(101) FUNDAMENTAL STUDY ON RELATIONSHIP BETWEEN BASE ISOLATION METHOD AND DYNAMIC CHARACTERISTICS OF UPPER STRUCTURES

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INTRODUCTION

Significance of electric power as one of life-line system has been increasing, as social system is coming to be highly developed: and aseismic base isolation system for power facilities has come to be considered as powerful measures for increasing reliability of power systems. This report will describe responses of base isolated structures using three kinds of isolation systems.

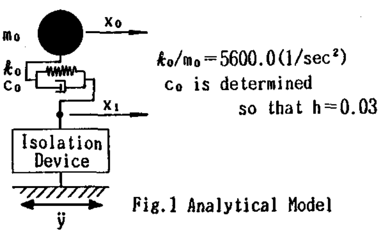


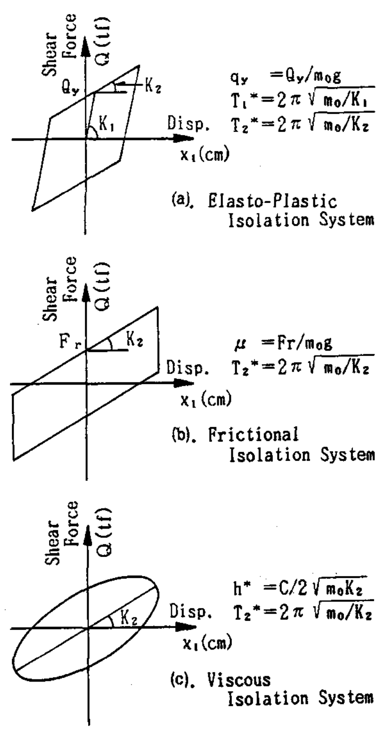
Fig.1 Analytical Model

ANALYTICAL MODEL

Analytical models are consist of structures with stiffness and viscous damping element and base isolation device, as shown in Figure 1. The upper structure has high natural frequency of 12 Hz.

Isolation devices used in this study are parallel-connected restoring spring and energy absorbing element. Three kinds of energy absorbing methods are selected; i.e. elasto-plastic system, frictional system, and viscous system. Characteristics of three kinds of isolation systems are as shown in Figure 2.

Response solutions were given by means of linear acceleration method of direct integration using equation of motion for each system.



Q_y : Yielding Shear Force
q_y : Non-dimensional Shear Foece
K_1, K_2 : Restoring Stiffness
F_r : Frictional Force
μ : Coefficient of Friction
C : Coefficient of Damping (Isolation Device)
h^* : Modified Damping Ratio

Fig.2 Characteristics of Three Kinds of Isolation System

CONDITIONS FOR RESPONSE ANALYSIS AND ITS RESULTS

Modified acceleration waves were applied for each analytical model. The modified waves were synthesized using phase characteristics of three kinds of actual observed waves and amplitude characteristics of response spectrum are shown in Figure 3. This spectrum is specified as Ground Spectrum of Group 2 currently used for design of road bridge foundations. As three kinds of phase characteristics did give almost the same responses, the modified wave based upon El Centro NS will be shown as representative in this paper.

At the first stage of analyzing in this chapter, parametric characteristics of energy absorbing system for each method were selected for the purpose of optimum parameter survey, using the same restoring spring characteristics: i.e. spring constant K_2 was settled so that each system have the same period T_2^* of 2.0 sec. Optimal characteristics for each isolating system resulted from the analysis in the first stage were used for the second stage.

In the second stage, parametric characteristics of restoring spring of isolator were used; i.e. frequency of structure by isolator's spring was selected for the purpose of comparing response accelerations and displacements of upper structures.

(1) Elasto-plastic Isolation System

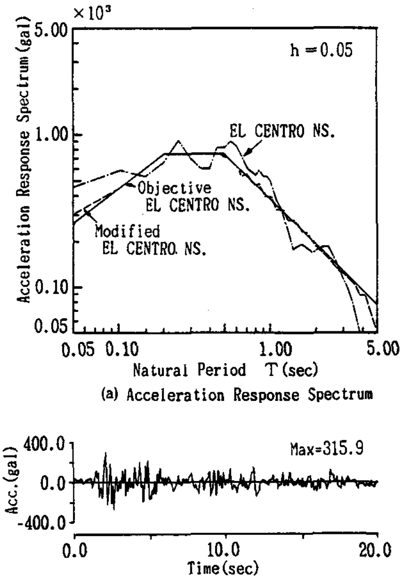
Figure 4(a) shows the result in the first stage. Spring constant of K_1 was selected so as to have period T_1^* to be 1.0 sec. As shown here, maximum response acceleration curve has minimum value in the region of q_y = 0.03-0.05, and its value is about one third of non-isolated. Response displacement is almost constant where q_y is larger than 0.03, while it comes to larger in the region of q_y less than 0.03.

