Performance of Base Isolated Structure for Tsunami Loading

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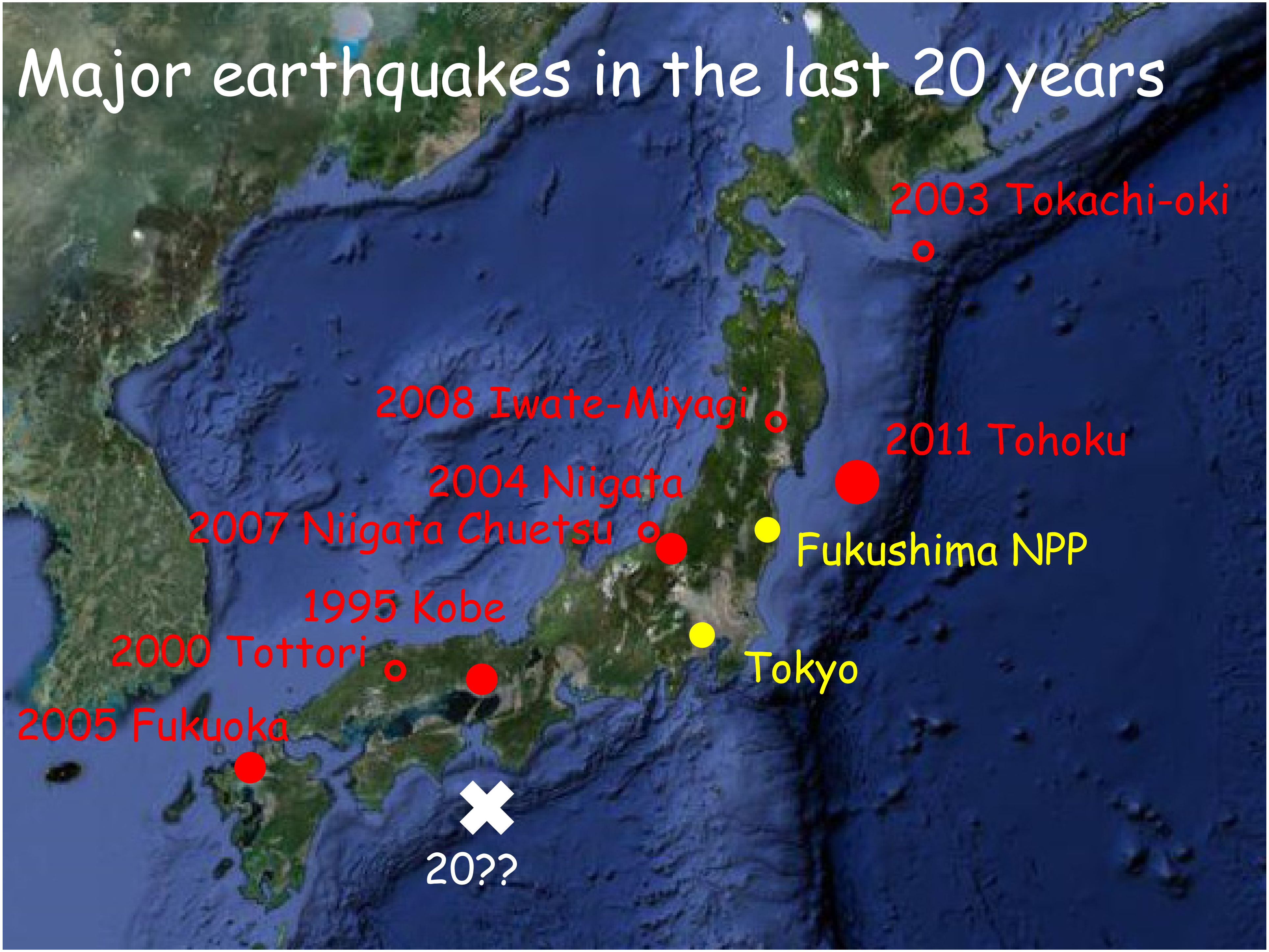
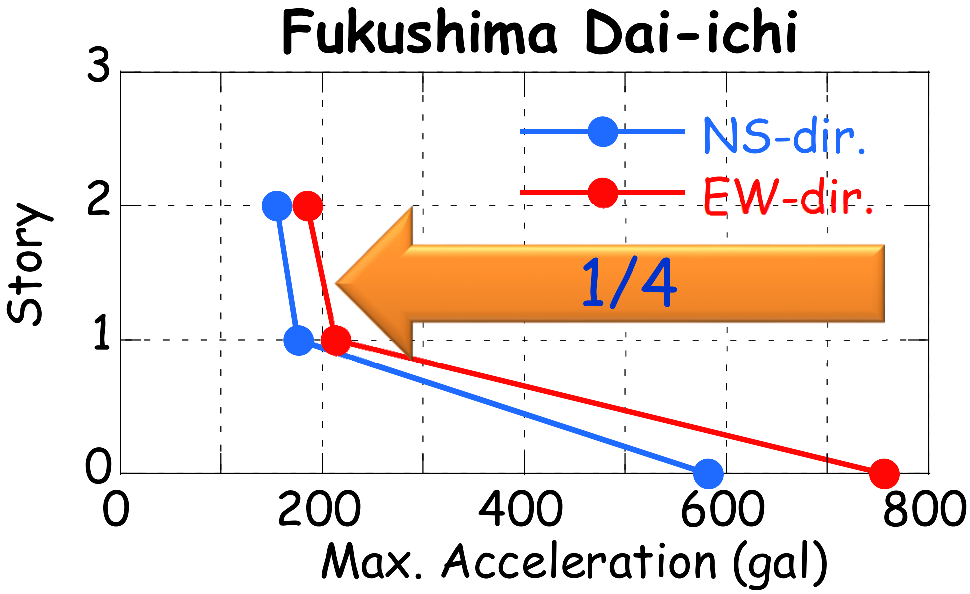
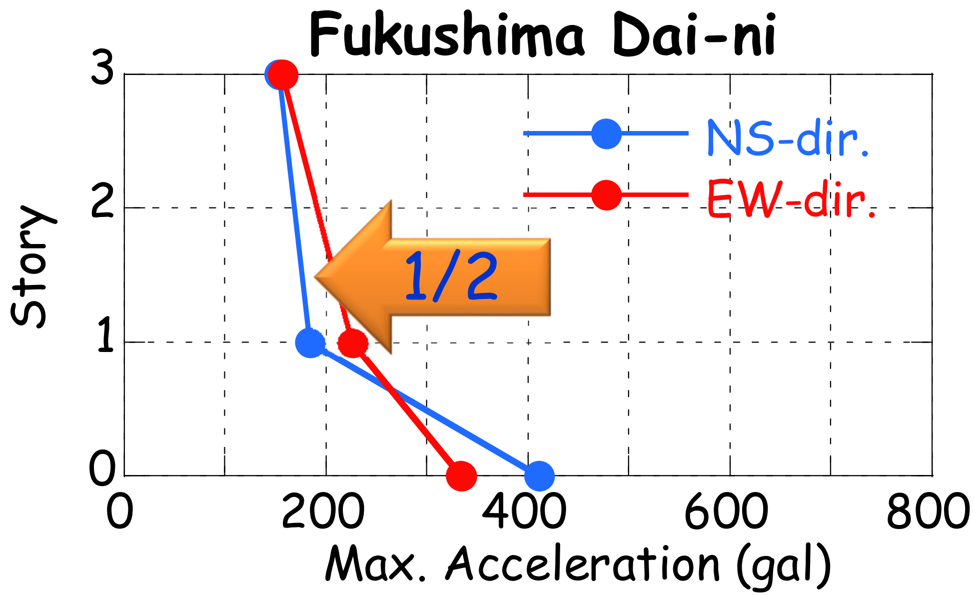
Topics

