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Seismic Responses of Seismically Isolated Buildings Considering Wind-Induced Residual Deformation in Isolation Layer

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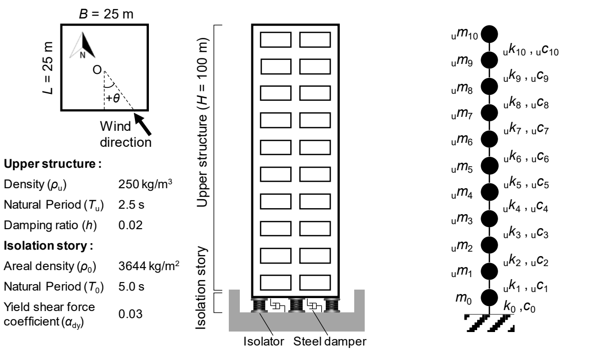
Abstract— **This paper investigated the seismic responses of seismically isolated buildings by carrying out continuous typhoon and seismic simulation. By comparing the results of time history analysis, this paper revealed if wind-induced residual deformation in isolation layer influences the seismic responses in the following seismic simulation.**

I. Introduction

A seismic isolation system is designed to reduce the seismic responses of a building. However, large and long duration wind loads such as typhoon may cause violent and continuous vibration of the seismically isolated buildings, leading to the residual deformation in the isolation layer. If a great earthquake follows, the residual deformation may cause larger seismic responses. Therefore, by continuous typhoon and seismic simulation, this paper investigates the influence of initial wind-induced residual deformation in isolation layer on the seismic responses of seismically isolated buildings.

II. Structural Model

Fig. 1(a) shows the outline of a seismically isolated building. For the upper structure, the height $H = 100$ m, the breadth $B = 25$ m, and the Depth $L = 25$ m. The Density $\rho_u = 250$ kg/m^3, the natural period $T_u = 2.5$ s ($= 0.025H$), and the damping ratio $h = 0.02$. In addition, the areal density of the isolation layer $\rho_0 = 3644$ kg/m^2, the natural period of the isolation layer, namely the natural period of the isolators, $T_0 = 5.0$ s ($= 2T_u$), and the yield shear force coefficient of the overall steel dampers $\alpha_{dy} = 0.3$. About the building orientation, the building breath B is north-south facing, and the northward wind direction is defined as $\theta = 0°$. As shown in Fig.1(b), the MDOF model is reduced to have 11 lumped masses[1)] according to the seismically isolated building. The upper 10 masses (1[st] ~ 10[th] story) indicate the upper structure, and the bottom mass (0[th] story) indicates the isolation layer.

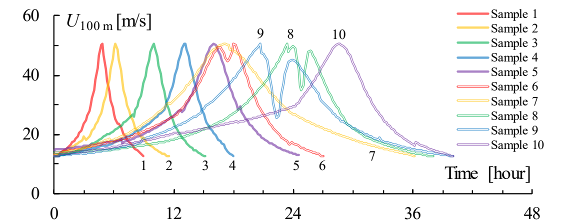


(a) Outline of the seismically isolated building (b) 11-DOF model
Fig. 1 Structural model

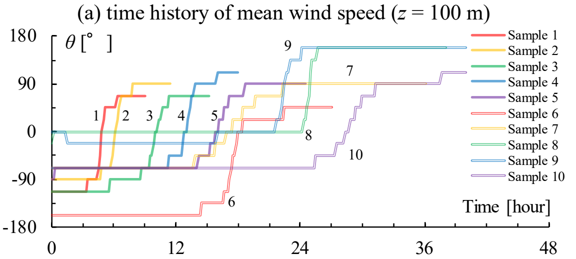
III. Outline of Typhoon and Seismic Simulation

A. Typhoon Simulation

As shown in Fig. 2, 10 assumed typhoon samples with different duration (9 ~ 40 hours) are considered in the typhoon simulation[2)]. Fig. 2(a) shows the time history of mean wind speed U_{100m} averaged over each 10-minute period at the height $z = 100$ m above ground. According to Japanese Recommendations for Loads on Buildings[3)], the maximum mean wind speed of 50.41 m/s is obtained on the basis of basic wind speed of 36 m/s, 500-year return period and surface roughness III. From Fig. 2(a), it can be seen that Sample 6 (1[st] peak: 49.54 m/s, 2[nd] peak: 50.41 m/s), Sample 8 (1[st] peak: 50.41 m/s, 2[nd] peak: 48.21 m/s) and Sample 9 (1[st] peak: 50.41 m/s, 2[nd] peak: 45.13 m/s) have two peaks, while the other samples have only one peak (peak: 50.41 m/s). Fig. 2(b) shows the time history of wind direction θ over each 10-minute period. For each sample, the wind direction is fixed at $\theta = 0°$ (northward) as the mean wind speed reaches the maximum mean wind speed of 50.41 m/s.



(a) time history of mean wind speed ($z = 100$ m)



(b) time history of wind direction
Fig. 2 10 assumed samples in typhoon simulation

B. Seismic simulation

As shown in Table 1, four observed seismic waves are considered in the seismic simulation. In this study, the torsion effect is ignored, so the time history analysis of the

11-DOF model was carried out along north-south and east-west direction respectively by using continuous typhoon and seismic simulation.