Figure 4(b) shows the result of the second stage when q_y is selected to be optimal value 0.03. Response acceleration decreases as T_2^* increases, while response displacement shows nearly the same value in the wide range.

(2) Frictional Isolation System

According to Figure 5(a), maximum response acceleration curve has minimum value in the region of μ = 0.03-0.05, and its value is about one third of non-isolated. Response displacement increases as μ decreases, particularly it increases enormously in the region of μ less than 0.08.

According to Figure 5(b), in which μ is selected to be optimal value 0.08, maximum response acceleration curve has nearly the same value in the region of T_2^* larger than 1.5 sec: while it increases enormously in the region of T_2^* less than 1.5 sec. Maximum response displacement is almost flat in the wide region.



(a) Acceleration Response Spectrum

(b). Time History of Modified EL CENTRO NS Wave

Fig.3 An Example of Input Wave

(3) Viscous Isolation System

According to Figure 6(a), maximum response acceleration is almost the same value in the region of h* = 0.1-0.4 . When h* is 0.3, it is about one third of non-isolated: while it increases in the region of h* less than 0.1, and larger than 0.4. Maximum response displacement decreases, as h* increases.

According to Figure 6(b), in which h* is selected to be optimal value of 0.3, as T_2^* increases, response acceleration decreases and displacement increases: this diagram is a kind of response spectrum itself.

COMPARISON OF EACH ISOLATION METHOD

Comparing study of three kinds of isolation system was carried out referring to the results mentioned above. In this study, parameters of energy absorbing elements were selected so as to give minimum response. The characteristics are as follows:

Elasto-plastic ;	q_y = 0.03,	T_2^* =2.0 sec
Frictional ;	μ = 0.08,	ditto
Viscous ;	h* = 0.3 ,	ditto

Response acceleration waves of each system are as shown in Figure 7. As shown here, in the case of elasto-plastic and viscous system, high frequency of response waves are cut, while in the case of frictional system, peak acceleration is chopped at almost 80-100 gals level.

Relationship between input maximum acceleration and response are shown in Figure 8(a) and (b). In the case of frictional system, maximum response acceleration is almost flat in wide range of higher input level, while in the case of elasto-plastic and viscous system, response acceleration increases slightly, as input acceleration increases. And, frictional system gives the least response displacement among the three.

Response spectrum diagram, using the response acceleration waves at the position of m_o, is shown in Figure 9. In the case of elasto-plastic and viscous systems, isolating effect is efficiently appeared in the low period region under 1.0 sec, although resonance effect can be seen about T = 2 sec, which is higher than non-isolated. In the case of frictional system, response acceleration is higher than the rest two system, but it gives almost the same response as non-isolated in the long period region.

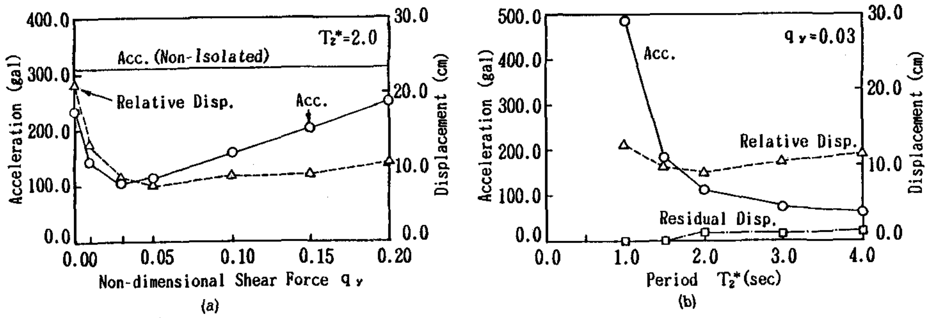


Fig.4 Maximum Response of Structure (Elasto-Plastic Isolation System)

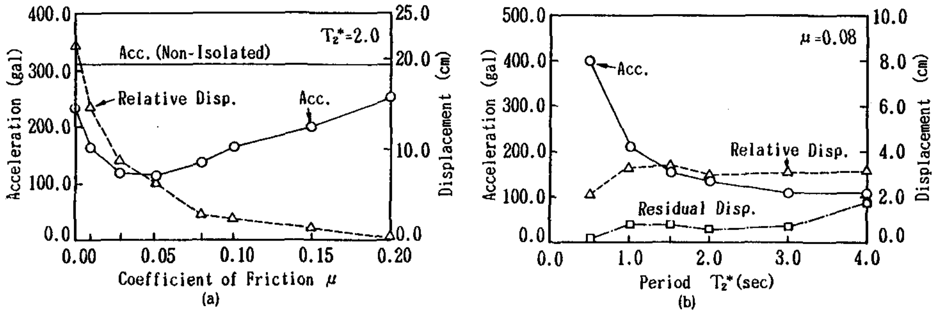


Fig.5 Maximum Response of Structure (Frictional Isolation System)

