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SEISMIC COLLAPSING ANALYSIS OF ONE-STORY WOODEN KINDERGARTEN STRUCTURE AGAINST STRONG EARTHQUAKE GROUND MOTION

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3-D collapsing process analysis of an old Japanese-style one-story wooden structure under two strong earthquake ground motions with a seismic intensity level was carried out in order to investigate the seismic performance of this one-story wooden structure without/with seismic retrofit. As a result, this wooden structure collapsed against a strong earthquake ground motion with the JMA seismic intensity "6 upper" level.

Keywords: Seismic response behaviour, Wood frame-based building, Collapsing model, Retrofit.

1 INTRODUCTION

It is well known in Japan that there are many Japanese-style wooden houses and they have much lower seismic performance against a strong earthquake with the Japan Meteorological Agency (JMA) seismic intensity of "6 upper" level. Generally, seismic retrofit design for a wooden house can be decided on the seismic performance ratio, which can be evaluated from a ratio of the necessary resistance strength of the wooden house against a strong earthquake to the possession strength. It is very important for structural engineers to take account of a seismic response of wooden house in the design process of seismic retrofit, in order to propose an effective countermeasure in the design process of seismic retrofit for the wooden house.

When the seismic performance behaviour of a wooden house built by Japanese wood frame-based building method is investigated by a numerical analysis, the wooden house's collapsing behaviour needs for consideration of the extremely non-linear properties of wooden members breaking or being dispersed, and this kind of collapsing process simulation of a wooden house during a strong earthquake ground motion becomes possible by means of a collapsing process analysis based on the Distinct Element Method (Cundall et al. 1979).

In order to investigate the seismic performance of an old one-story kindergarten wooden structure, 3-D collapsing process analysis (Nakagawa *et al*. 2010, Takatani *et al*. 2012) of the wooden structure under a strong earthquake ground motion with the JMA seismic intensities of "6 upper" levels is carried out in this paper.

2 OUTLINE OF ONE-STORY KINDERGARTEN WOODEN STRUCTURE AND ITS COLLAPSING MODEL

2.1 Seismic Retrofit of One-story Kindergarten Wooden Structure

Table 1 shows the seismic performance ratio of this one-story kindergarten wooden structure, and the seismic performance ratios of both X and Y directions are 0.28 and 0.21, respectively. Photo1 shows views of one-story kindergarten wooden structure ret-

Table 1. Seismic performance ratio of one-story kindergarten wooden structure.

	Direction	Necessary resistance strength	Possession strength	Seismic performance ratio
Ground floor	X	307.71 (kN)	86.53 (kN)	0.28
	Y	279.74 (kN)	60.46 (kN)	0.21

North side West Side East Side

Photo 1. View of one-story kindergarten wooden structure retrofitted with "*BRACE-X*".

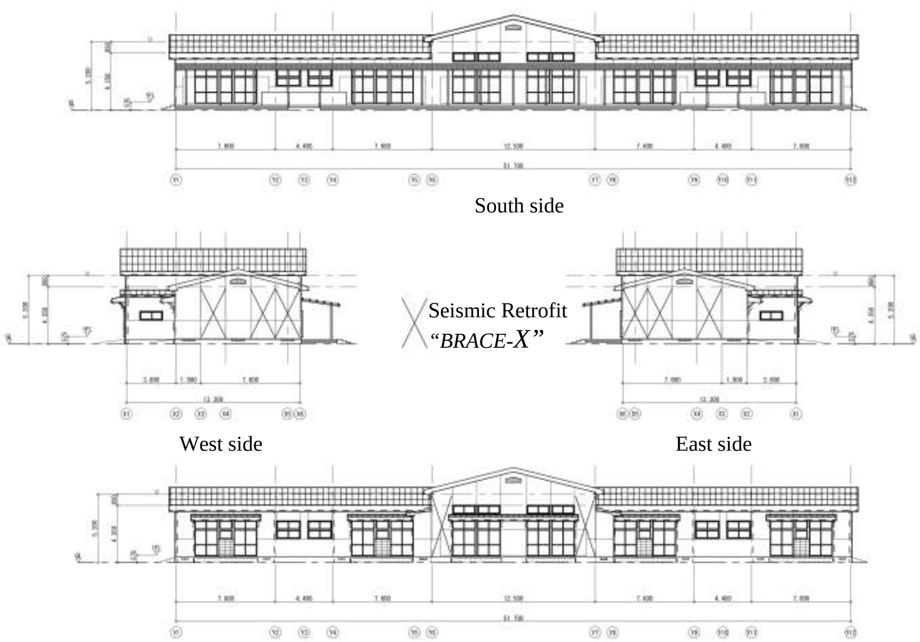


Figure 1. Seismic retrofit elevation plan of one-story kindergarten wooden structure (unit : mm).

rofitted with "*BRACE-X*" using the Carbon Fiber Reinforced Plastic material. Figure 1 indicates seismic retrofit elevation plan of this wooden structure using "*BRACE-X*" whose details are not presented in this paper due to the limited space.

