, μ_d, c : Target parameters

μ_s : Static frictional coefficient

μ_d : Dynamic frictional coefficient

c : Index attenuation coefficient

Identification method

$$f^k = \sum \left(x_i * - x_i^{\ k}\right)^2 \left(\ddot{x}_i * - \ddot{x}_i^{\ k}\right)^2$$

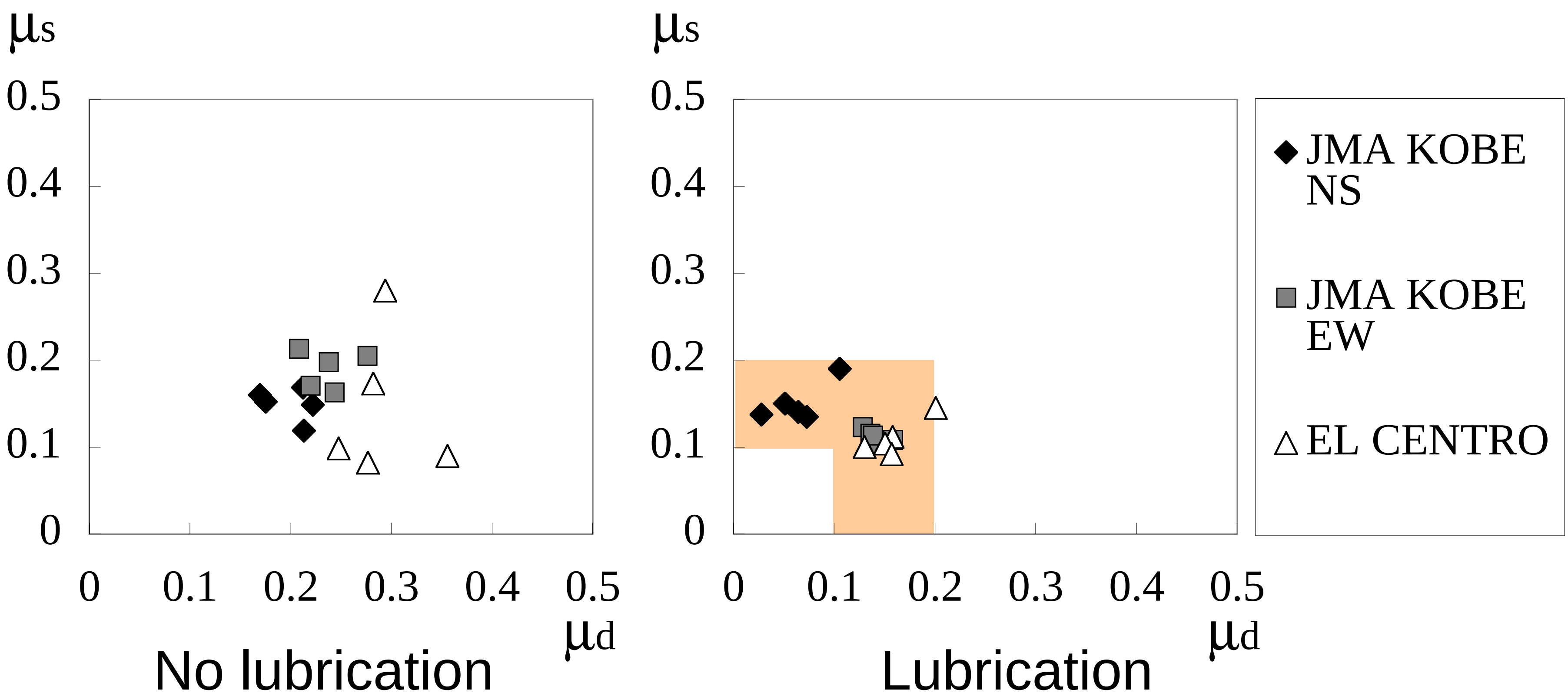
----> Minimizing

Determine μ_s, μ_d, c

$x_i *$ observed responses

x_i calculated responses by using trial parameter μ_s, μ_d, c

Identified values



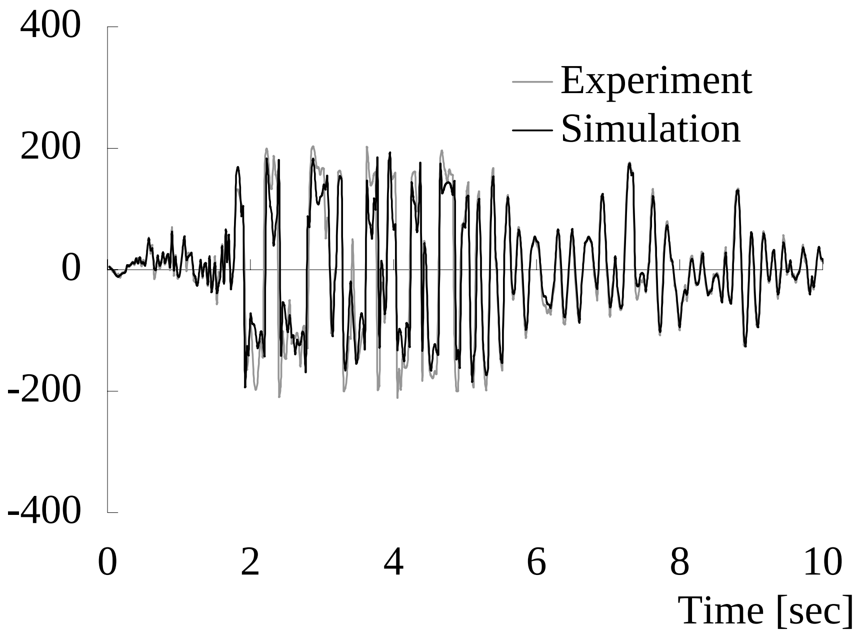
μ_s =0.08~0.21

μ_d=0.17~0.36

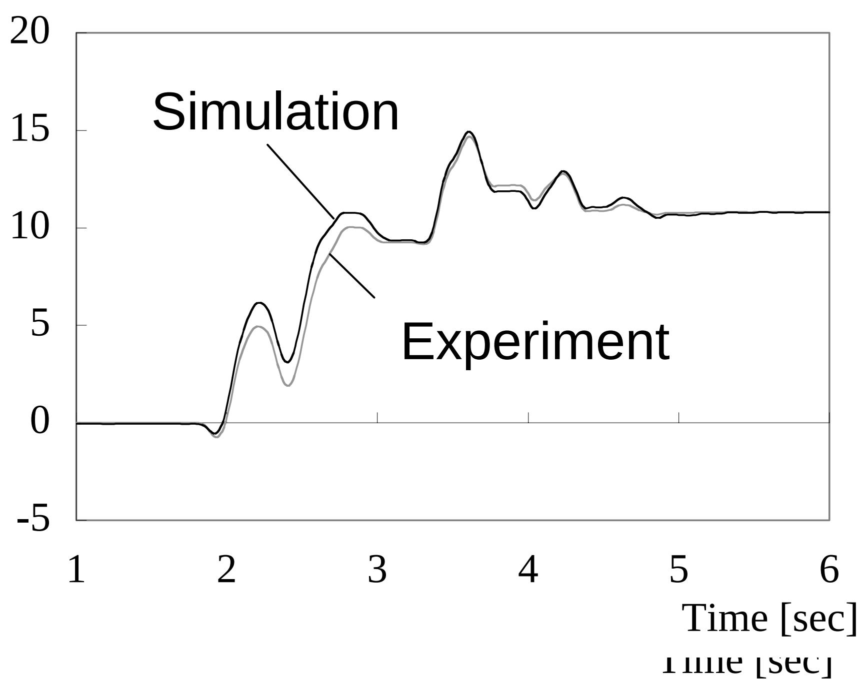
μ_s =0.09~0.19

μ_d=0.03~0.20

Comparison of simulations with experiments