- Performance of Seismically Isolated Buildings based on Earthquake Records
- Guideline for Structural Design of Tsunami Evacuation Buildings
- Response of Seismically Isolated building due to Tsunami Wave Force

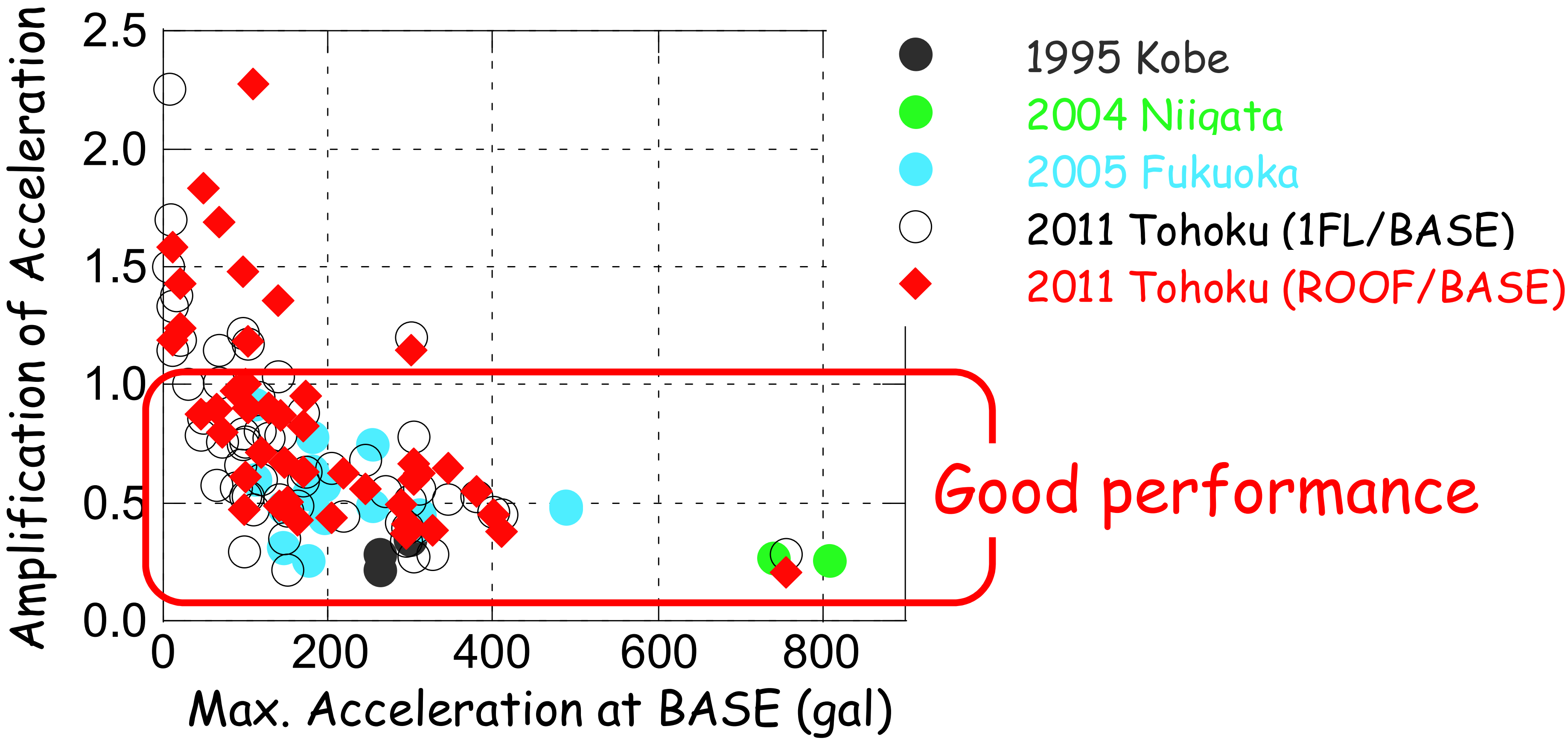

Major earthquakes in the last 20 years
2003 Tokachi-oki
2008 Iwate-Miyagi
2011 Tohoku
2004 Niigata
2007 Niigata Chuetsu
Fukushima NPP
1995 Kobe
2000 Tottori
Tokyo
2005 Fukuoka
20??

Seismically Isolated Building at Fukushima Dai-ichi & Dai-ni NPP





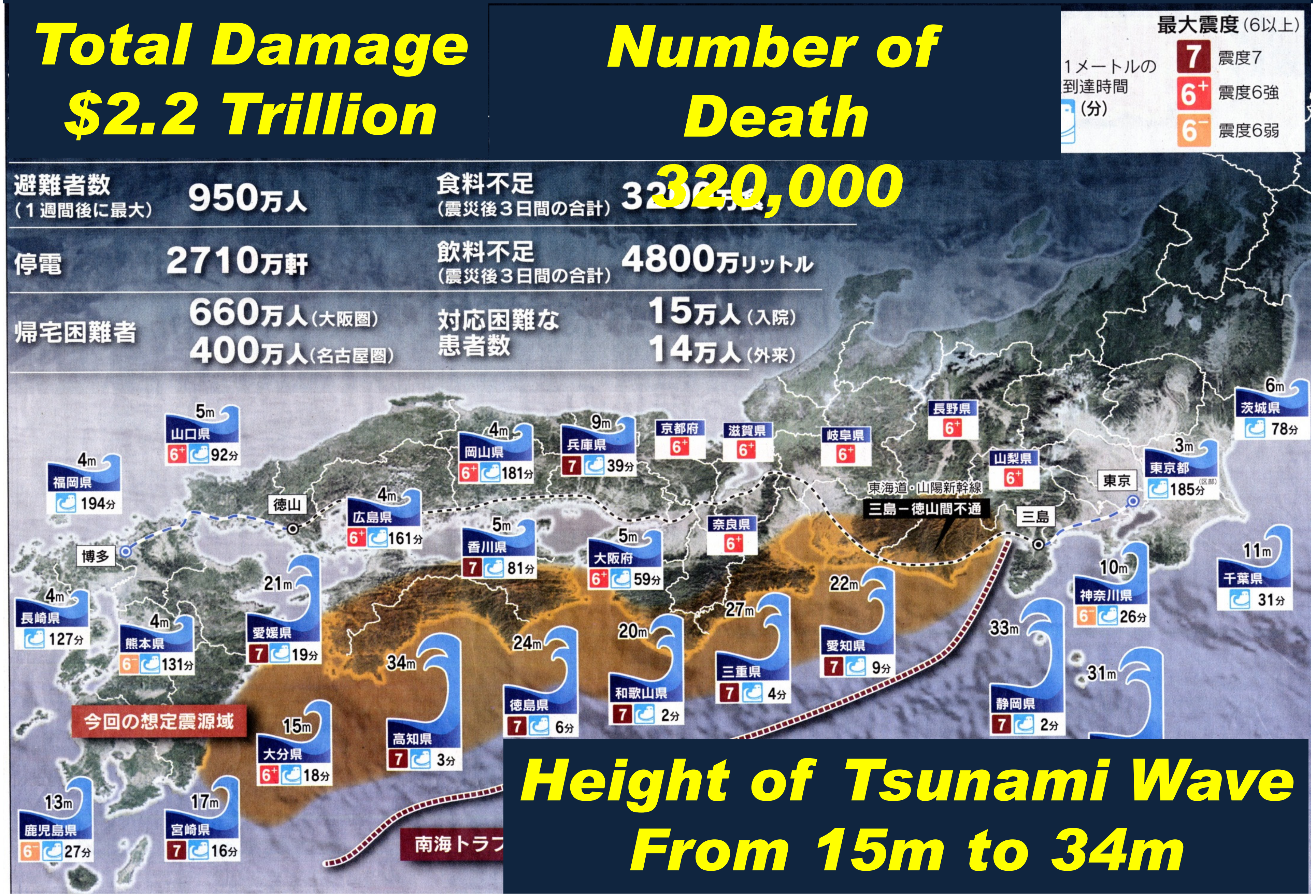
Amplification Factor of Acceleration of Seismically Isolated Buildings



