Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

7-9-8

EARTHQUAKE RESPONSE ANALYSES OF BASE ISOLATION SYSTEMS WITH AND WITHOUT FAIL-SAFE MECHANISM

Michihiro OHORI[1], Tadao MINAMI[2] and Yutaka OSAWA[2]

1. Graduate Student, Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Tokyo, JAPAN
2. Professor, Earthquake Research Institute, University of Tokyo, Bunkyo-ku, Tokyo, JAPAN

SUMMARY

We studied numerically the elastic and elastic-plastic responses of structures which have the base isolation system with and without fail-safe mechanism, in comparison with those of a structure with its base fixed. Two types of fail-safe mechanisms were considered; the chain system with elastic springs and the Kelly's skid frame that restores frictional forces. Results showed that the latter is more effective than the former for both elastic and elastic-plastic responses. Moreover, in some cases, base isolation systems make more heavy damage to the first story of structures that have relatively low yielding strengths.

INTRODUCTION

Recently, the base isolation system is becoming popular in building constructions in Japan. The base isolation system is composed of three elements; the isolator that lengthen the period of structure out of the range in which the frequency components of the ground motion predominate, elastic-plastic or viscous damper which dissipates vibration energy during an earthquake, and fail-safe mechanism which prevents the structure from falling down by destructive ground motion beyond expectation.

So far, we can find many studies on base isolation system with isolators and dampers, but those on fail-safe mechanism are very limited. Therefore, we investigated the effects of fail-safe mechanism on earthquake response through numerical analyses and compared the responses with those of ordinary structures and base isolated structure without fail-safe mechanism.

METHOD

We modeled the superstructure as follows. The 5 mass-shear model was used, which has the 1st period of 0.3 sec and modal damping factor of 2 %. The mass and height of each story is 100 ton and 3.5 m respectively, and the story stiffnesses vary along the height in the parabolic form. In the elastic-plastic analyses, the elasto-plastic hysteretic model was used, the yielding strengths being determined so as to make the accumulative plastic deformation, when normalized by the yield displacement, uniform along the height of the building according to Matsushima's method (Ref.2) and base shear coefficient was set 0.2.

The following assumptions were made in the analyses. Isolator remains elastic, and the 1st period elongates to 2.0 sec when the isolator was connected to the foundation of the superstructure. Then we prepared two types of fail-safe mechanisms; the chain system that has an elastic spring with parabolic skeleton curves (Fig.1), and the Kelly's skid frame that has frictional restoring force with the same skeleton curves (Fig.2). Fig.3 shows restoring force curves of each fail-safe mechanism. We didn't put any damper.

We used the accelerogram recorded at the Tohoku Univ. in 1978 off-Miyagi Prefecture earthquake. The maximum acceleration was 258 gal. Fig.5 shows the response spectra for acceleration and displacement. In numerical integration, the Wilson's theta method was used with the theta being equal to 1.4 and the time intervals of 0.002 sec.

RESULTS

We calculated the responses of the superstructure in elastic analyses and in elastic-plastic analyses. Moreover, in both analyses, we compared the responses of isolated structure with and without fail-safe mechanisms, to those of ordinary structure. In determining the skeleton curves of each fail-safe mechanisms, we used two parameters (Fig.4); one is the equivalent stiffness (Group1), and the other is the trigger displacement at which fail-safe mechanism begin to operate (Group2).

(a) Elastic analyses

Fig.6 to fig.9 show the maximum responses for displacement, acceleration, shear force, and shear coefficient for the case in which the superstructure remains elastic.

Fig.6 and fig.7 indicate that all the responses except for displacement decrease by use of isolator as compared to the case of ordinary structures. By chain system, all responses increase in all stories and sometimes exceed those of ordinary structures.

Fig.8 and fig.9 indicate that the skid frame makes all the responses, except for displacement, larger, especially in the low and top stories, as compared to the case without a fail-safe mechanism. The maximum responses, however, are, in general, smaller than those for ordinary structures.

(b) Elastic-plastic analyses

Fig.10 to fig.13 show the maximum responses for displacement, acceleration, equivalent velocity of the energy input (Ref.4) and ductility factors for the case in which the superstructure undergoes plastic deformation.

Fig.10 and fig.11 indicate that the existence of isolator increases damage in the first story tremendously as compared with a non-isolated structure, and the chain system makes greater damage in all stories than the base-isolated structure without a fail-safe mechanism.

