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Effect of Time Step of THA for Isolated Building with Displacement Controller

構造－振動

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SDOF Model, Huge earthquake, Isolated building, Controller, Time history analysis, Time step

1. INTRODUCTION

The isolated building showed the benefits of restraining the damage of the mainframe and being easy to repair after an earthquake comparing with the aseismic structure. Therefore, the number of isolated building has increased year by year. Furthermore, in recent years, the probability of the occurrence of huge earthquakes above the design level is extremely high. Therefore, it is becoming more important to introduce a displacement controller for fail-safe.

In Nomura et al.[1)]'s research, the purpose was to qualitatively and easily evaluate the response characteristics of a single degree of freedom (SDOF) isolated building that incorporated a displacement controller when damping ratio h_f = 0.02. However, when considering a high viscous system such as an oil damper, it is necessary to extend the damping to higher viscous damping.

In this paper, as the initial stage, it is necessary to confirm the time step of the time history analysis (THA) method. And I discuss the response of SDOF isolated building with controller model.

2. ANALYSIS MODEL AND GROUND MOTIONS

2.1 ANALYSIS MODEL

Figure 1 shows an analysis model of the isolation structure for the SDOF model. The system consists of an isolation layer, a hysteretic damper, a viscous damper, and controller. The isolation layer supports the gravity of the building and is in elastic deformation. The hysteretic damper that absorbs seismic energy presents elastic-plastic behavior. Here, k_f represents the stiffness of isolation layer, k_d represents the stiffness of hysteretic damper, c represents the viscous damping coefficient, $\alpha_{d,y}$ represents the yield shear force coefficient of isolation layer, $\delta_{c,gap}$ represents the deformation at which the controller started to work and k_c represents the stiffness of hysteretic damper. In addition, $_f$ represents the isolation layer, $_d$ represents the hysteretic damper and $_c$ represents the controller.

Figure 2 shows the restoring force characteristic of model. Here, (a) is the restoring force characteristic of the isolated layer, (b) is the restoring force characteristic of the hysteretic damper, (c) is the restoring force characteristic of the viscous damping, and (d) is the restoring force characteristic of the controller, and (e) is the restoring force characteristic of the system, respectively. Here, $Q_{f,\max}$: Maximum shear force of isolator, $Q_{d,y}$: Yield shear force of hysteretic damper, $Q_{c,\max}$: Maximum shear force of controller, $\alpha_{d,y}$: yield shear force coefficient of hysteretic damper, $\delta_{\max}$: Maximum deformation of isolated layer, $\delta_{d,y}$: Yield deformation of hysteretic damper and $\delta_{c,gap}$: the deformation at which the controller started to work.

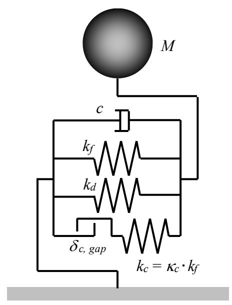
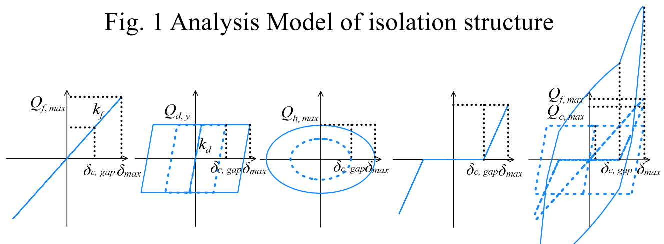


Fig. 1 Analysis Model of isolation structure



(a) Isolator　(b) Damper　(c) Damping　(d) Controller　(e) System

Fig. 2 Restoring Force Characteristic of system

Effect of time step of time history analysis for isolated building with hardening-type displacement controller

Jing LI, Daiki SATO, Takuya UEKI, Ryota TOBARI

The parameters of system can be calculated from following Eq. (1) to Eq. (4).

$$Q_{f,\max} = k_f \cdot \delta_{\max} \tag{1}$$

$$Q_{d,y} = k_d \cdot \delta_{d,y} \tag{2}$$

$$Q_{c,\max} = k_c \cdot (\delta_{\max} - \delta_{c,gap}) \tag{3}$$

$$\alpha_{d,y} = Q_{d,y} / Mg \tag{4}$$

Here, $Q_{f,\max}$: the maximum shear force of isolated layer, $Q_{d,y}$: the yield shear force of damper, $Q_{c,\max}$: the yield shear force of controller, $\delta_{\max}$: the maximum deformation of isolated layer, $\delta_{c,gap}$: the deformation at which the controller started to work and $\alpha_{d,y}$: the yield shear force coefficient of hysteretic damper.

