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

7-9-23

STUDY ON A SLIDING-TYPE BASE ISOLATION SYSTEM -MULTI-DIMENSIONAL RESPONSE ANALYSIS-

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SUMMARY

Authors developed a base isolation system to reduce horizontal seismic acceleration, which was named TASS system (TAISEI SHAKE SUPPRESSION SYSTEM). Slip occurs between sliding bearings and bearing plates and Coulomb damping is genarated to absorb seismic energy. The fundamental response characteristics were studied by one-dimensional lumped mass model and detailed response characteristics such as torsional or rocking vibration were analyzed three dimensionally.

It was made clear that TASS system has good isolation effects, i.e. when input acceleration is 50cm/sec, the response acceleration of a base-isolated building is reduced to 1/2~1/8 of the non base-isolated one, and the maximum relative displacement of the base is within 30cm, which is adopted as maximum response displacement in the design. The acceleration mitigation effects are not disturbed by vertical and rocking vibration and torsional response scarcely occurs.

INTRODUCTION

The fundamental response characteristics of the sliding-type base isolation system were studied by one-dimensional lumped mass model. And the detailed response characteristics such as torsional or rocking vibration were analyzed three-dimensionally.

MODEL AND INPUT WAVES

The properties of the model for one-dimensional analysis are shown in Fig.1. The vibration model assumed a five-story reinforced concrete building. The stiffness of each story was determined so as to make the fundamental period as 0.3sec and the first mode triangular in fixed base condition. The building was assumed to behave in the elastic range. The building model for three dimensional analysis is shown in Fig.2. The model is constructed by three-dimensional beam element attached on to a rigid base plate. Nine elastic sliding bearings support the base plate and four horizontal springs are attached between the base plate and the foundation. Model constants are decided to fit the one-dimensional lumped mass model.

The force-displacement relationship of TASS system can be modeled as shown in Fig.1. The coefficient T_1 means the first period of the total system in the elastic range without slide and the coefficient T_2 the apparent period of the total system with the second slope k_2 in the sliding stage.

EL CENTRO 1940 NS and HACHINOHE 1968 NS were chosen for the input waves. Three input levels were selected as follows; 50Gal (moderate earthquake motion: frequently expected), 25cm/sec (strong earthquake motion: expected to occur once in 50 years), 50cm/sec (severe earthquake motion: expected to occur once in 100 years). Maximum acceleration of these waves were normalized to the three levels.

ONE-DIMENSIONAL ANALYSIS

Items for Investigation The following items were investigated of their effects; 1) type of sliding bearing, 2) variety of coefficient of friction, 3) horizontal springs, 4) input waves, 5) frequency response of the isolated building.

Methods and Results

(1) Type of Sliding Bearings (Fig.3) Three types of sliding bearings: rigid sliding bearing and elastic sliding bearings of T_1=1sec and T_1=2sec were selected. When input acceleration is 50Gal, no slip occurs and the response with rigid sliding bearings is the same as the case without base isolation but the acceleration response with elastic sliding bearings mitigates by the period-lengthening effect. When input acceleration increases to 50cm/sec and slip occurs, acceleration mitigation effect becomes clear, i.e. for the case with rigid sliding bearings maximum response acceleration becomes about 1/2~1/4 of that without TASS system and for the case with elastic sliding bearings about 1/4~1/8 of that without TASS system. The maximum relative displacement of the base is within 30cm.

(2) Variety of Coefficient of Friction (Fig.4) Coefficient of friction (μ) was varied from 0.05 to 0.20. Maximum response acceleration of the building top increases as coefficient of friction increases, i.e. when input level is 50 cm/sec, the maximum response acceleration for μ=0.2 is about twice of that for μ=0.05. Maximum relative displacements are almost the same and less than 30 cm regardless of μ.

(3) Horizontal Springs (Fig.5) Stiffness of horizontal springs was varied. The equivalent period of the building is varied from 3 sec to ∞ sec (K_2=0) in the sliding stage. Horizontal springs add slight restoring force in the sliding stage not to increase base shear coefficient of the building so much but remarkablly reduce slide displacement compared with the case without horizontal springs, i.e. when input level is 50cm/sec, the maximum relative displacement of the base is about 25cm for the case without horizontal springs but it is reduced to about 10cm with horizontal springs of T_2=5sec.