2.2 Collapsing Process Model of One-story Kindergarten Wooden Structure

Figure 2 shows a seismic collapsing frame model of one-story kindergarten wooden structure, which has walls and braces in the complete frame model with roof rafters.

Two earthquake ground motion wave records with the JMA seismic intensity of "6 upper" level are employed as an input earthquake ground motion data in this seismic collapsing analysis. Table 2 shows some parameters of earthquake ground motion wave records used as an input excitation of the collapsing process analysis.The effect of an

Table 2. Earthquake ground motion wave records (the 1995 Hyogo-ken Nambu Earthquake).

Record Name	I_{JMA}	Peak Ground Acceleration (cm/s^2)	Peak Ground Velocity (cm/s)	f_p (Hz)	Duration (s)
JMA Kobe	6.4	818	91	1.43	15
JR Takatori	6.4	657	126	0.81	30

f_p : peak frequency of root mean square value of Fourier spectrum

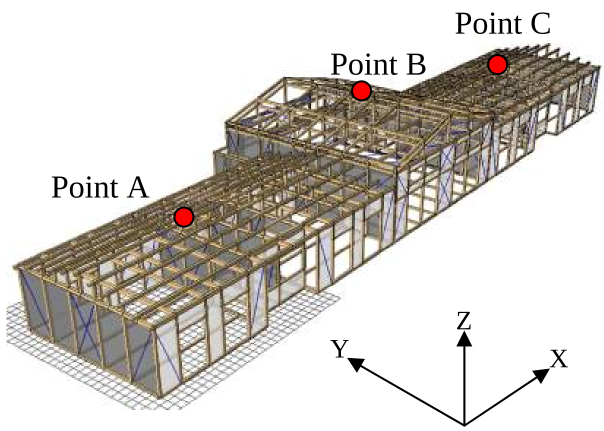


Figure 2. Seismic collapsing model of one-story kindergarten wooden structure.

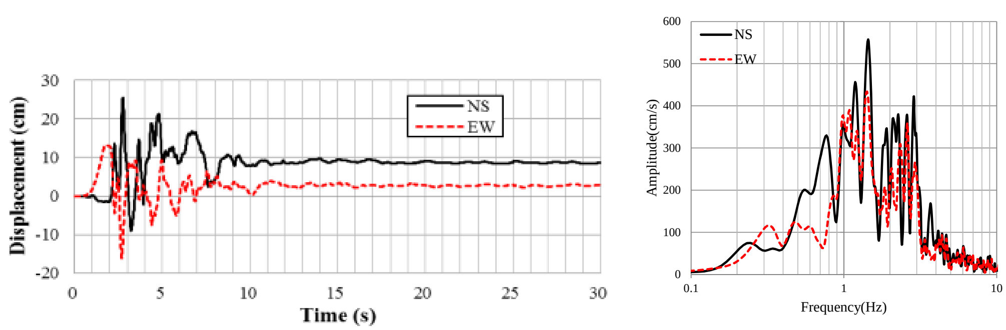


Figure 3. Displacement waves and Fourier acceleration spectra of JMA Kobe wave.