Eq. 2.5 shows the period of the isolated layer.

$$T_f = 2\pi\sqrt{\frac{M}{k_f}} \tag{5}$$

Eq. 2.6 shows the period of the system.

$$T_s = 2\pi\sqrt{\frac{M}{k_s}} \tag{6}$$

Eq. 2.7 shows the stiffness of the isolation layer k_f. Eq. 2.8 shows the stiffness of the damper k_d. Eq. 2.9 shows the stiffness of the system k_s.

$$k_f = \frac{4\pi^2}{T_f^{\,2}} M \tag{7}$$

$$k_d = \frac{\alpha_{d,y} \cdot w}{\delta_{d,y}} \tag{8}$$

$$k_s = k_f + k_c \tag{9}$$

Here, M represents the mass, w represents the weight.

In this paper, it is assumed that the base isolated building model with a viscous damping and installs a hysteretic damper and a controller in the seismic isolated layer. Table 1 shows the parameters of the model. Mass M : 100 tons, T_f : period of isolator, h_f: damping ratio of isolation layer, $\alpha_{d,y}$: yield shear force coefficient of hysteretic damper, $\delta_{d,y}$: yield deformation of hysteretic damper, $\delta_{c,gap}$: deformation at which the controller started to work, κ_c : Proportion of k_f to k_c.

2.2 INPUT GROUND MOTIONS

The artificially generated earthquake ground motions created to match the announcement spectrum are used as the input ground motions, and ${}_pS_v$ was set as constant at a corner period T_C > 0.64 s. In this paper, ART KOBE 80 cm/s and ART HACHI 80 cm/s are adopted as the ground motions. ART KOBE is artificially generated pulse-like ground motion, and ART HACHI is artificially generated long period ground motion. Figure 3 shows the acceleration time history of the ground motions. (a) represents ART-KOBE and (b) represents ART-HACHI. Figure 4 shows the pseudo-velocity response ${}_pS_v$ (h = 0.05) and energy spectrum V_E = 120 cm/s (h = 0.10). Fig. 4 shows the case where ${}_pS_v$ was constant at 80 cm/s. In this analysis, the velocity conversion value of the total input energy in ART KOBE, V_E = 118, 89, and 108 cm/s, when Period of isolator T_f = 2, 3, 4s. In ART HACHI, V_E = 218, 183, and 247 cm/s, when Period of isolator T_f = 2, 3, 4s.

Table 1 Parameters of model

Period of isolator T_f (s)	2.0, 3.0, 4.0
Damping ratio of isolated layer h_f	0.02, 0.04, 0.10
Mass M (ton)	100
Yield shear force coefficient of hysteretic damper $\alpha_{d,y}$	0.02, 0.03
Yield deformation of hysteretic damper $\delta_{d,y}$ (cm)	3
Deformation at which the controller started to work $\delta_{c,gap}$ (cm)	10
Proportion of k_f to k_c: κ_c	10, 20, 30

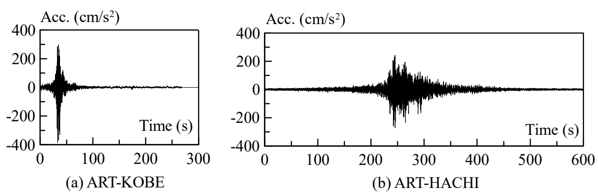


Fig. 3 Earthquake Ground Motion (${}_pS_v$ = 80 cm/s)

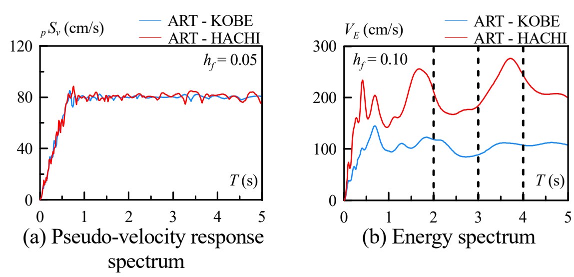


Fig. 4 Earthquake ground response spectrum

3. Effect of Time Step

Fig. 5,6 shows the relationship between the ratio of period of system to time step $T_s / \Delta t$ and the maximum response for the SDOF model. Fig. 5 shows results of the ground motion is ART-KOBE. Fig. 6 shows results of the ground motion