Fig.12 and fig.13 indicate that the skid frame makes damage in lower stories smaller and that in higher stories greater as compared to the base-isolated structure without a fail-safe mechanism.

CONCLUDING REMARKS

We obtained some remarks as follows.

(1) The Kelly's skid frame is more effective than the chain system both for the elastic and elastic-plastic responses, because the Kelly's one absorbs a large amount of the vibration energy in friction during an earthquake.

(2) In some cases, the use of isolators increases damage in the first story as compared to a non-isolated structure. A care must be paid, therefore, in application of base isolation systems to a structure with relatively

low yielding strengths.

ACKNOWLEDGMENTS

We thank our former research fellows, Dr. S. Suzuki of Kansai University, Mr. N. Kurata of Kajima Corporation, and Mr. T. Kashima of Building Research Institute, Ministory of Construction for helpful suggestions in numerical analyses.

REFERENCES

1. Japan Structural Consultants Association, Structure,NO-20,(1986.10).
2. Matsushima,Y., "Optimum Distribution of Shear Coefficients for Multi-Degree-Of-Freedom Systems subjected to White Excitations", Transactions of AIJ, NO-342,(1984.8).
3. Kelly,J.M., Becke,K.E., Skinner,M.S., "Experimental Testing of a Friction Damped Aseismic Base Isolation System with Fail-Safe Characteristics", Earthquake Research Center Report UCB/EERC-80/18,(1980).
4. Kato,B., Akiyama,H., "Energy Input and Damages in Structures subjected to Severe Earthquakes", Transactions of AIJ,NO-235,(1975.9).

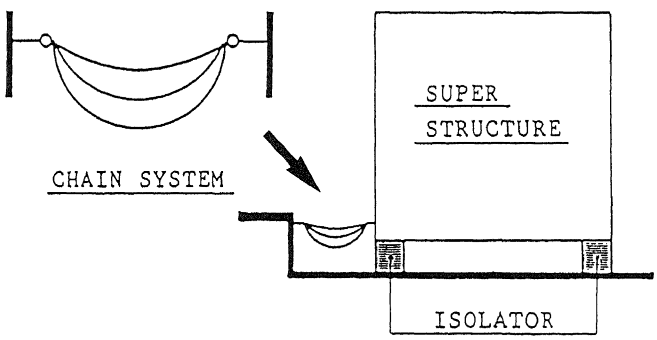

Fig.1 Outline of Chain System.

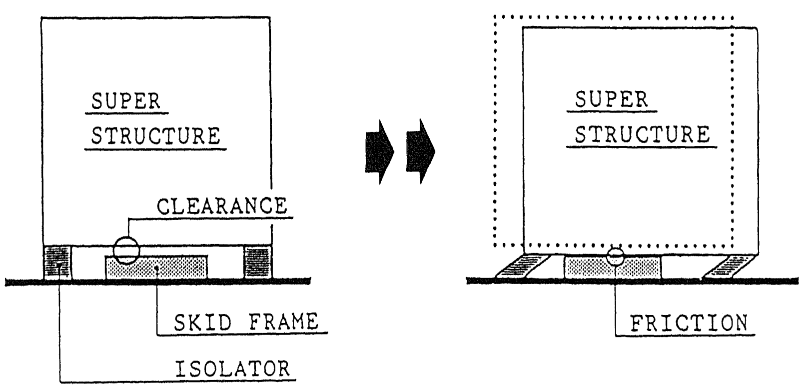

Fig.2 Outline of Skid Frame.

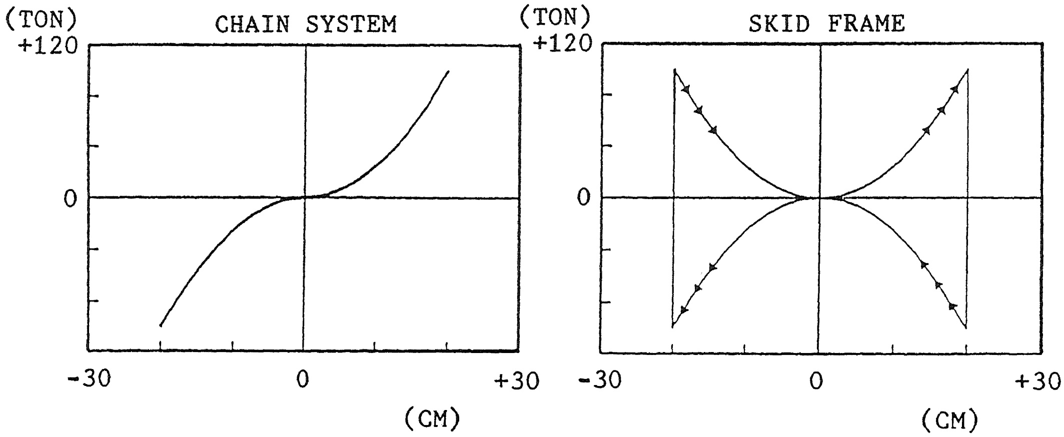

Fig.3 Restoring Force of Fail-Safe Mechanism.