Damage Estimation of Nankai Trough Earthquake

Total Damage $2.2 Trillion

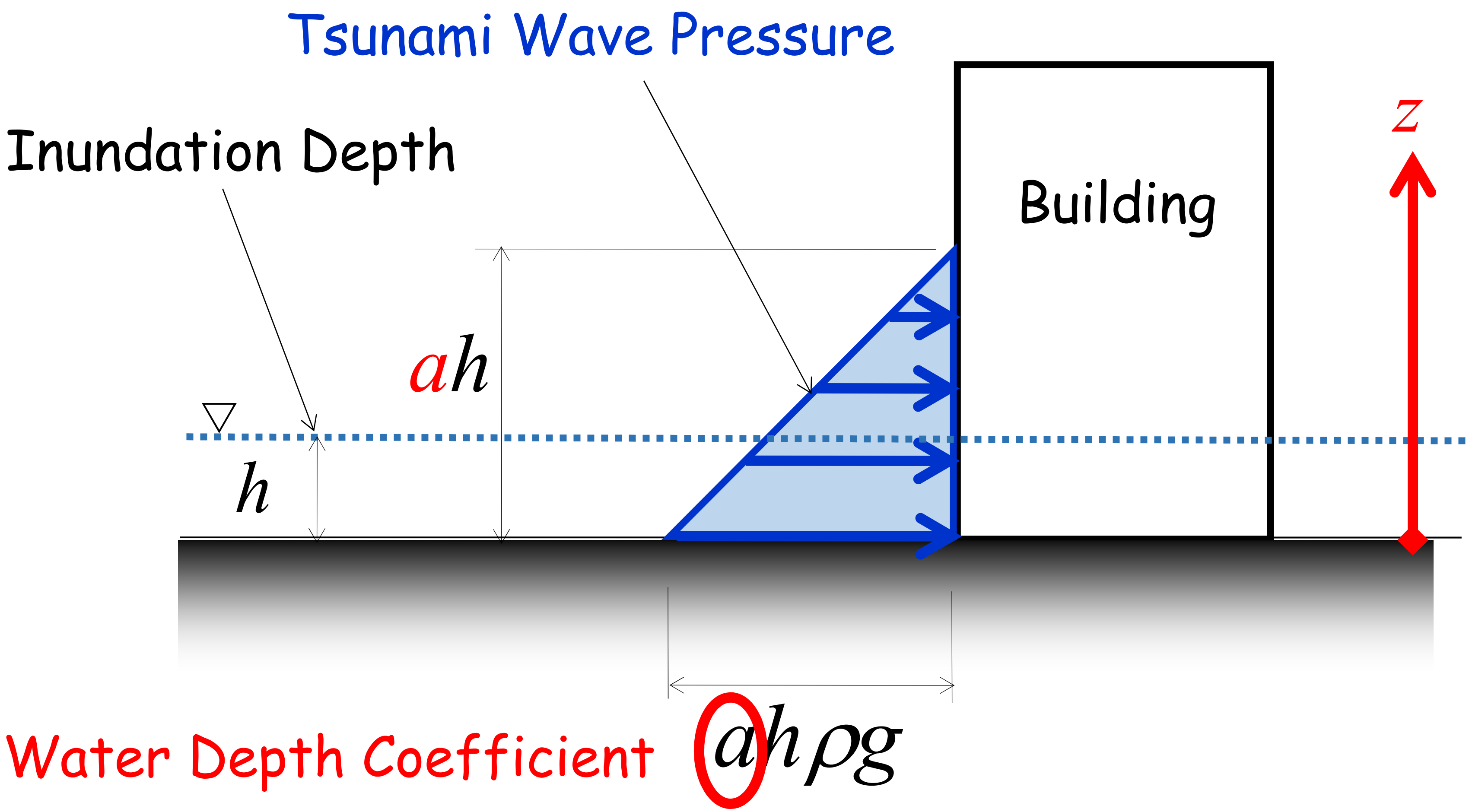
Number of Death 320,000



Height of Tsunami Wave From 15m to 34m

Hydrostatic Force Distribution due to Tsunami Wave

Japanese Guidelines for Tsunami Evacuation Building



$a h \rho g$

Tsunami Pressure

$$q_Z = \rho g(ah - z)$$

q_Z : Tsunami pressure

ρ : The mass of unit volume of water (1.0 t/m^3)