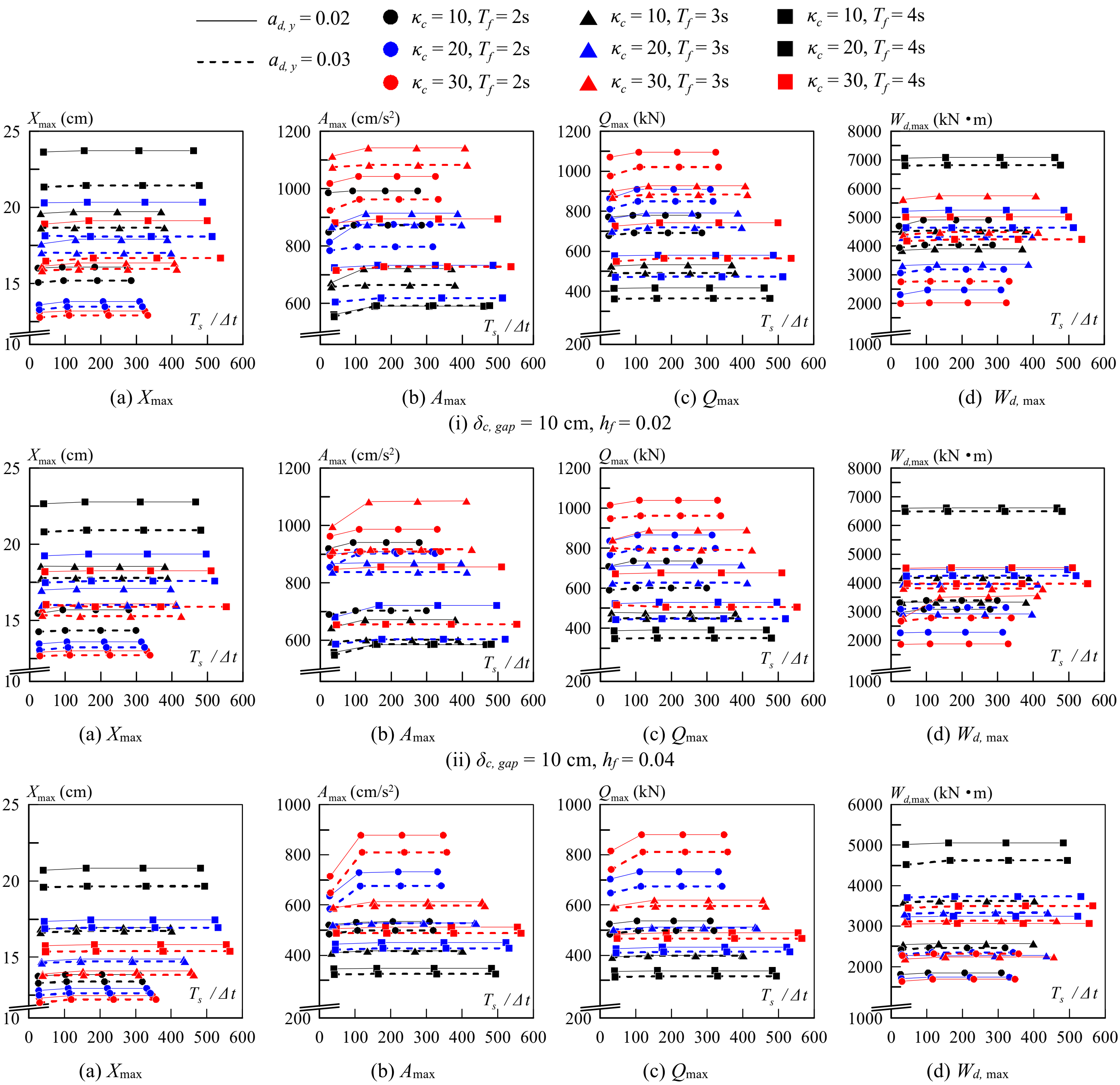
ART-HACHI. (a) shows the maximum deformation X_{max}, (b) shows the maximum Acceleration A_{max}, (c) shows the maximum sheer force Q_{max} and (d) shows damage causing energy by hysteretic damper W_d. For legends, solid line and dotted line show $\alpha_{d,y}$ = 0.02, 0.03; ○, △ and □ show T_f = 2s, 3s and 4s; black, bule, and red show κ_c = 10, 20 and 30, respectively.

According to Fig. 5,6 we can observe that the maximum response values are almost equal from $T_s/\Delta t > 100$. So $T_s/\Delta t = 100$ is good enough as the parameter of THA when ground motions are not only ART-KOBE and ART-HACHI.

4. CONCLUSION

This time, we discussed the response of SDOF isolated building with displacement controller model by time history analysis method.

According to the results we can know that As $T_s/\Delta t > 100$, the accuracy is good enough for the isolation with a hysteretic damper and a hardening type displacement controller SDOF model when ground motions are not only ART-KOBE and ART-HACH.