(4) Input Waves (Fig.6) Four famous great earthquake motions were selected and four artificial waves were made for the analysis. The profiles of artificial waves are shown in Table 1. Maximum base shear coefficients are all within 0.15 and maximum relative displacements of the base are all within 30 cm.

(5) Frequency Response of the Isolated Building (Fig.7) The transfer function of the building top from the foundation was calculated for rigid sliding bearings and elastic sliding bearings of T_1=1 sec and T_1=2 sec. For 50Gal input, some resonant frequencies are seen according to natural periods of the building with TASS system. For 50cm/sec input, slip occurs and resonant frequencies disappear.

THREE-DIMENSIONAL ANALYSIS

Items for Investigation The following items were investigated of their effects; 1) change in axial force by vertical and rocking vibration, 2) variety of coefficient of friction for each sliding bearings.

Methods and Results

(1) Change in Axial Force (Fig.8) Uni-, bi- and tri-axial excitation of the model were conducted. There is little difference between the response characteristics of the model. The acceleration mitigation effects are not disturbed by vertical and rocking vibration. The ratios of torsion are very little and it seems that the change in axial force by vertical and rocking vibration gives little influence on the torsional response of the model, i.e. ratios of torsion(ratios of the horizontal displacement by torsional response to that by sway response) is within 5%. The maximum slide displacement of each elastic sliding bearings is within 30cm. Ratios of torsion is shown in Table 2.

(2) Variety of Coefficient of Friction (Fig.9, Fig.10) Coefficient of friction for each elastic sliding bearings was varied as shown in Fig.9. Type-A and Type-B correspond to the extreme cases. For Type-A coefficient of friction varies in one way and for Type-B in two way from 0.05 to 0.15. For Type-C coefficient of friction is given at random according to the experimental data. Torsional response scarcely occurs, i.e. ratios of torsion is 25 % for the worst case. Slide displacement of each elastic sliding bearings is within 30cm. Ratios of torsion is shown in Table 3.

CONCLUSIONS

To investigate the isolation effects of TASS system, multi-dimensional dynamic response analysis was conducted. It was made clear that TASS system has good isolation effects, i.e. when input level is 50cm/sec, the response acceleration of a base isolated building is reduced to 1/2~1/8 of the non-isolated one, and the maximum relative displacement of the base is within 30cm, which is adopted as maximum response displacement in the design. The acceleration mitigation effects are not disturbed by vertical and rocking vibration and torsional response scarcely occurs.

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2. Nagashima, I., Kawamura, S., Kitazawa, K., and Hisano, M.(1987), Study on a Base Isolation System, 3rd Conference on Soil Dynamics and Earthquake Engineering, Vol.43, pp359-373.