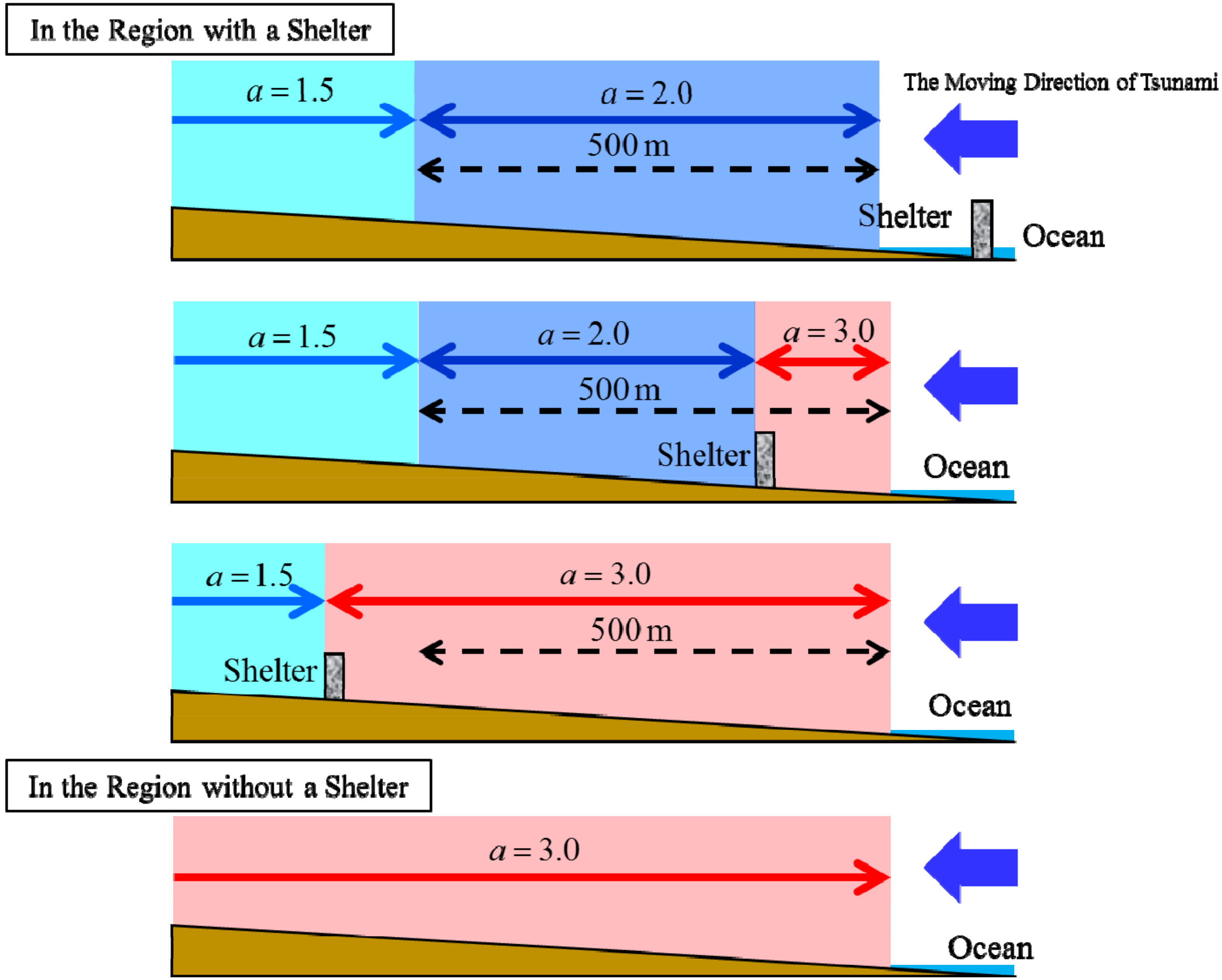
g : Gravitational acceleration (9.8 m/s^2)

$\boxed{h}$: Design Inundation depth (m)

z : The height of the part of interest from the ground level, $0 \leq z \leq ah$ (m)

$\boxed{a}$: Water depth coefficient

Water Depth Coefficient "a"



Tsunami Force

$$Q_Z = \rho g \int_{Z_1}^{Z_2} (ah - z) \cdot B \cdot dz$$

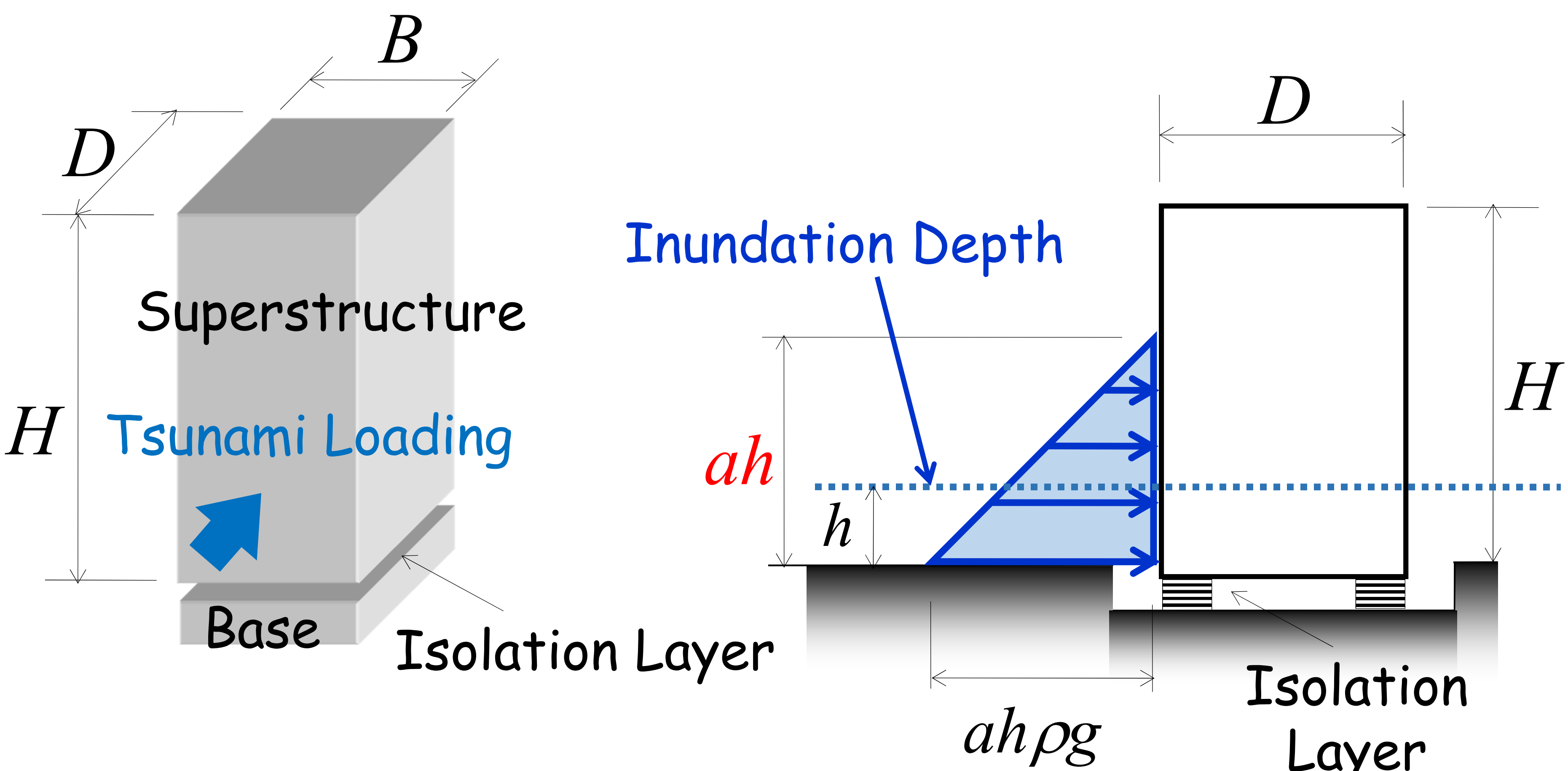
Q_z: Tsunami force in direction of travel for structural design (kN)

B: Width of pressure-receiving surface of relevant part (m)

Z_1: Minimum height of pressure-receiving surface ($0 \leq Z_1 \leq Z_2$) (m)

Z_2: Maximum height of pressure-receiving surface ($Z_1 \leq Z_2 \leq ah$) (m)

Seismically Isolated Building Model for Tsunami Response



Building Model Dimensions

No. of stories N	Height H (m)	Depth D (m)		
		H/D =1	H/D =3	H/D =5
5	15	15	5	3
10	30	30	10	6
15	45	45	15	9
20	60	60	20	12
30	90	90	30	18