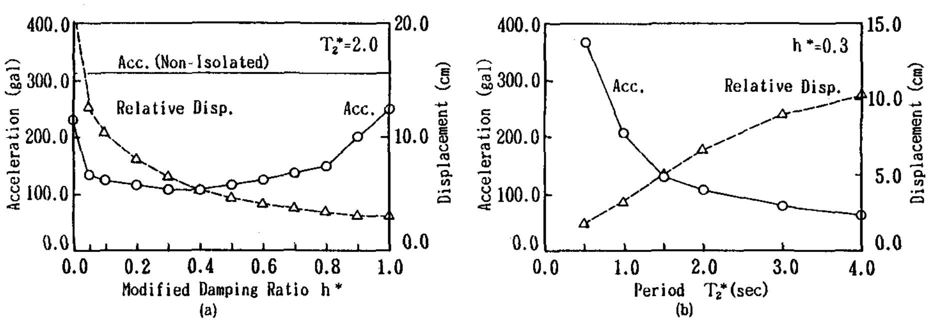


Fig.6 Maximum Response of Structure (Viscous Isolation System)

For one of case studies, supposing an auxiliary equipment is connected on the mass m_o, response analysis was carried out. Result of response acceleration waves of the auxiliary equipment are shown in Figure 10. Natural frequency of the auxiliary equipment is selected to be 5.0 Hz. As shown here, elasto-plastic and viscous system give almost the same response wave as that of mass m_o as shown in Figure 7, on the other hand, frictional system gives the response with high frequency.

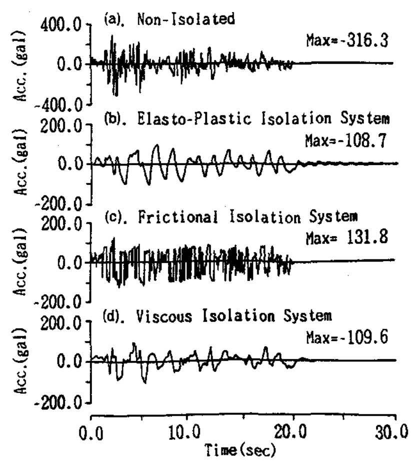
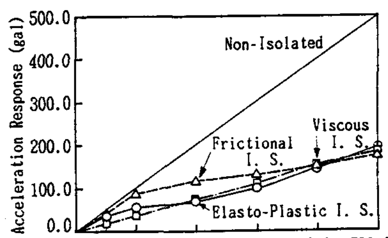
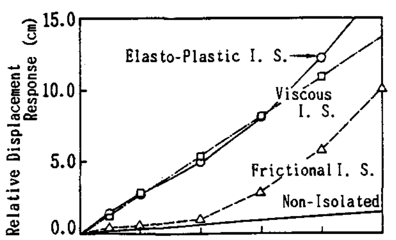


Fig.7 Acceleration Response Time History of Structure



Input Maximum Acceleration (gal)

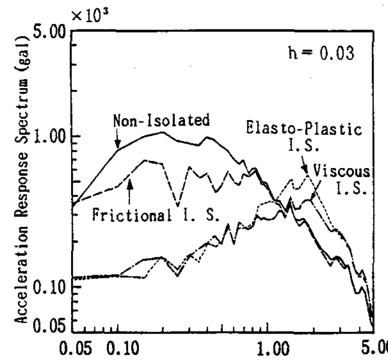
(a) Acceleration Response of Structure



Input Maximum Acceleration (gal)

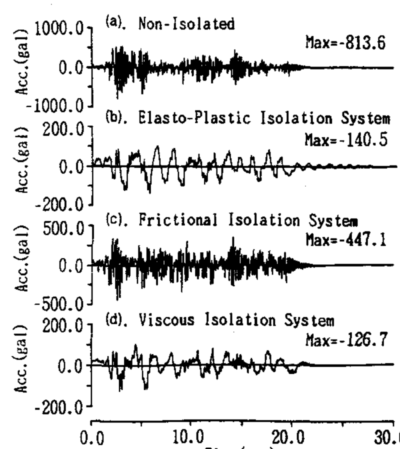
(b) Relative Displacement Response of Structure

Fig.8 Relation between Input Maximum Acceleration and Maximum Response



Natural Period T (sec)

Fig.9 Acceleration Response Spectrum of Structure



Time(sec)

Fig.10 Acceleration Response Time History of Equipment on Structure

CONCLUSION

Fundamental review of three kinds of base isolation system was carried out, and some quantitative knowledge were obtained concerning the comparison of energy absorbing system. Studies on base isolation system for various facilities and ground conditions are planned to execute.

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