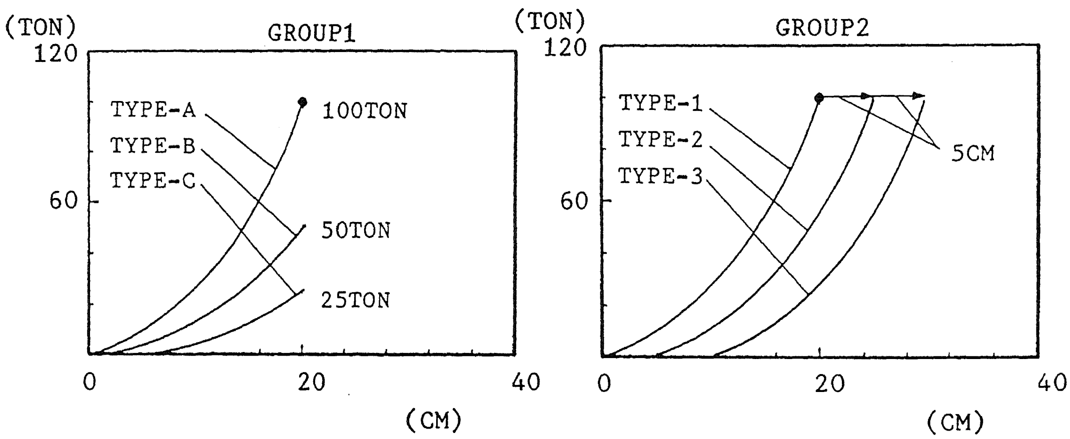

Fig.4 Skeleton Curves of Fail-Safe Mechanism.

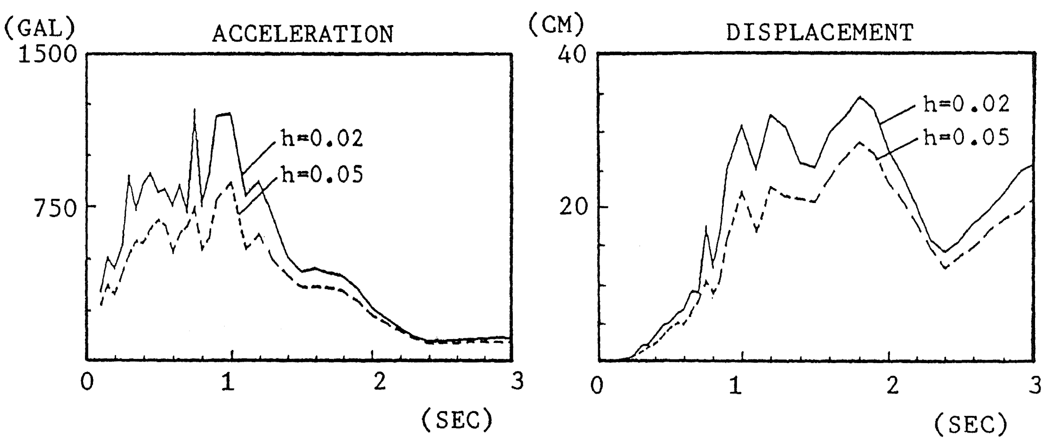

Fig.5 Response Spectra of Tohoku Univ. 1978-NS.

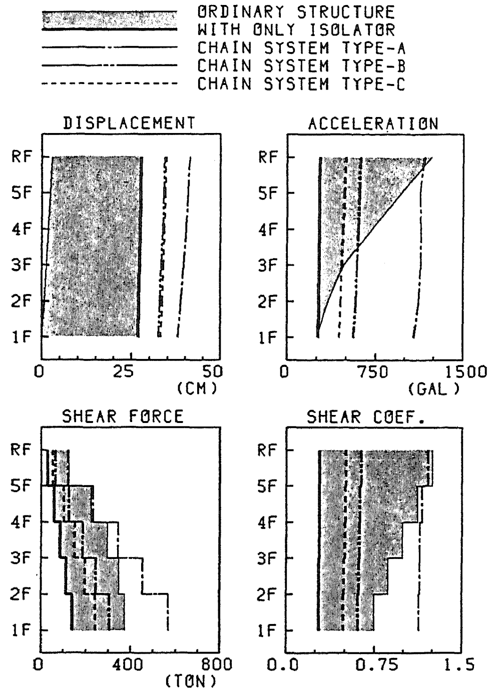

Fig.6 Elastic Analyses.