Total Weight of Building Models

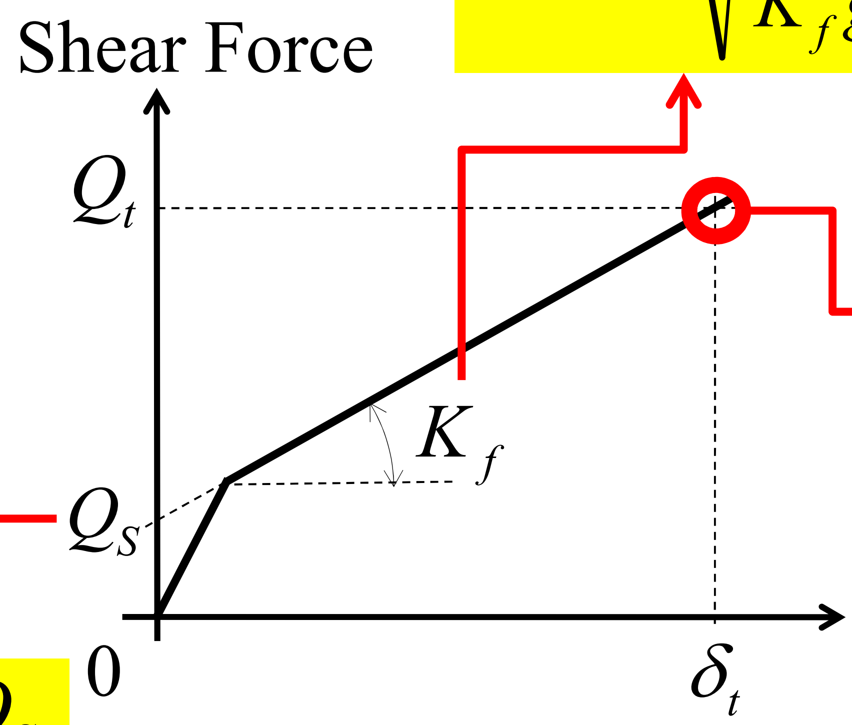
$$W = w(N+1)DB$$

$(w=12\ \mathrm{kN/m^2})$

Hysteresis Characteristics of Isolation Layer

$$T_f = 2\pi\sqrt{\frac{W}{K_f g}}$$

Isolation Period



$$\frac{Q_t}{W} = \frac{4\pi^2}{T_f^2 g}\delta_t + \alpha_S$$

$$\alpha_S = \frac{Q_S}{W}$$

Yield Shear Coefficient

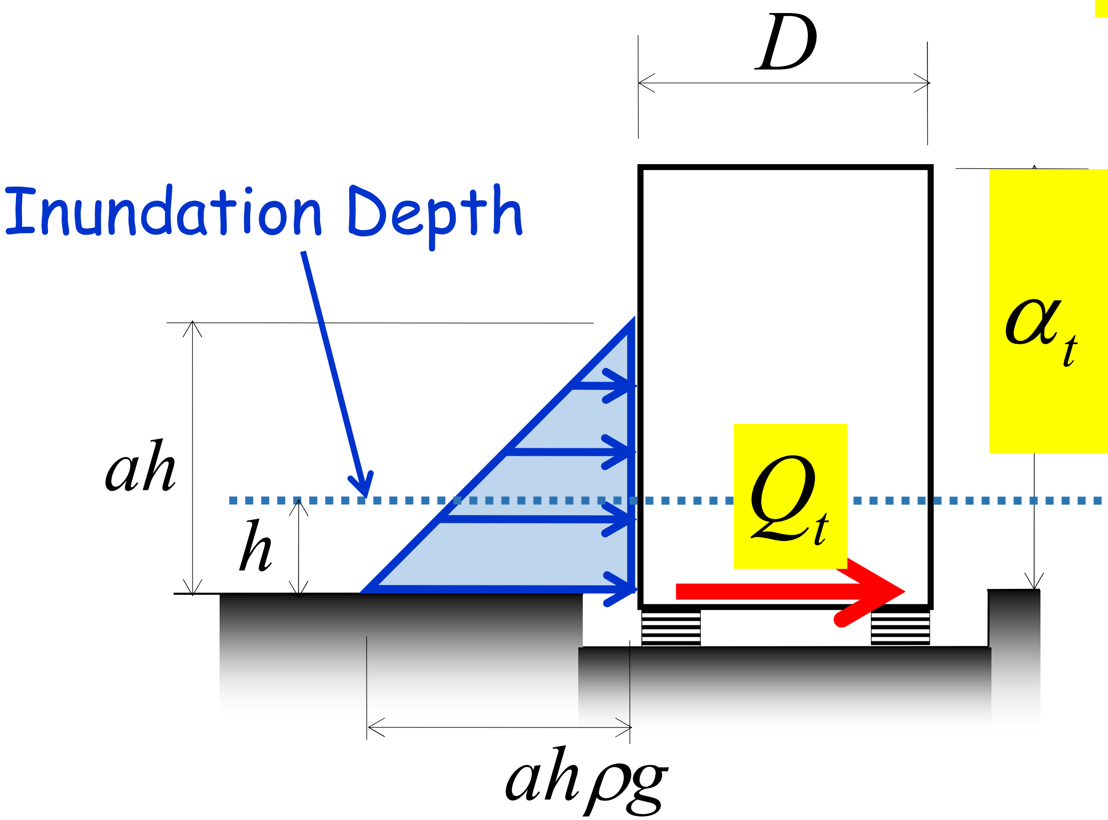
Tsunami Load Acting on Isolation Layer

These influences were not included:

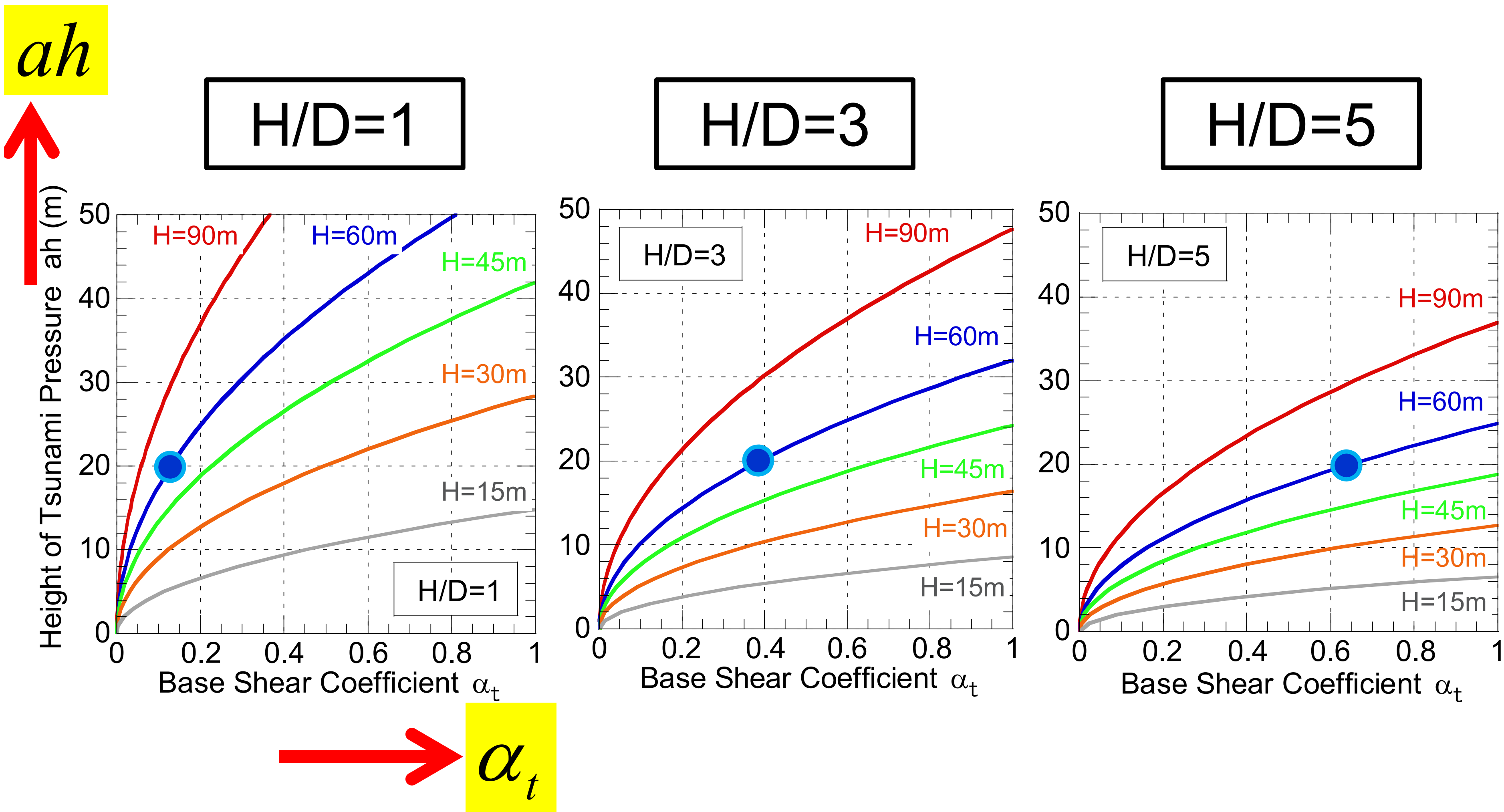
- Openings such as windows
- Buoyancy
- Floating debris