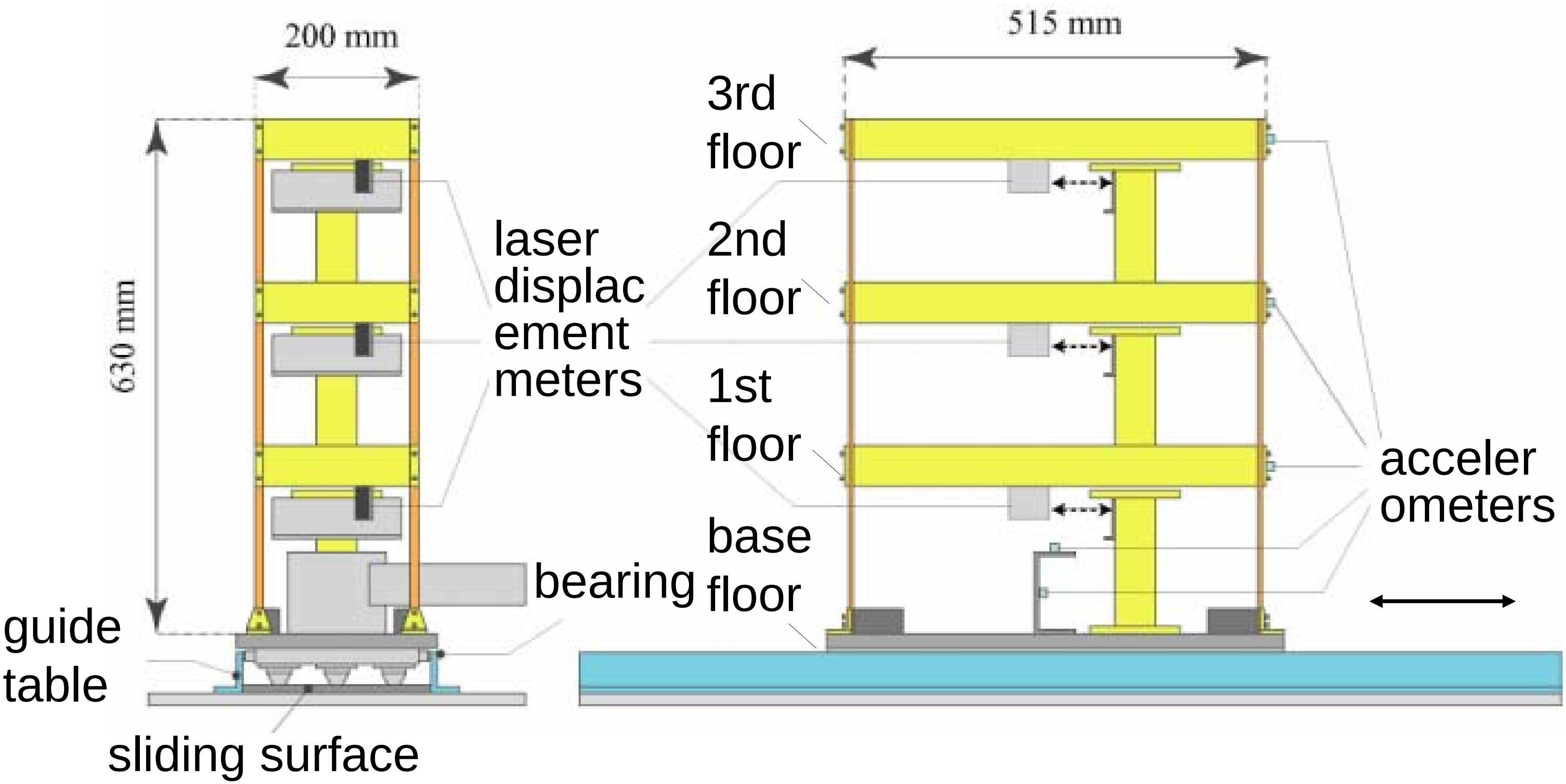


Acceleration



Displacement

Three story frame



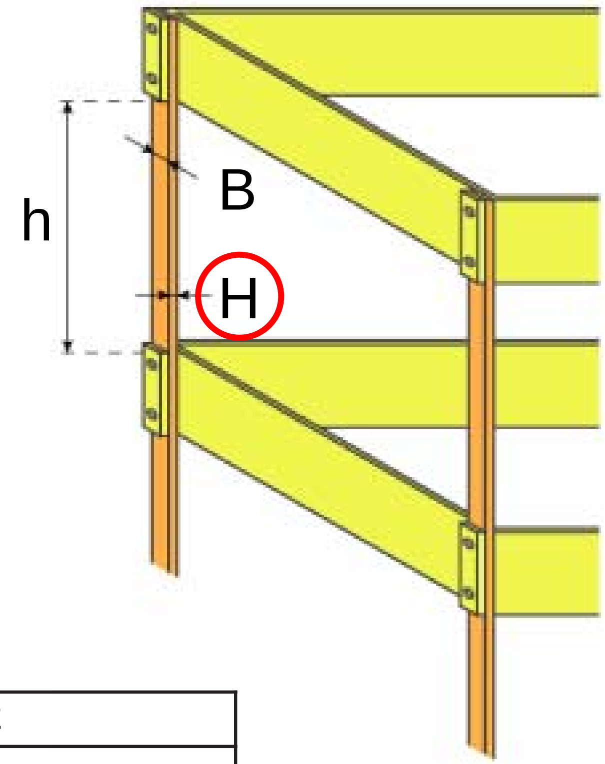
Weight and stiffness of models

Calculation of stiffness

	Model 1	Model 2
Modulus of longitudinal elasticity [N/cm]	10976000	10976000
B [cm]	0.9	0.9
H [cm]	0.3	0.4
h [cm]	15.0	15.0
4k [N/cm]	316.1	749.3

$$k = \frac{12EI}{h^3}$$

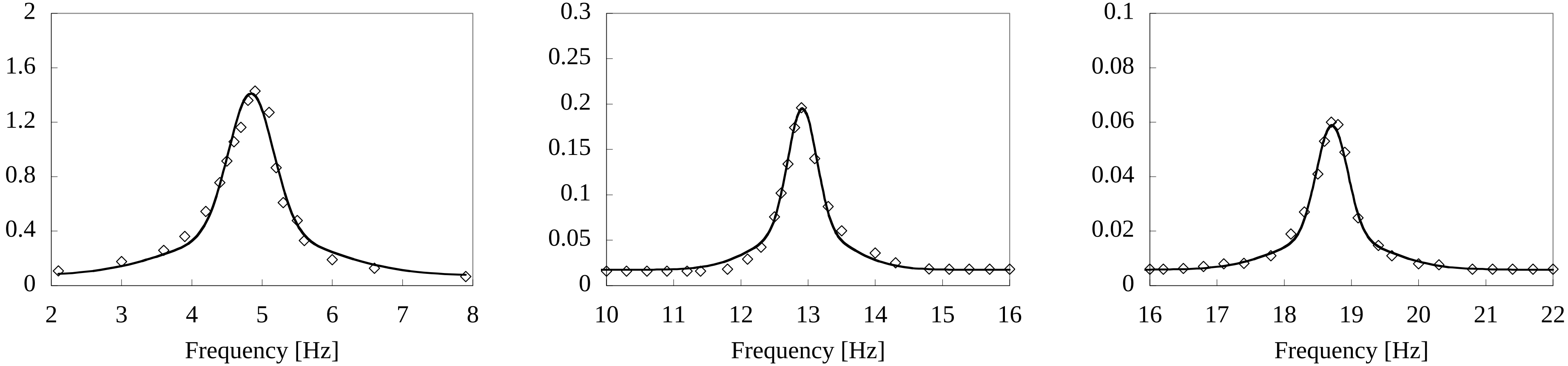
$$I = \frac{BH^3}{12}$$



Weight and stiffness

	Model-1		Model-2	
	Weight [N]	Stiffness [N/cm]	Weight [N]	Stiffness [N/cm]
3rd Floor	54.1	316.1	54.1	749.3
2nd Floor	69.6	316.1	69.6	749.3
1st Floor	73.5	316.1	73.5	749.3
Base	256.8	0.0	256.8	0.0