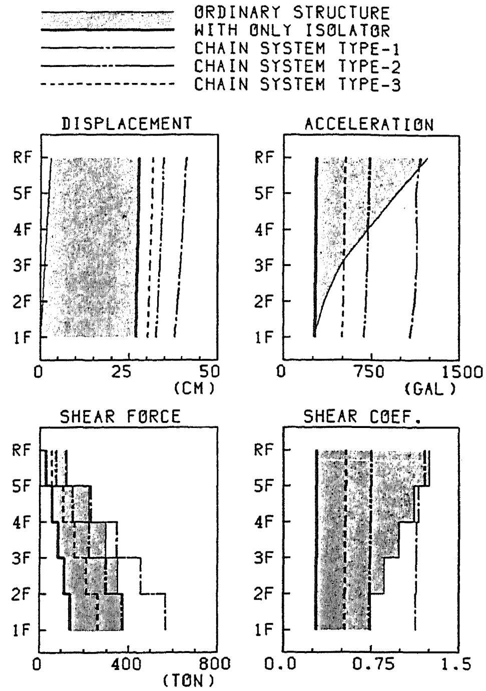

Fig.7 Elastic Analyses.

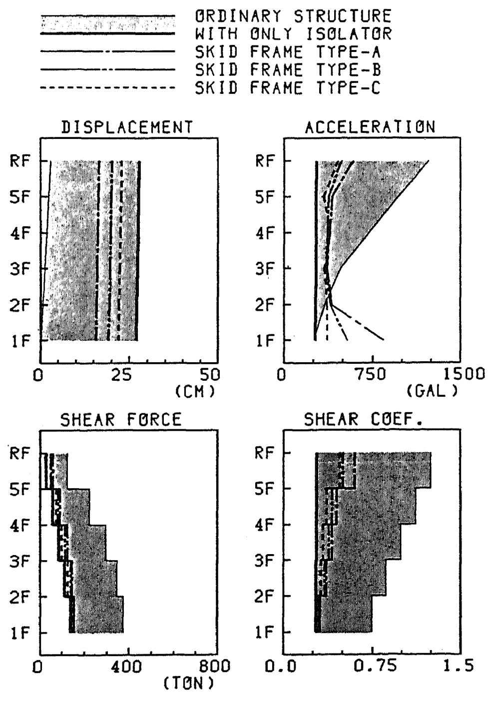

Fig.8 Elastic Analyses.

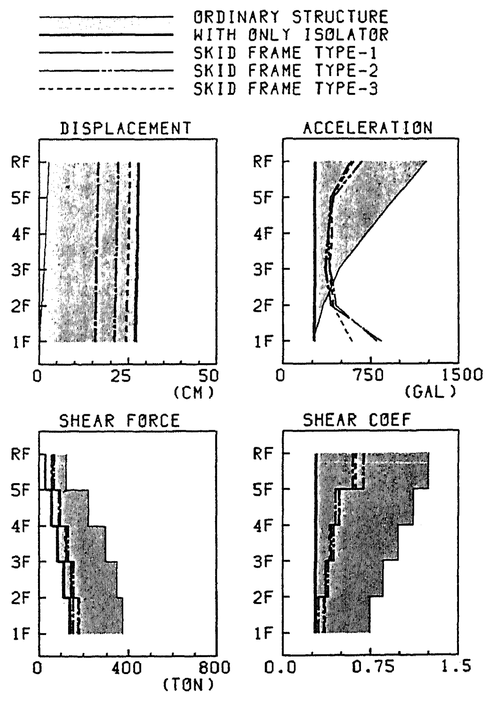

Fig.9 Elastic.Analyses.