$$Q_t = \frac{1}{2}(ah)^2 \rho g B$$

$$\alpha_t = \frac{Q_t}{W} = \frac{(ah)^2 \rho g}{2w(N+1)D}$$



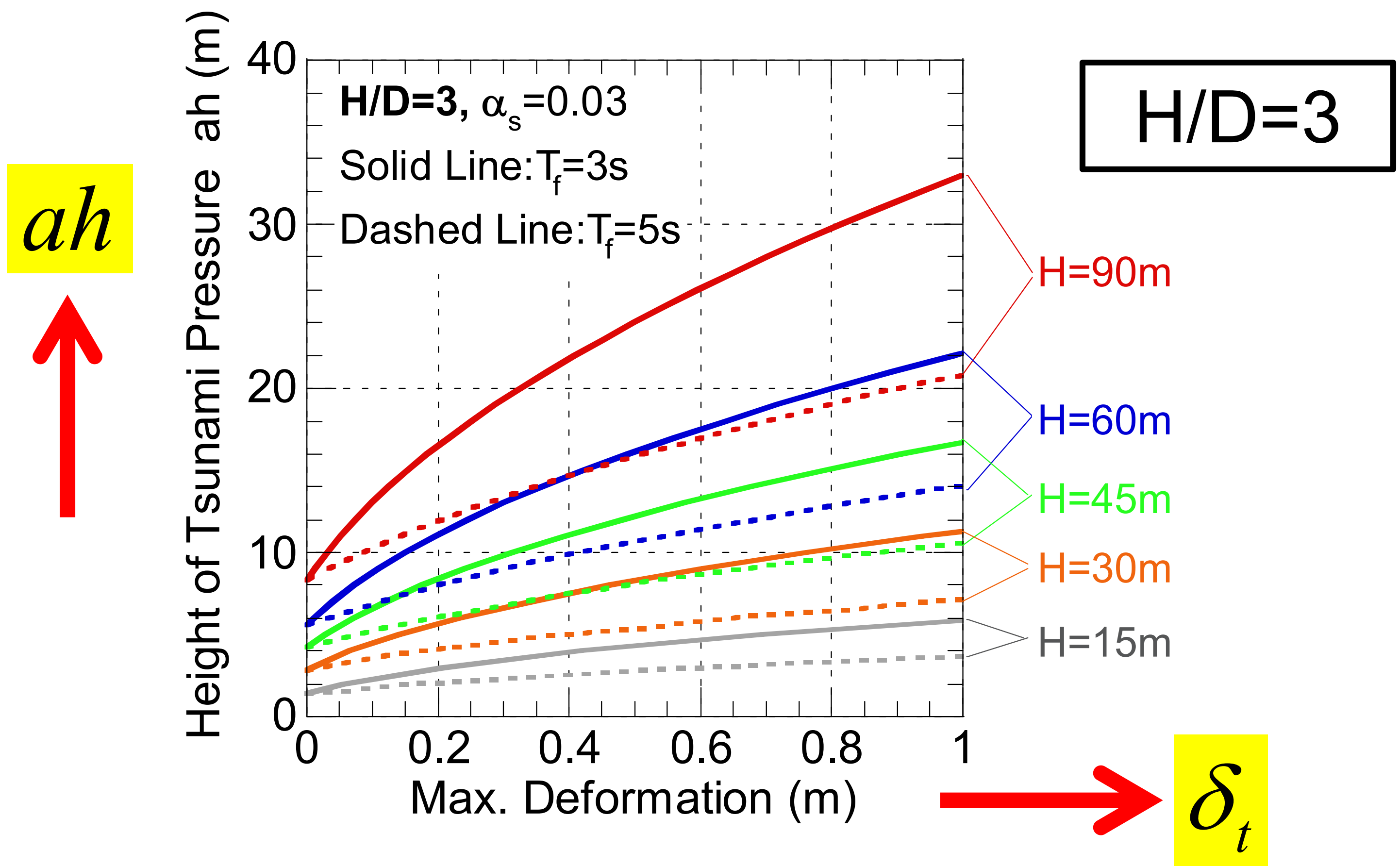
Height of Tsunami Pressure "*ah*" vs. Base Shear Coefficient