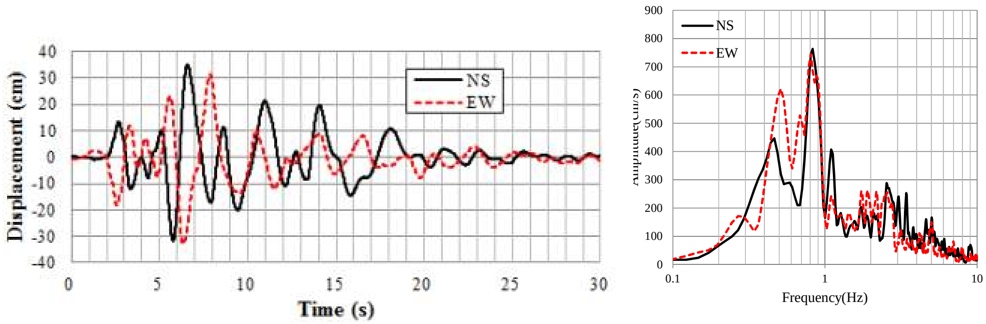
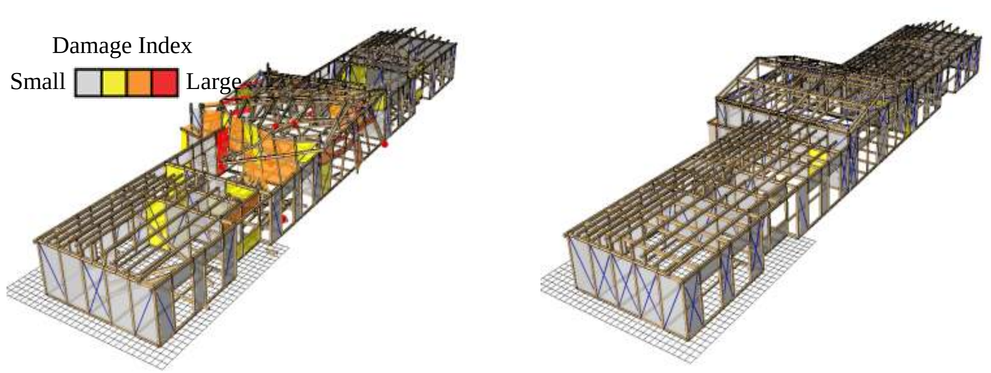
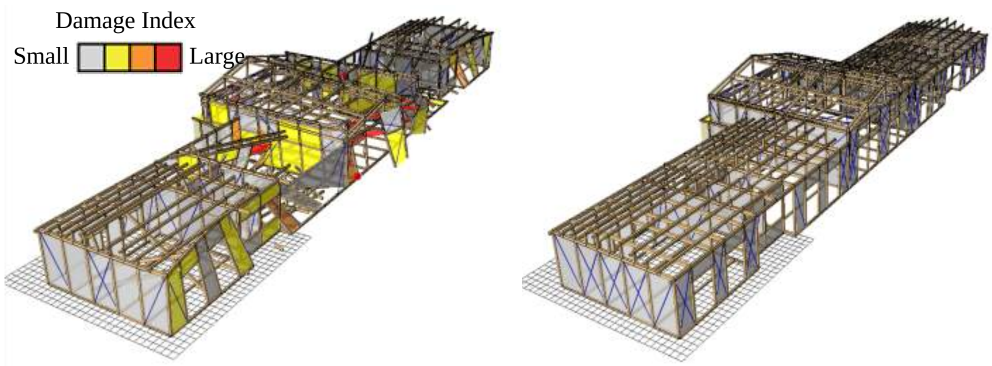


Figure 4. Displacement waves and Fourier acceleration spectra of JR Takatori wave.



(a) Without seismic retrofit (b) With seismic retrofit

Figure 5. Seismic collapsing behavior against a strong earthquake ground motion (JMA-Kobe).



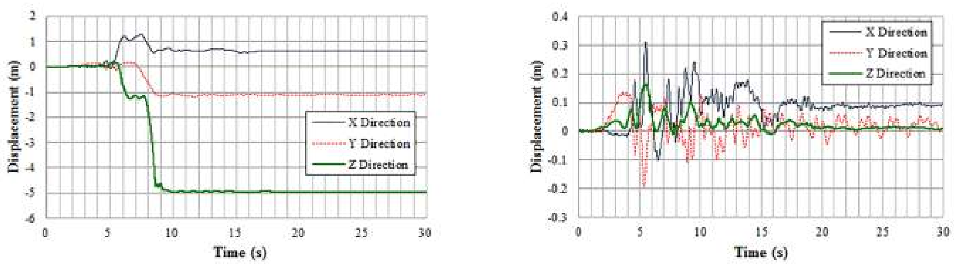
(a) Without seismic retrofit (b) With seismic retrofit

Figure 6. Seismic collapsing behaviour against a strong earthquake ground motion (JR-Takatori).

earthquake motion spectrum on the difference of seismic response can be investigated by using two earthquake wave records whose same level intensity has a different peak frequency in Fourier acceleration spectra. Figures 3 and 4 indicate two displacement wave data and their Fourier acceleration spectra for both NS and EW components in each earthquake ground motion record shown in Table 2. In the JMA Kobe wave record shown in Figure 3, a peak frequency in each wave component is from 1Hz to1.5Hz, and also a peak in each wave component of JR Takatori wave record illustrated in Figure 4 exists about 0.8Hz.