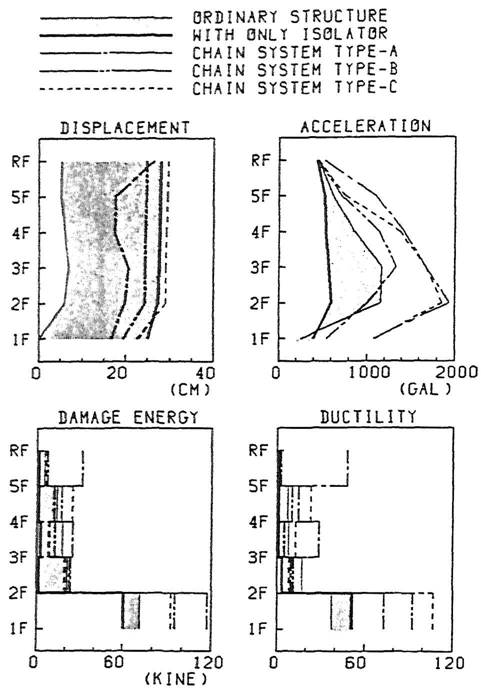

Fig.10 Elastic-Plastic Analyses.

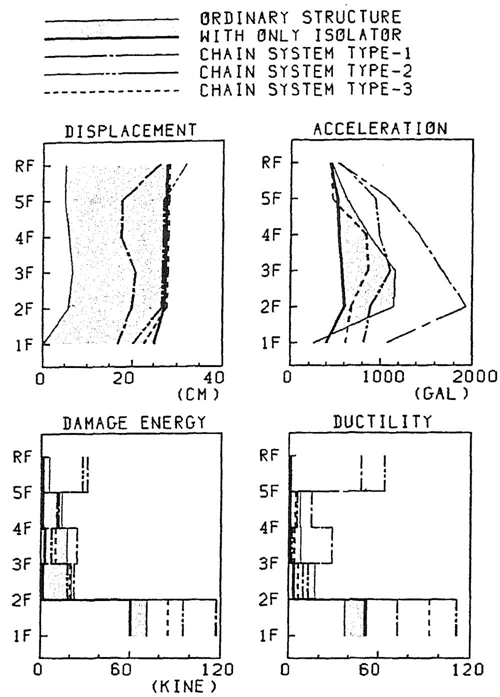

Fig.11 Elastic-Plastic Analyses.

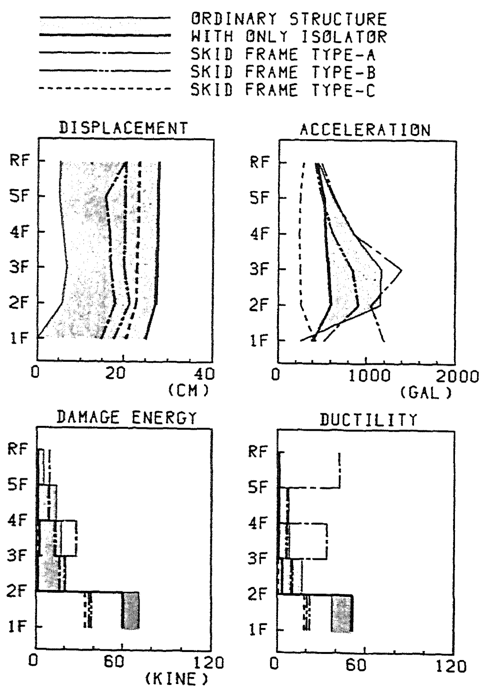

Fig.12 Elastic-PLastic Analyses.

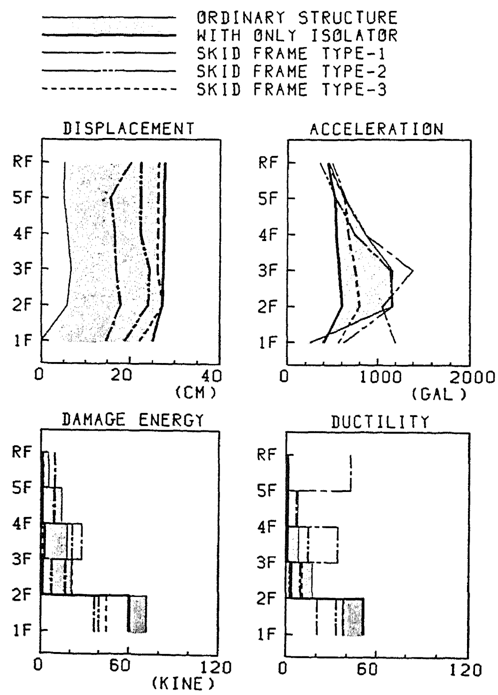

Fig.13 Elastic-Plastic Analyses.