(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,max}$

(i) $\delta_{c,gap}$ = 10 cm, h_f = 0.02

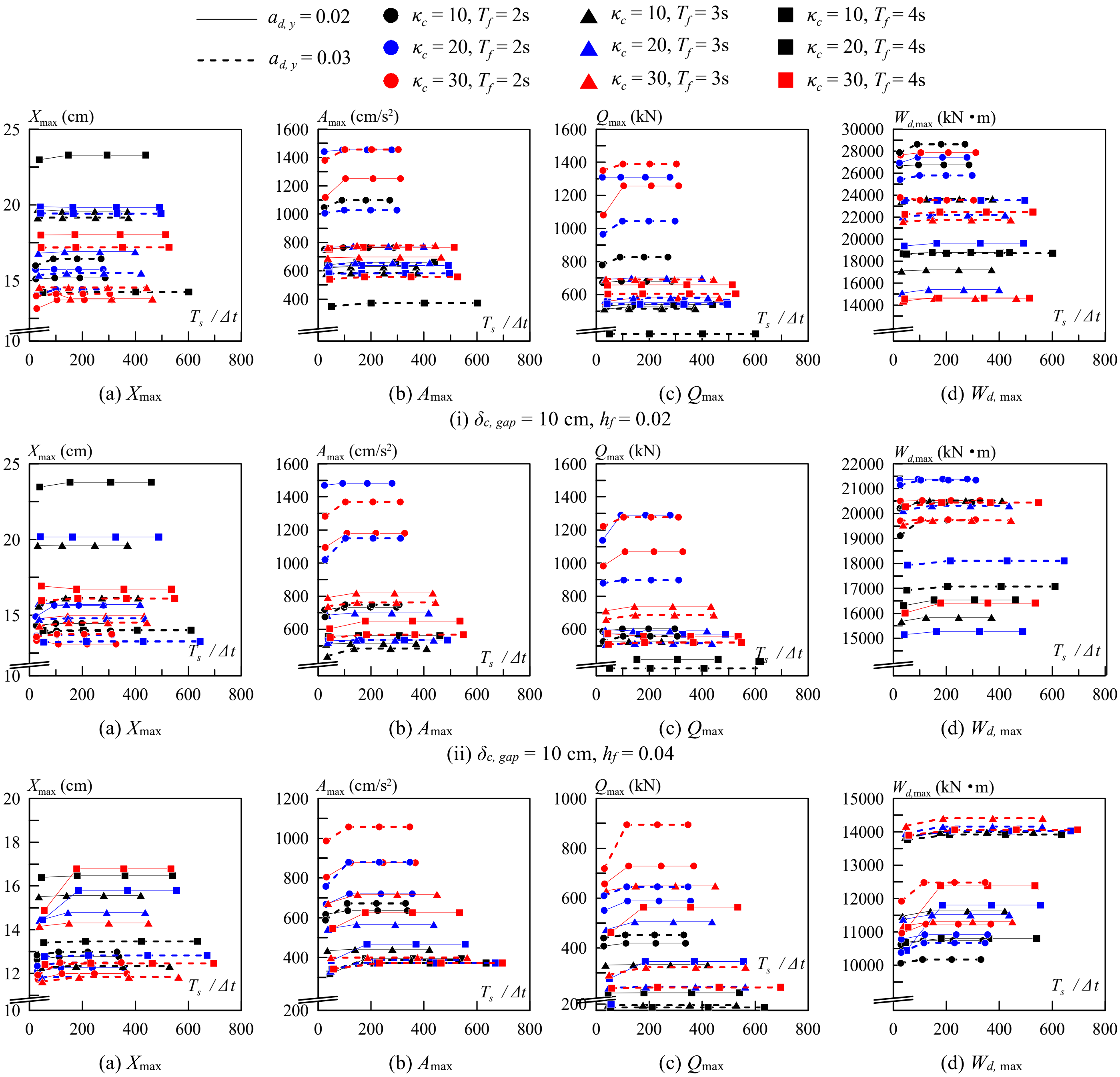
(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,max}$

(ii) $\delta_{c,gap}$ = 10 cm, h_f = 0.04

(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,max}$

(iii) $\delta_{c,gap}$ = 10 cm, h_f = 0.10

Fig. 5 THA results of the isolation with a hysteretic damper and a controller model (ART - KOBE)



(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,\ max}$

(i) $\delta_{c,\ gap}$ = 10 cm, h_f = 0.02

(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,\ max}$

(ii) $\delta_{c,\ gap}$ = 10 cm, h_f = 0.04

(a) X_{max} (b) A_{max} (c) Q_{max} (d) $W_{d,\ max}$

(iii) $\delta_{c,\ gap}$ = 10 cm, h_f = 0.10

Fig. 6 THA results of the isolation with a hysteretic damper and a controller model (ART - HACHI)

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