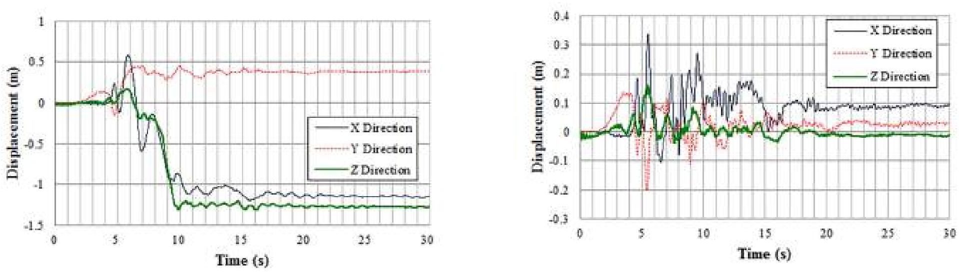
3 SEISMIC COLLAPSING RESULTS

Figure 5 shows seismic collapsing results of one-story kindergarten wooden structure without/with seismic retrofit after JMA Kobe wave. The centre part of this one-story wooden structure without seismic retrofit collapses after JMA Kobe wave. On the other hand, there is little earthquake damage in the wooden structure after JMA Kobe wave



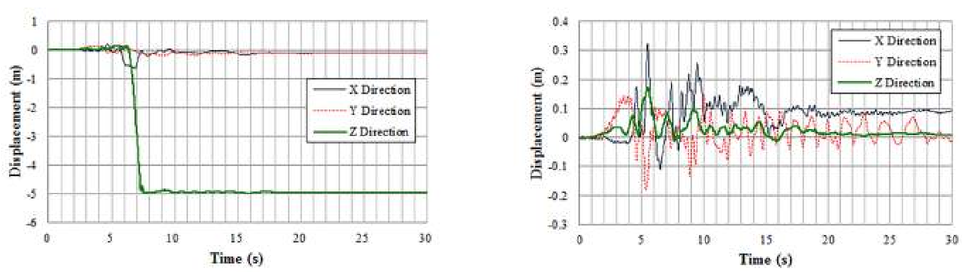
(a) Without seismic retrofit. (b) With seismic retrofit.

Figure 7. Seismic response behaviour at Point A during a strong earthquake ground motion.



(a) Without seismic retrofit. (b) With seismic retrofit.

Figure 8. Seismic response behaviour at Point B during a strong earthquake ground motion.



(a) Without seismic retrofit. (b) With seismic retrofit.

Figure 9. Seismic response behaviour at Point C during a strong earthquake ground motion.

shown in Figure 5(b) because of seismic retrofit.

Figure 6 indicates seismic collapsing results of one-story kindergarten wooden structure without/with seismic retrofit after JR Takatori wave. It is found from this figure that the seismic damage of one-story wooden structure against JR Takatori is much larger than that against JMA Kobe. This is because JR Takatori wave record seems to have a peak frequency to cause severe damage of one-story wooden structure in comparison with JMA Kobe.

Figures 7, 8 and 9 show the displacement response behaviors at Points A, B and C in the one-story kindergarten wooden structure without/with seismic retrofit for during JMA Kobe wave, respectively. Seismic response behaviors of Z direction at Points A and C in the wooden structure without seismic retrofit shown in Figures 7 and 9 are almost 5m after 10 seconds because of the collapse of these parts of this wooden structure. On the other hand, there is a large displacement over 30cm in each displacement of Y direction in the seismic response behaviors at three points in the one-story wooden structure with seismic retrofit, and the collapse does not occur because of seismic retrofit. This implies that the seismic retrofit may have an effective seismic effect to avoid the damage of one-story wooden structure against a strong earthquake ground motion. Consequently, it is found that 3-D seismic collapsing analysis can numerically simulate the seismic response behaviour of an old one-story wooden structure without/with seismic retrofit during a strong earthquake ground motion.

4 CONCLUSIONS

In order to investigate the seismic performance of an old Japanese–style one-story wooden kindergarten structure, 3-D collapsing process analysis of the wooden kindergarten structure under two strong earthquake ground motions with the JMA seismic intensities of “6 upper” level was carried out in this paper.

The summary obtained in this paper is as follows.

(1) Seismic behaviour of Japanese-style one-story wooden kindergarten structure under a strong earthquake ground motion can be numerically simulated by 3-D collapsing process analysis.

(2) Seismic damage of Japanese-style one-story wooden kindergarten structure against a strong earthquake ground motion depends on not only the JMA seismic intensity level but also the peak frequency corresponding to a predominant period of the wooden kindergarten structure.

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