Frequency-response curve



(a) First (b) Second (c) Third

Frequency-response curve of Model 1

Natural frequency

Model	1st [Hz]	2nd [Hz]	3rd [Hz]
Model 1	5.0	12.9	18.8
Model 2	7.3	19.2	27.8

Experimental condition

Input motion

Modified earthquake motions:

JMA KOBE NS*, JMA KOBE EW*, El Centro NS**

(* time scale factor = 0.5)

(** time scale factor = 0.5, amplification scale factor = 2.0)

Installation

Three installation conditions: Fixed base model,

Sliding base model (two sliding surfaces:

No lubrication and Lubrication)

Measurement

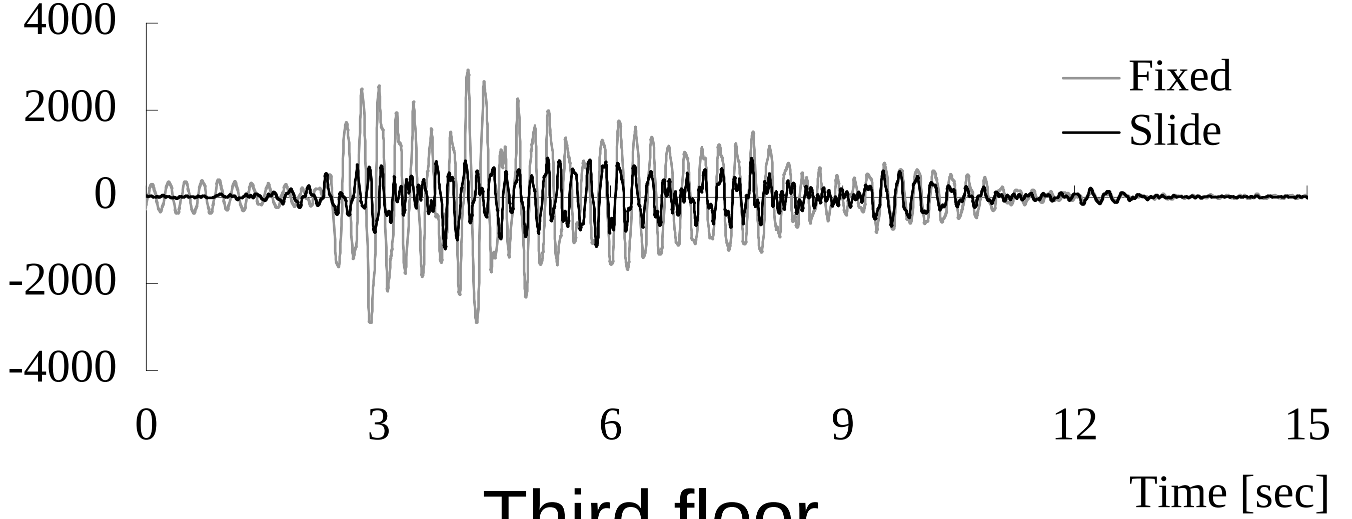
Each story’s acceleration and inter-story drift