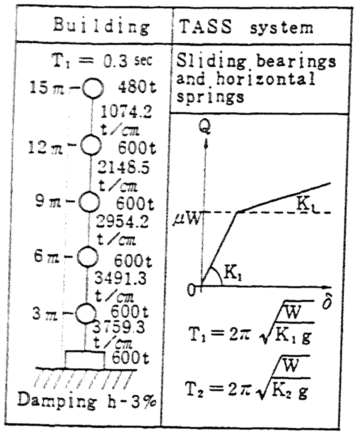


Fig.1 Profiles of the Model for One-Dimensional Analysis

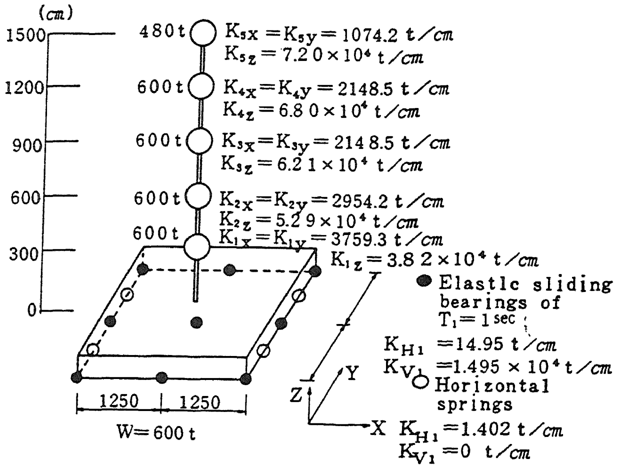


Fig.2 The Building Model for Three-Dimensional Analysis

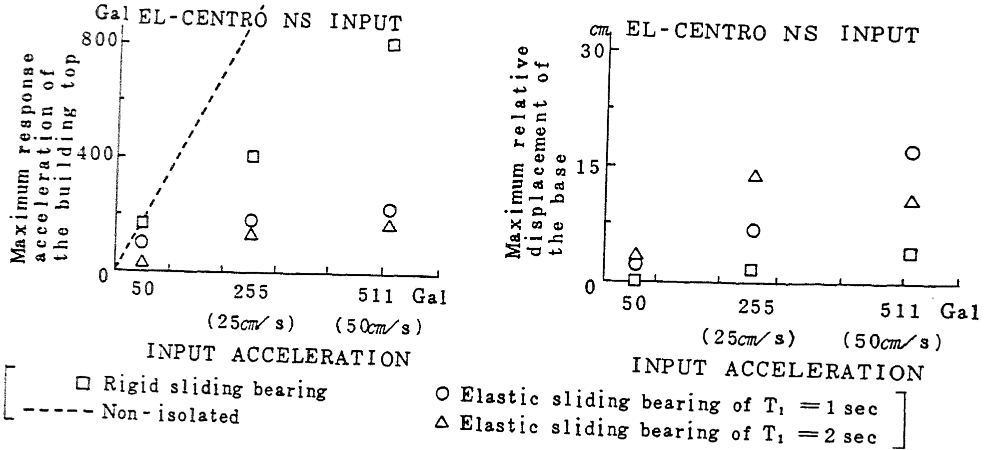


Fig.3 Type of Sliding Bearings (μ=0.1, T_2=5 sec)

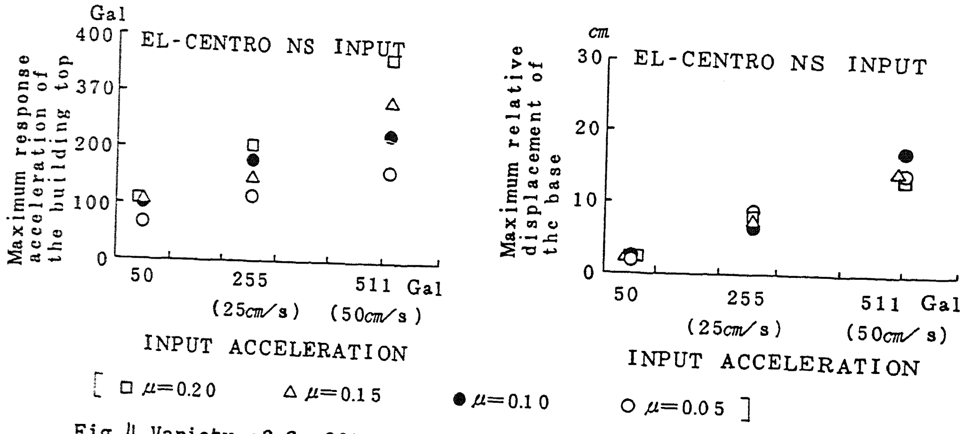


Fig.4 Variety of Coefficient of Friction (T_1=1 sec, T_2=5 sec)