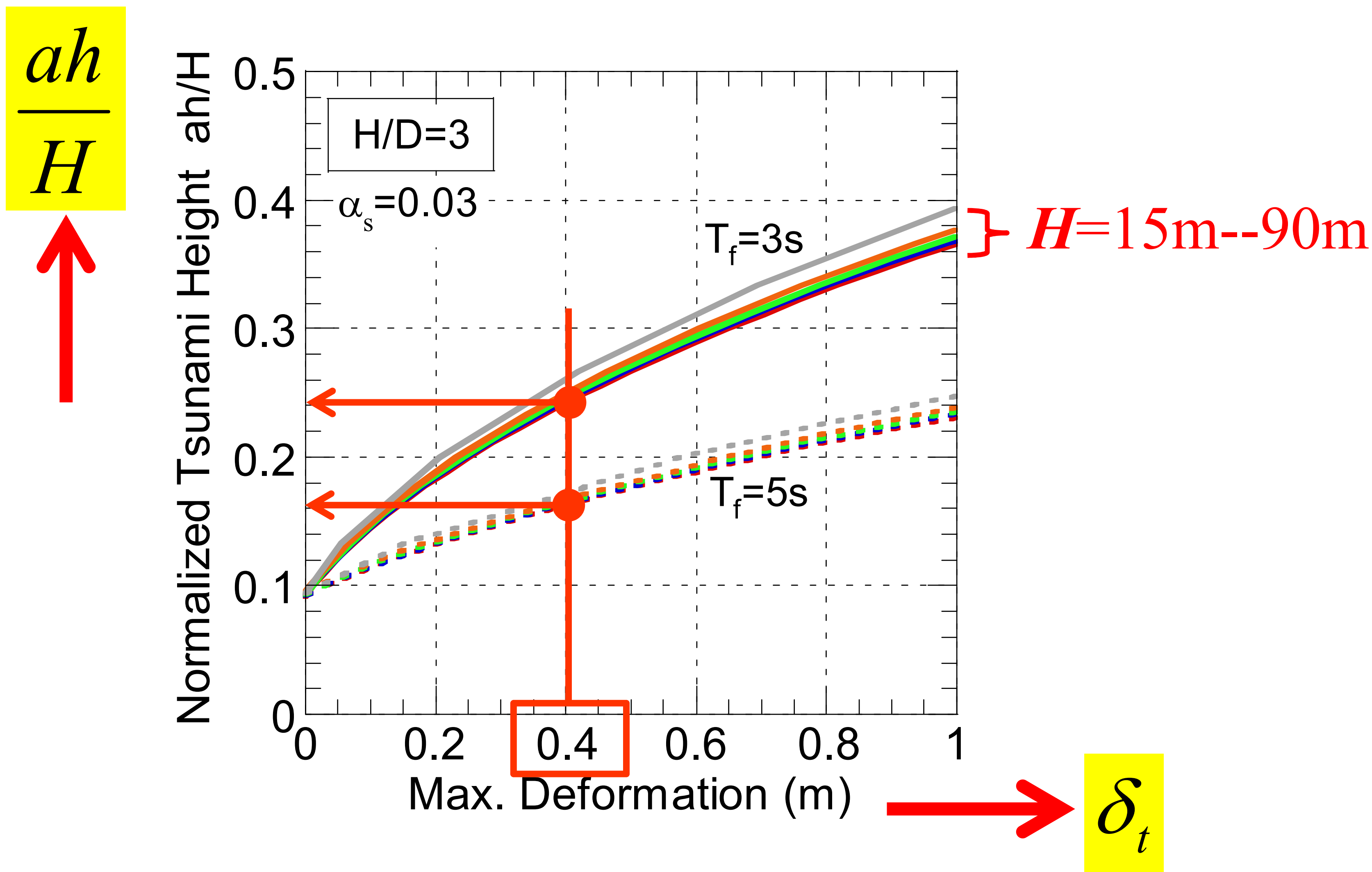
Prediction of Max. Deformation

$$\delta_t = \frac{T_f^2 g}{4\pi^2}(\alpha_t - \alpha_S)$$

$$\begin{pmatrix} T_f = 3\sec \text{ or } 5\sec \\ \alpha_S = 0.03 \end{pmatrix}$$



Normalized Height of Tsunami Pressure vs. Max. Deformation



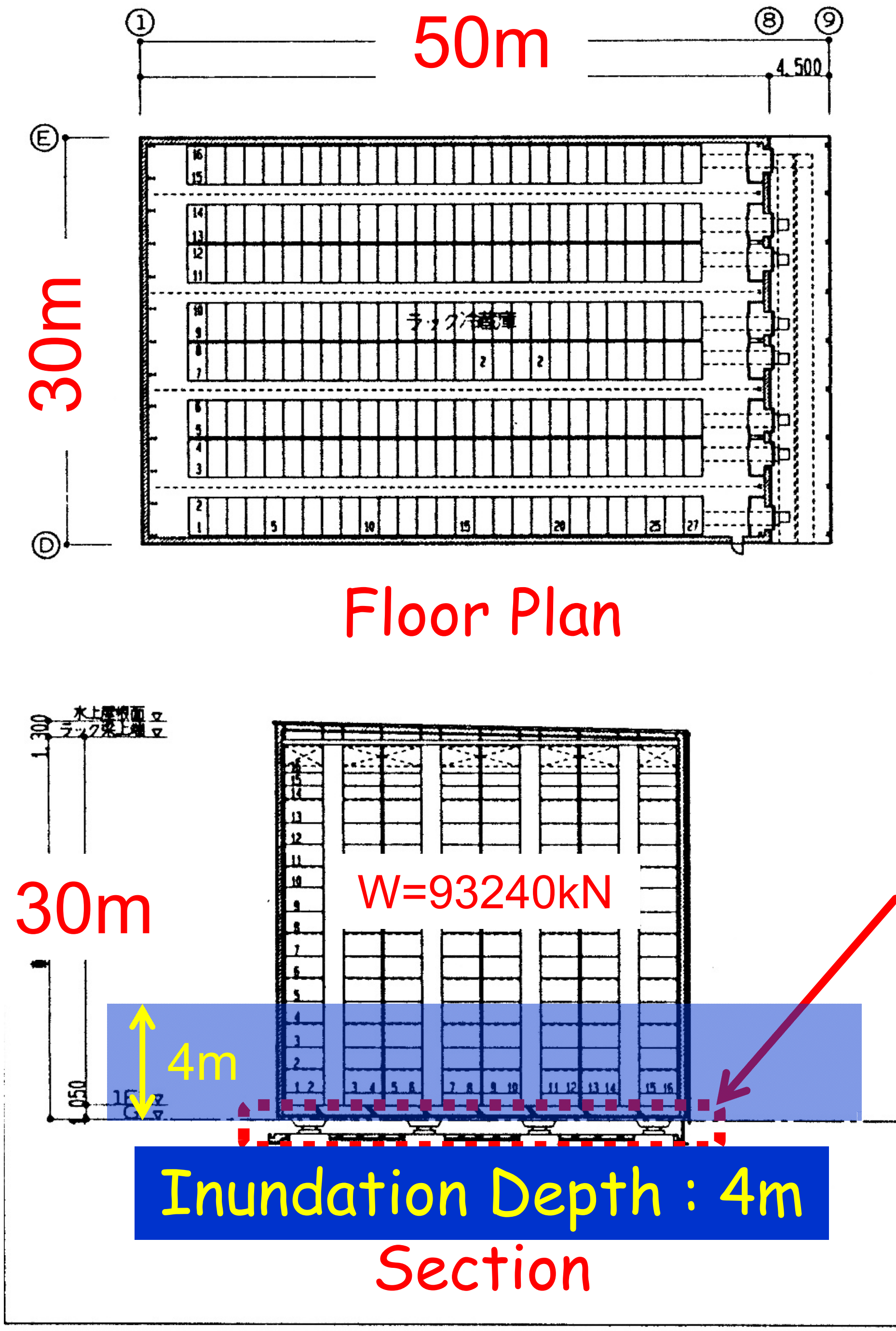
Tsunami Inundation Depth when Max. Deformation of Isolation Layer Reaches 40 cm

α_S = 0.03

T_f	a	H/D =1	H/D =3	H/D =5
3sec	3	0.14H	0.08H	0.06H
	1.5	0.28H	0.16H	0.13H
5sec	3	0.10H	0.05H	0.04H
	1.5	0.20H	0.10H	0.08H

Isolated Warehouse hit by the Tsunami, 2011 Tohoku Eq.