Video

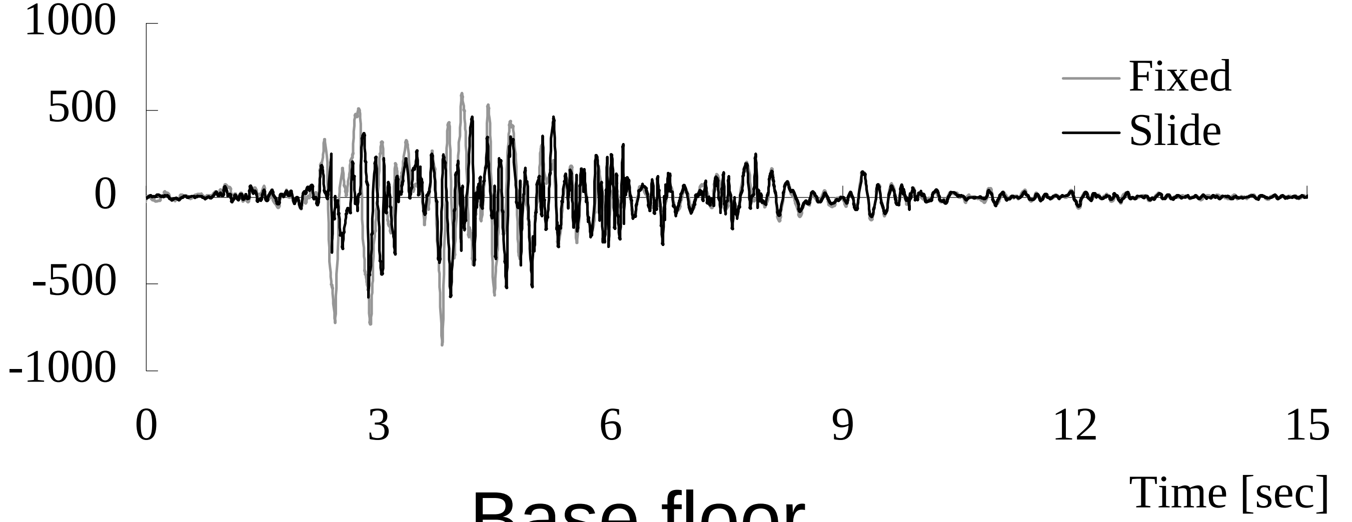
Video-1

Video-2

Acceleration time histories

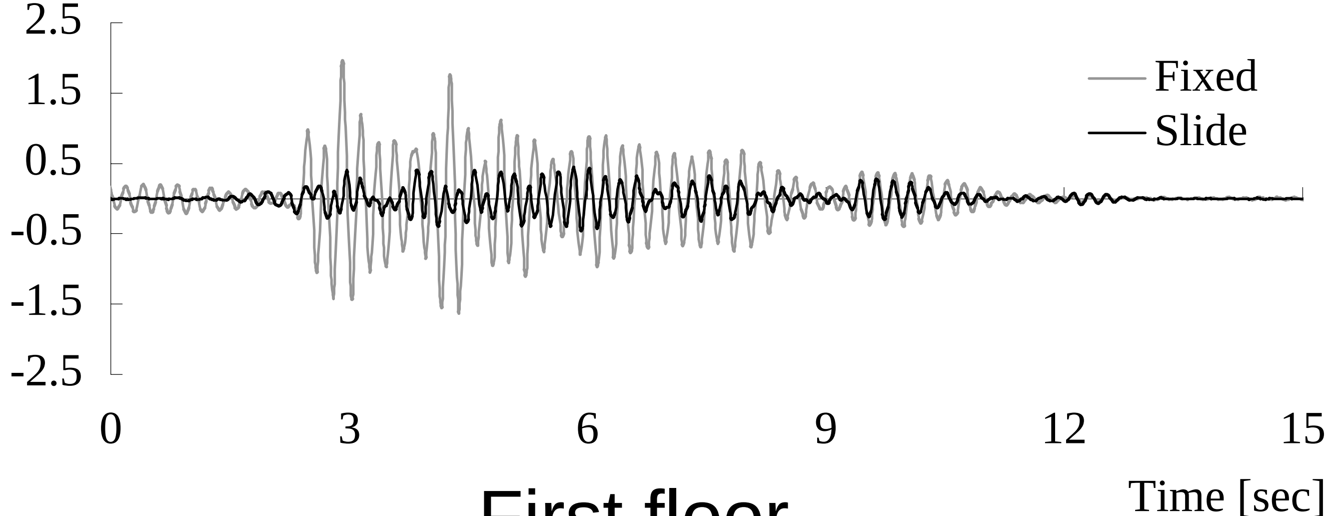


Third floor

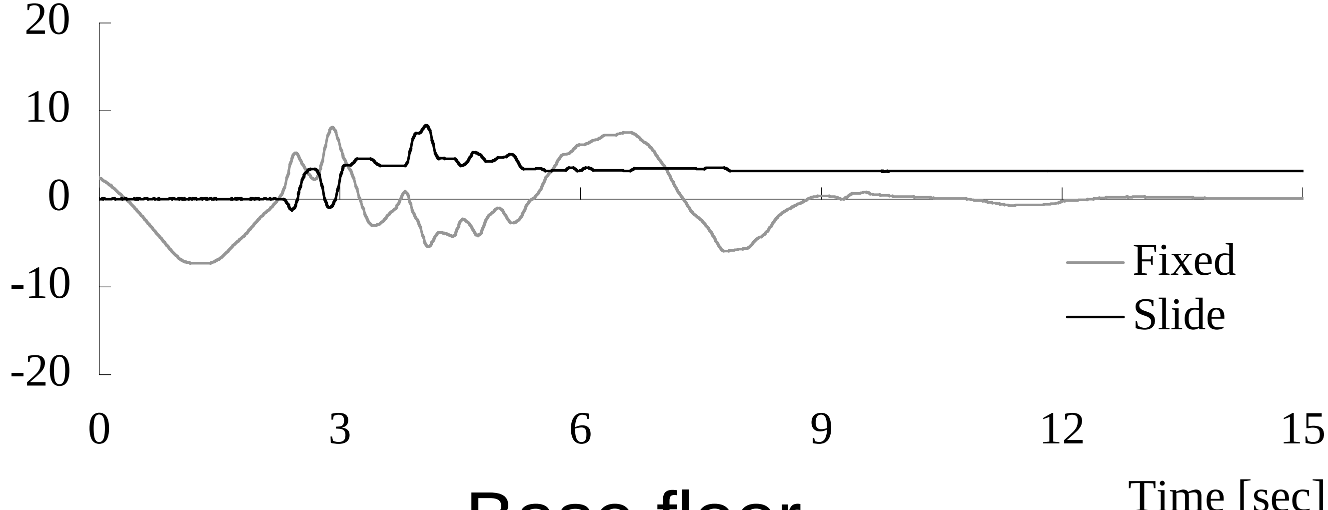


Base floor

Inter-story drift