Table 1 Four observed seismic waves

Seismic wave	Direction	Max. acc [cm/s^2]	Durarion [s]	Time interval [s]
El Centro 1940	NS	341.7	54	0.02
	EW	210.1		
Taft 1952	NS	152.7	54	0.02
	EW	175.9		
Hachinohe 1968	NS	229.6	51	0.02
	EW	180.2		
Kobe 1995	NS	580.8	150	0.02
	EW	619.2		

IV. Results of Simulation

A. Residual deformation in isolation layer

Fig. 3 shows the residual deformation (NS) in the isolation layer in the seismic simulation. The black line segment indicates the residual deformation in the initial typhoon simulation. In addition, the plots with different colours indicates the results considering the initial residual deformation due to initial typhoon simulation, while the lines indicate the results without initial residual deformation. From Fig. 3, it was found that the initial residual deformation has little influence on the residual deformation in the seismic simulation.

B. Maximum displacement of 10th story

Fig. 4 shows the maximum displacement (NS) of the 10th story in the seismic simulation. It was found that the initial residual deformation influenced the maximum displacement of the 10th story in the seismic simulation. Especially in the seismic simulation by using Taft wave, the maximum displacement considering initial residual deformation is 8 cm larger than that without regard to the initial residual deformation.

C. Maximum acceleration of 10th story

Fig. 5 shows the maximum acceleration (NS) of the 10th story in the seismic simulation. It was found that the initial residual deformation hardly influenced the maximum acceleration in the seismic simulation, because there is no obvious difference between the results with initial residual deformation and the results without initial residual deformation in the isolation layer.

D. Maximum deformation in isolation layer

Fig. 6 shows the maximum deformation (NS) of the isolation layer in the seismic simulation. It was found that the initial residual deformation influenced the maximum deformation in the isolation layer, and the result is similar to that in Fig. 4.

V. Conclusions

This paper investigated the influence of initial wind-induced residual deformation in isolation layer on the seismic responses of seismically isolated buildings by carrying out continuous typhoon and seismic simulation. The results show that the initial residual deformation influenced the maximum displacement of the 10th story and the maximum deformation of isolation layer in the seismic simulation. However, the residual deformation and the maximum acceleration in the seismic simulation is non-sensitive to the initial residual deformation caused by typhoon simulation.

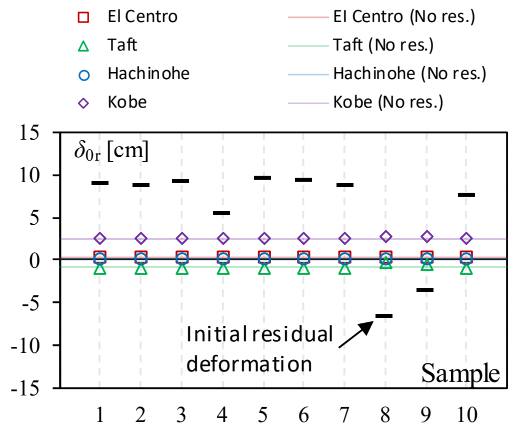


Fig. 3 Residual deformation in isolation layer (NS)

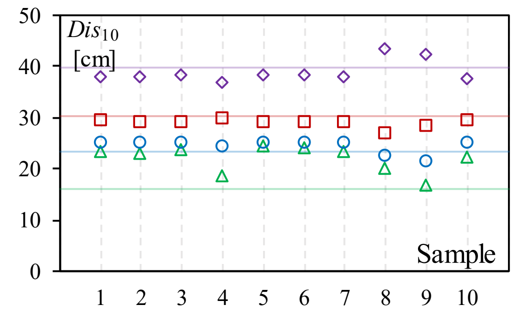


Fig. 4 Maximum displacement of 10th story (NS)

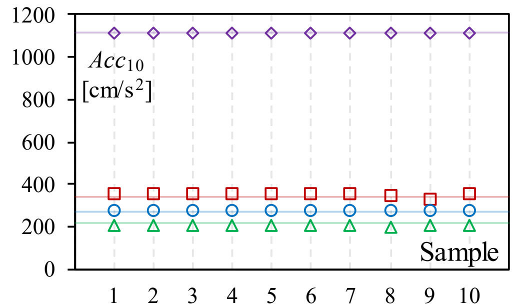


Fig. 5 Maximum acceleration of 10th story (NS)

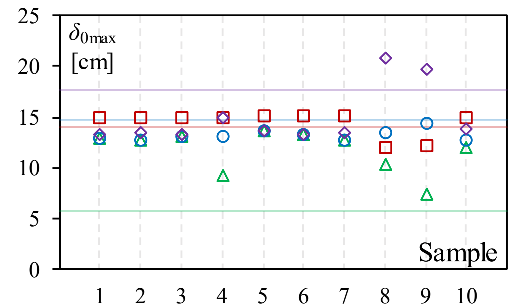


Fig. 6 Maximum deformation in isolation layer (NS)

Acknowledgment

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References

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