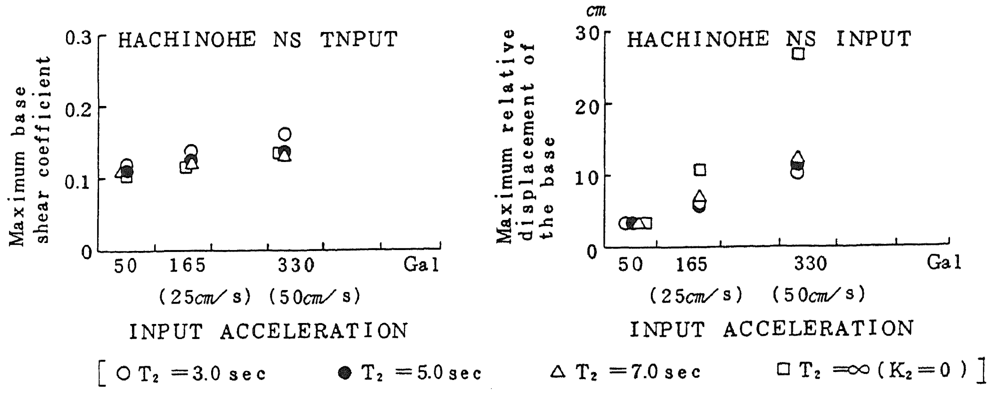


Fig.5 Horizontal Springs

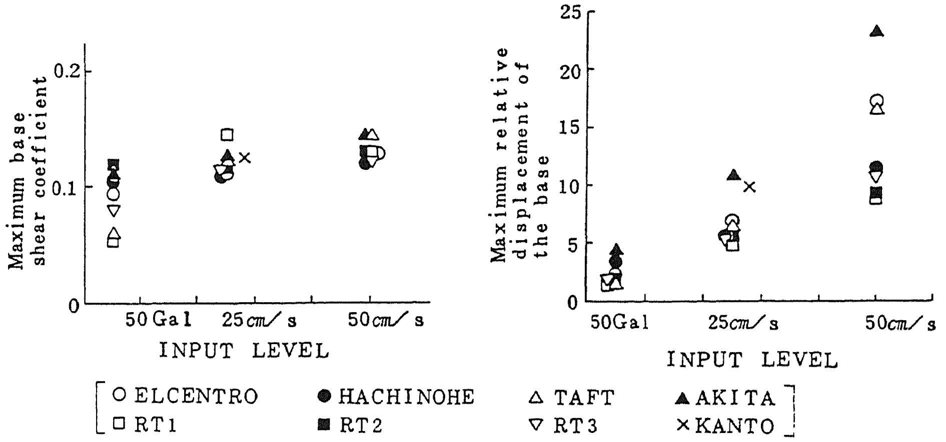


Fig.6 Input Waves (μ=0.1, T_1=1 sec, T_2=5 sec)

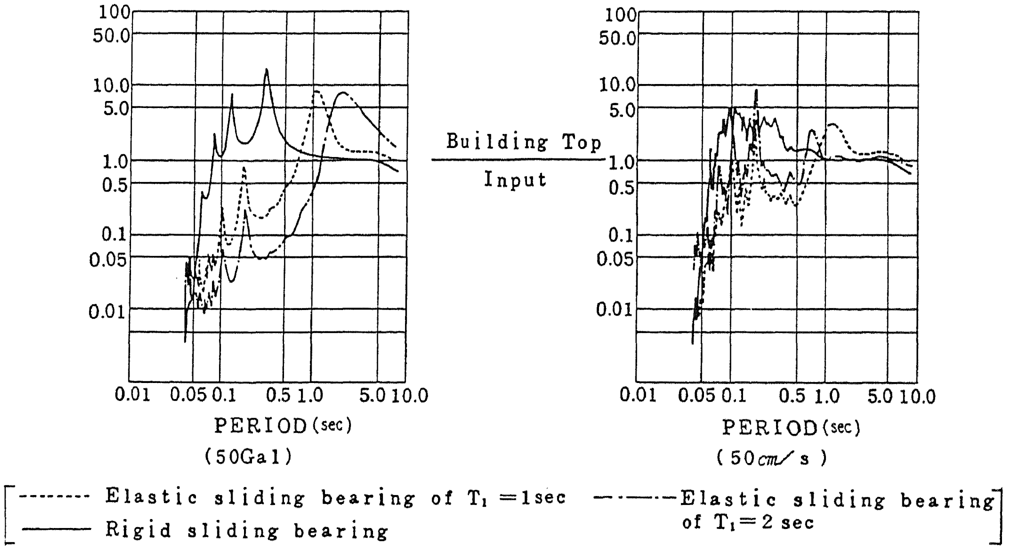


Fig.7 Frequency Response of the Isolated Building
(μ=0.1, T_2=5 sec)