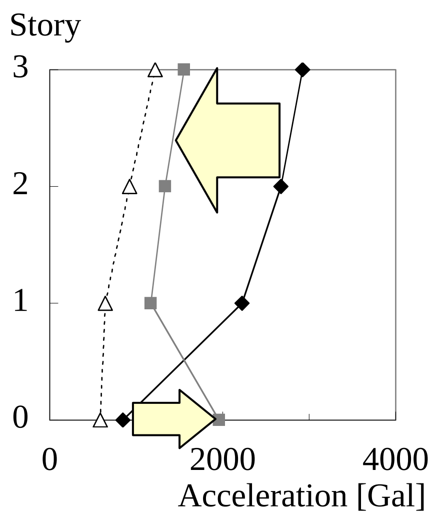
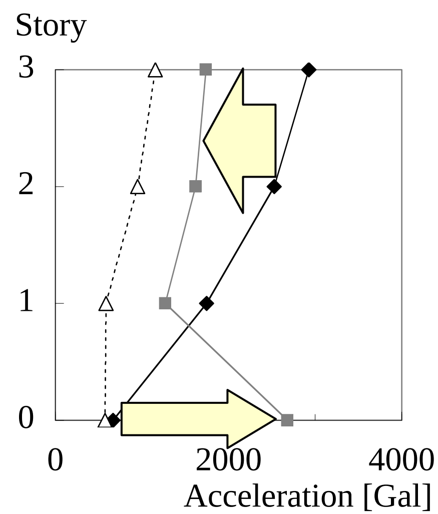
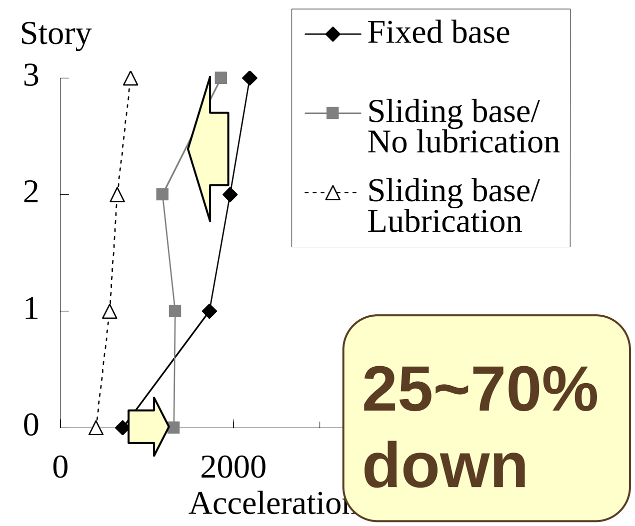
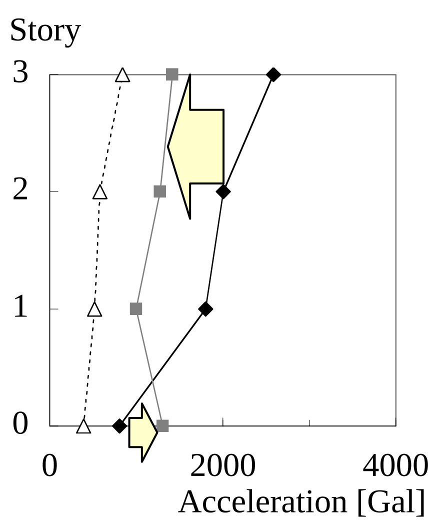
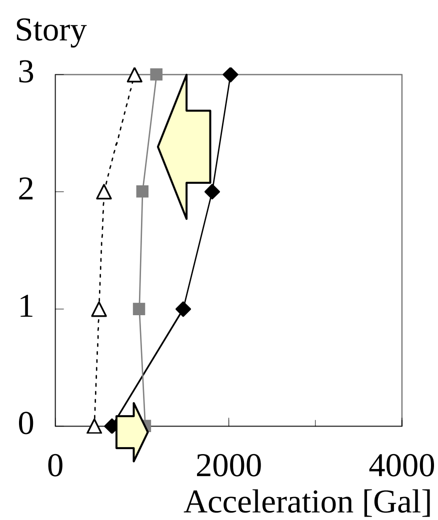
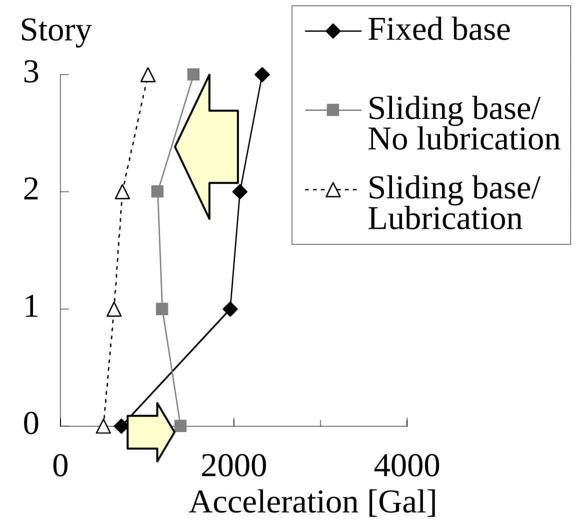