Structural System of Warehouse



Superstructure :
Steel structure

Isolation System :
24 HDRs

Diameter :
800mm or 850mm

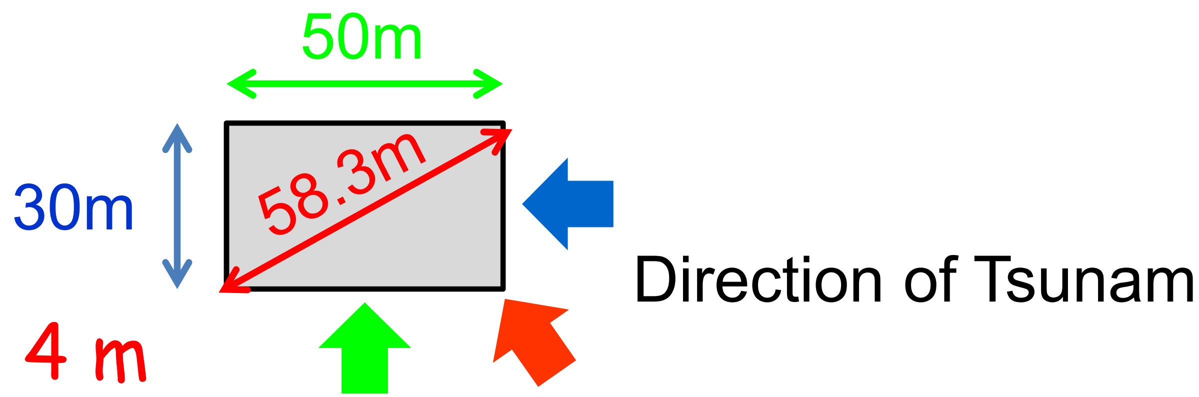
Isolation Period :

$T_f = 4.2\,\mathrm{sec}$

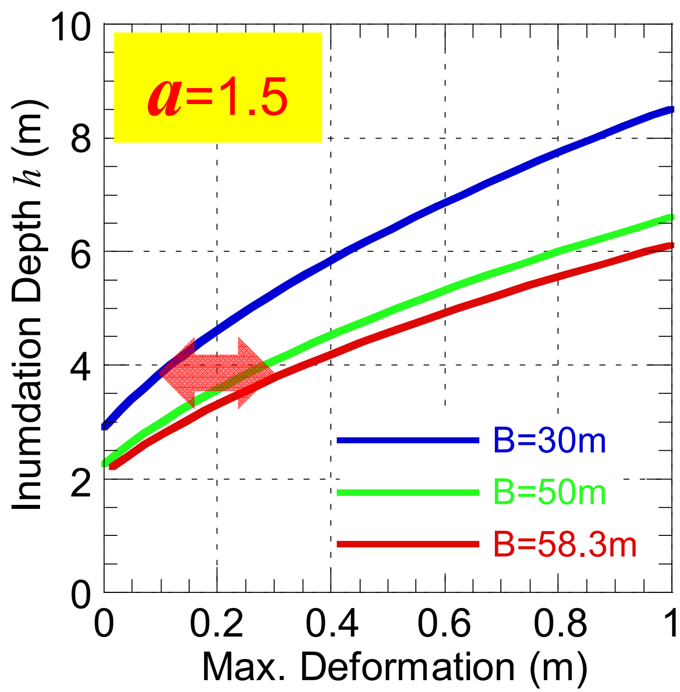
Yield Shear Coefficient:

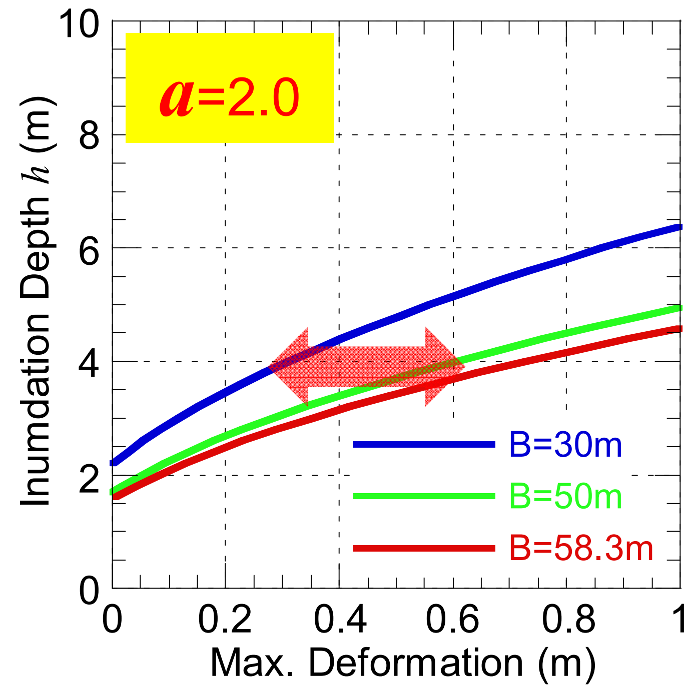
$\alpha_s = 0.03$

Calculation of Max. Deformation



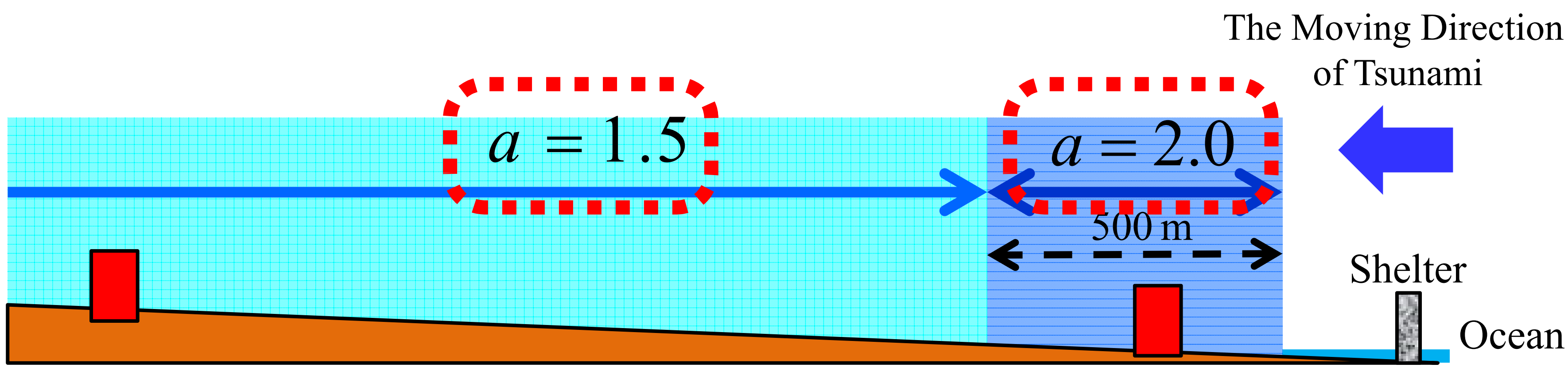
Tsunami Height : 4 m





Observed Max. Deformation : 21 cm

Selection of Water Depth Coefficient



Can the hydrostatic tsunami pressure become applicable to seismically isolated buildings?

Further research into matters such as the validity of the method used to set the tsunami load and the influence of buoyancy is required to confirm the tsunami safety of seismically isolated buildings.

Conclusions

- It was confirmed that most seismically isolated buildings demonstrated an adequate seismic isolation effect in response to the earthquake.
- In this research, we applied the same tsunami loads as those used in the design of tsunami evacuation buildings. As tsunami inundation depth increases, large shear forces and deformation occur in the isolation layer.
- The smaller the size of the building (height and depth) and the more flexible the isolation layer, the greater the deformation of the isolation layer.

Thank you for your attention

"Disaster will attack when you have forgotten"