Table 1 Profiles of Artificial Waves

Name	Maximum level	Duration	Target spectrum	Fault rupture
RT1	50cm/sec	20.48sec	RT spectrum of 1st kind	not considered
RT2	〃	〃	RT spectrum of 2nd kind	〃
RT3	〃	〃	RT spectrum of 3rd kind	〃
KANTO	681.0 Gal	81.92sec	Kobayashi and Midorikawa	considered

Table 2 Ratios of Torsion

INPUT LEVEL	50 Gal	25cm/sec	50cm/sec
BI-AXIAL	0	0.05	0.02
TRI-AXIAL	0	0.05	0.03

Table 3 Ratios of Torsion

	UNI-AXIAL	BI-AXIAL
TYPE-A	0.25	0.20
TYPE-B	0.15	0.24
TYPE-C	0.07	0.11

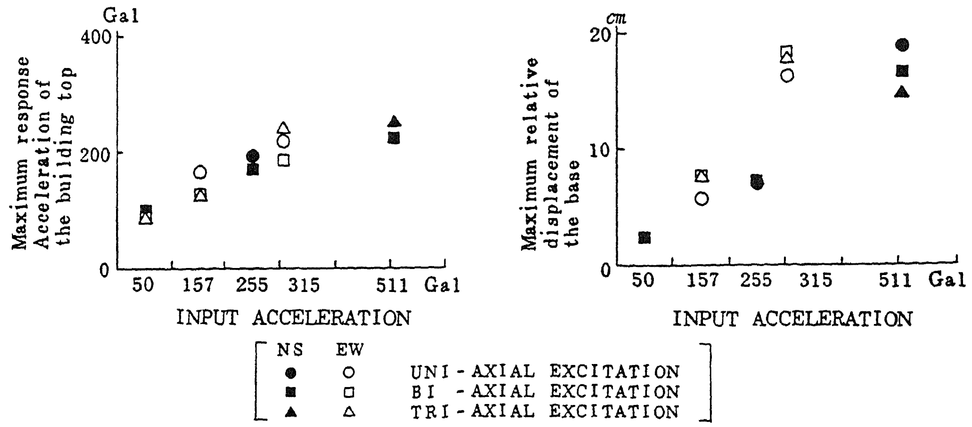


Fig.8 Change in Axial Force (μ=0.1, T_1=1 sec, T_2=5 sec)

0.15	0.15	0.15
0.10	0.10	0.10
0.05	0.05	0.05

TYPE-A

0.15	0.15	0.10
0.15	0.10	0.05
0.10	0.05	0.05

TYPE-B

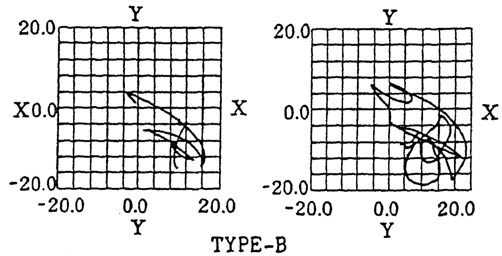
0.12	0.09	0.06
0.15	0.16	0.10
0.09	0.12	0.10

TYPE-C

Y
X

Each number means coefficient of friction for each elastic sliding bearings

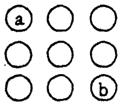
Fig.9 Variety of Coefficient of Friction
(T_1=1 sec, T_2=5 sec)



TYPE-B

ⓐ μ=0.15 ⓑ μ=0.05

Bi-axial excitation



Layout
of sliding bearings

Fig.10 Slide Displacement
of Sliding Bearings