First floor

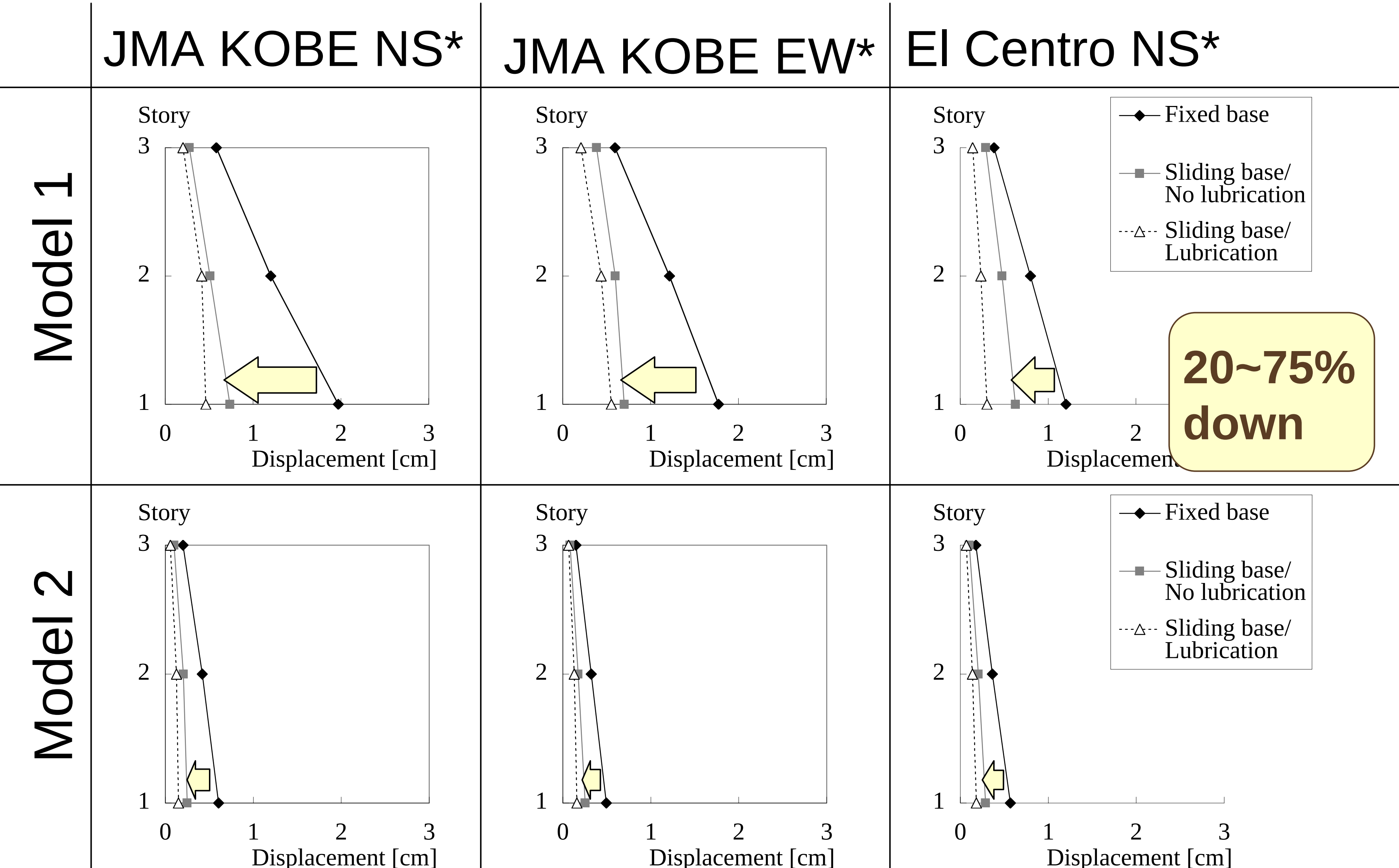


Base floor

Each story's maximum acceleration

	JMA KOBE NS*	JMA KOBE EW *	El Centro NS *
Model 1			
Model 2			

Maximum inter-story drifts

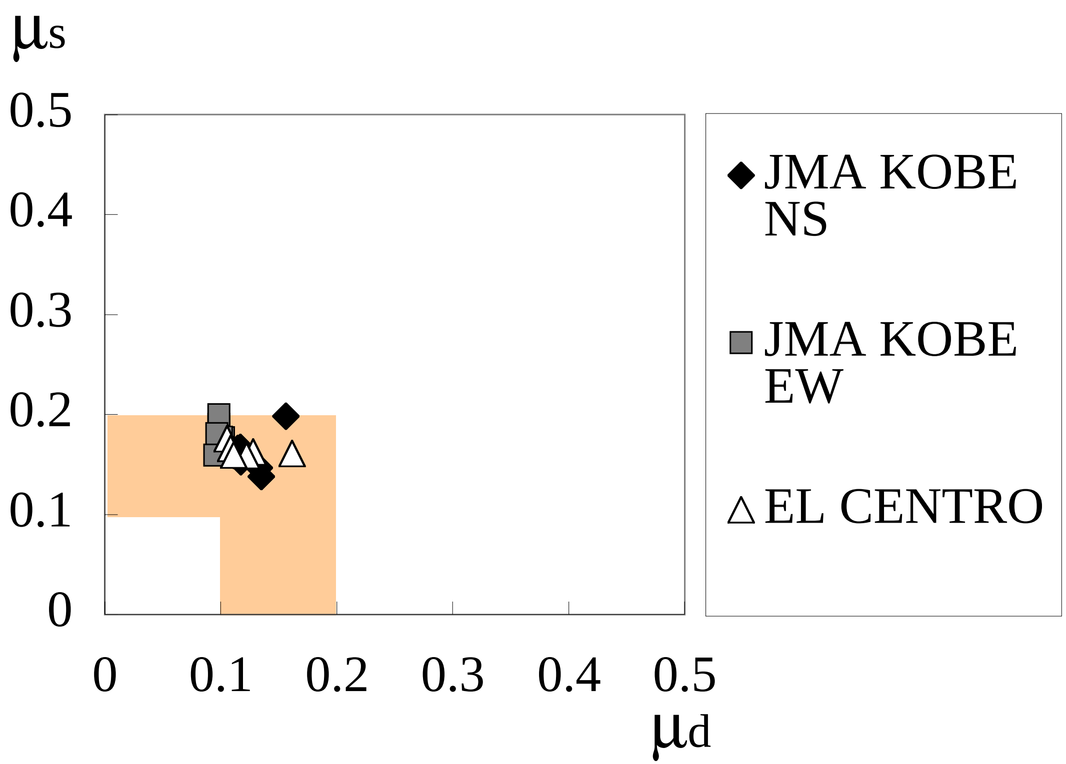


Sliding displacements at the base

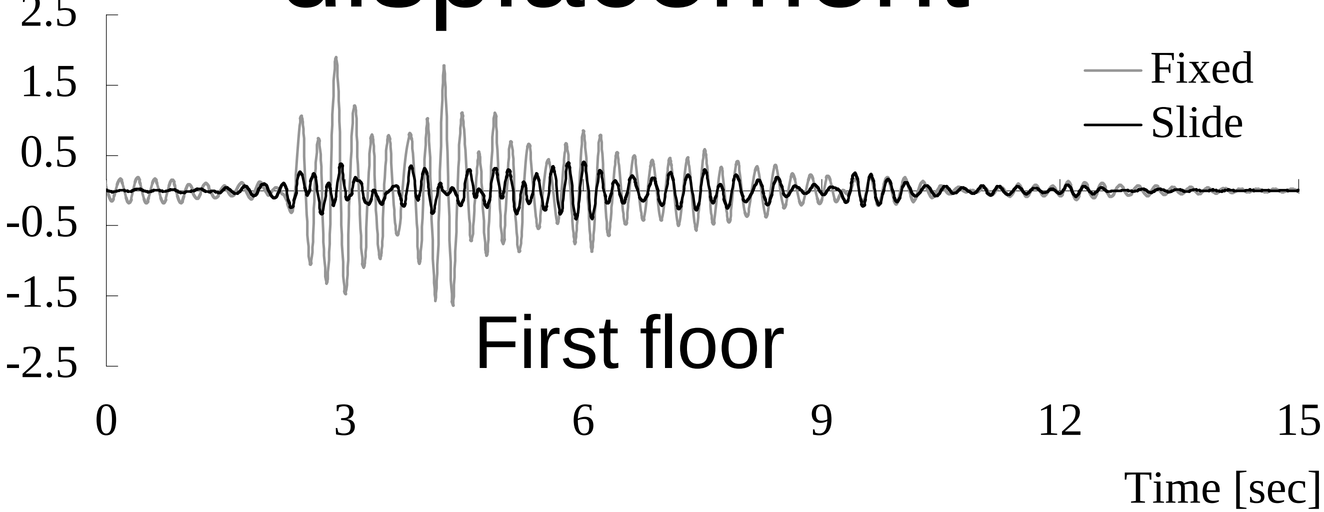
Input	Installation conditions	Model	Max. Disp. of Base [cm]	Residual Disp. of Base [cm]
JMA KOBE NS*	No lubrication	Model 1	10.24	9.12
JMA KOBE NS*	Lubrication	Model 1	8.93	4.07
JMA KOBE EW*	No lubrication	Model 1	1.54	1.08
JMA KOBE EW*	Lubrication	Model 1	5.80	5.08
El Centro NS**	No lubrication	Model 1	4.27	4.12
El Centro NS**	Lubrication	Model 1	4.05	0.98
JMA KOBE NS*	No lubrication	Model 2	10.24	9.73
JMA KOBE NS*	Lubrication	Model 2	10.78	6.04
JMA KOBE EW*	No lubrication	Model 2	2.89	2.38
JMA KOBE EW*	Lubrication	Model 2	7.89	6.57
El Centro NS**	No lubrication	Model 2	2.13	2.13
El Centro NS**	Lubrication	Model 2	3.12	0.31

Identification of frictional coefficients

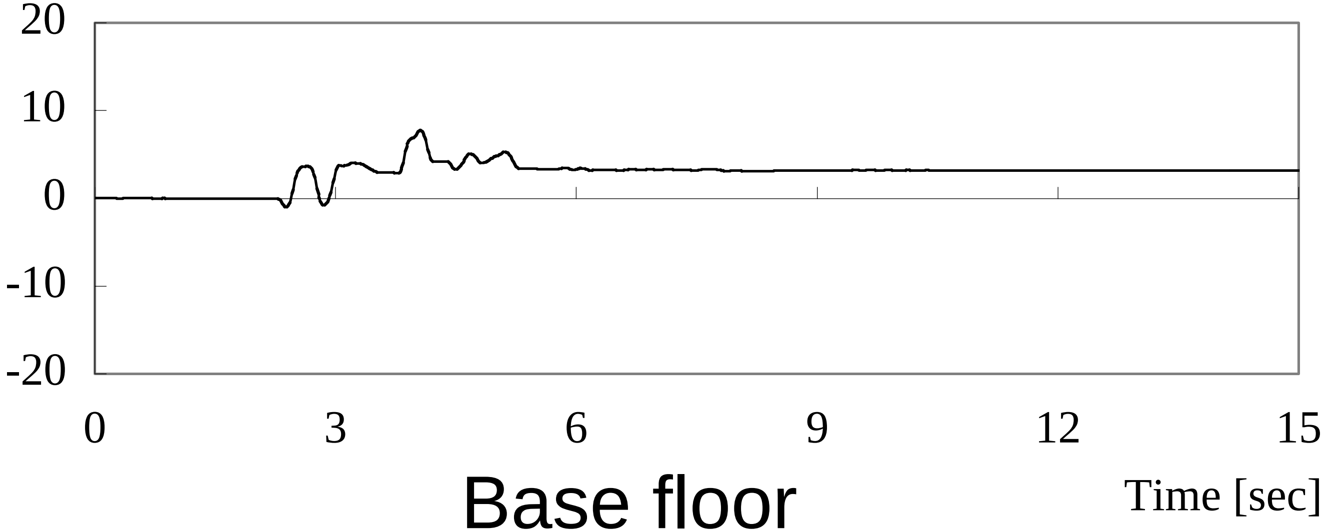
μ_s =0.15~0.20
μ_d=0.10~0.16



Time histories of simulated displacement



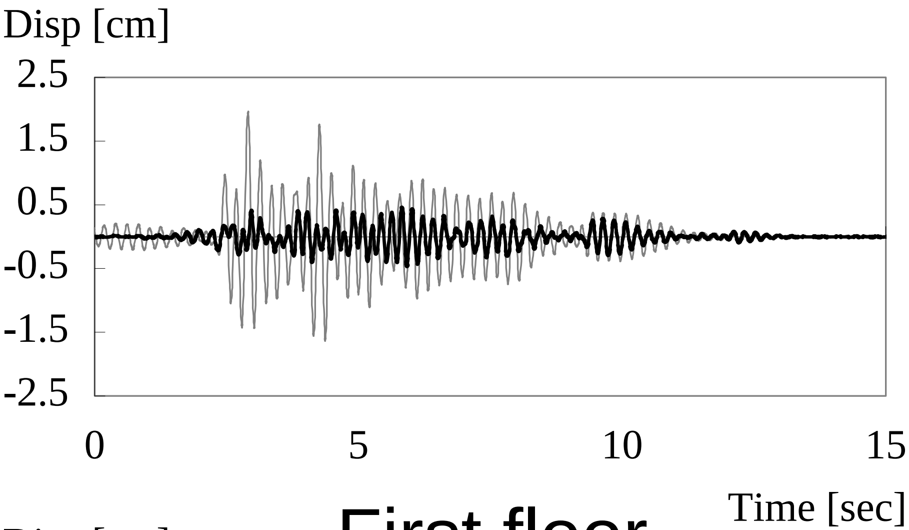
First floor



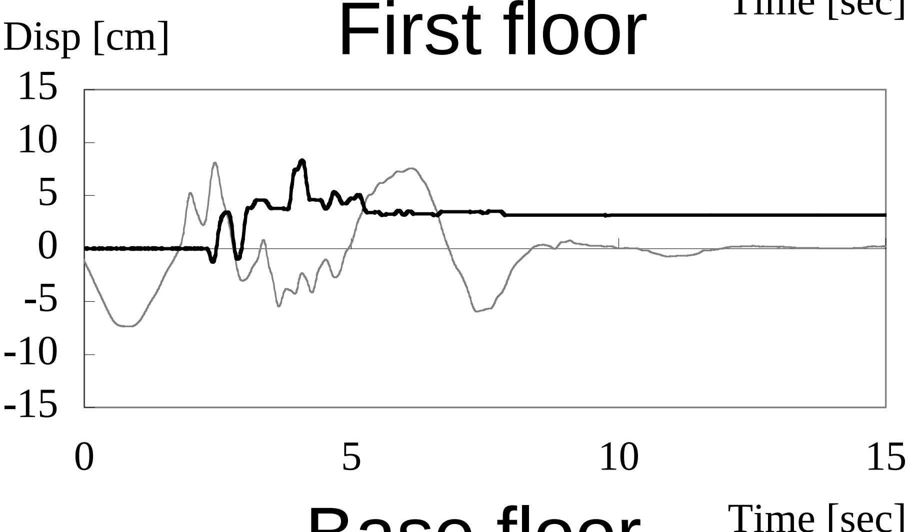
Base floor

Comparison

Experiments

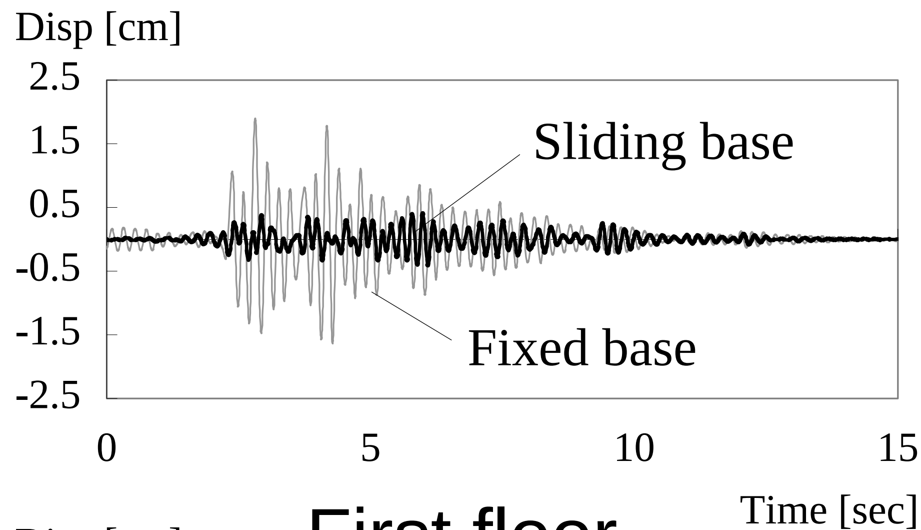


First floor

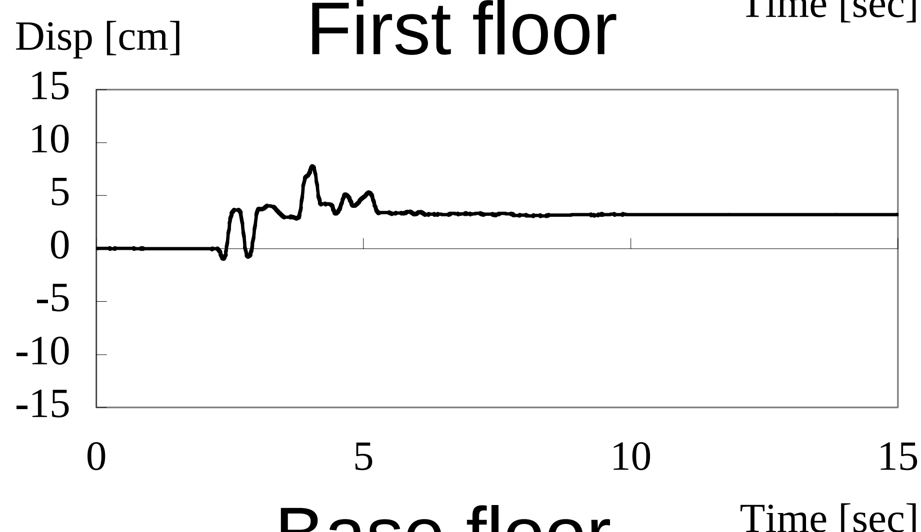


Base floor

Simulations



First floor



Base floor

Acknowledgement

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Comment

I hope this old and simple method contribute to save many persons from seismic hazard.

Thank you.