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STUDY ON A SLIDING-TYPE BASE ISOLATION SYSTEM -SYSTEM COMPOSITION AND ELEMENT PROPERTIES-

Soichi KAWAMURA, Koji KITAZAWA, Masayoshi HISANO and Ichiro NAGASHIMA

Technology Research Center, Taisei Corporation,
Totsuka-ku, Yokohama, Japan

SUMMARY

A sliding-type base isolation system has been developed and implemented in an actual building. The system is essentially composed of sliding bearings, bearing plates and horizontal springs. The configuration and material of each element are introduced. Behavior of the system under earthquake motion is schematically explained. The superiorities of the system are itemized based on these characteristics. The mechanical properties of isolators and horizontal springs are made clear based on their loading tests.

INTRODUCTION

To mitigate the seismic forces acting on structures, many types of response control measures have been thought out. Period-lengthening type base isolation systems using elastomeric bearings are most popular at present. However, they have their own natural periods generally, which may cause resonance to earthquake motions with longer predominant periods.

Authors have developed a sliding-type base isolation system to reduce horizontal acceleration, which never resonat to any types of earthquake motion. It has been named "TASS System" which stands for "TAISEI Shake Suppression System".

SYSTEM COMPOSITION AND ELEMENTS

TASS system is essentially composed of sliding bearings, bearing plates and horizontal springs as shown in Fig.1. Sliding bearings and bearing plates support the vertical load of a superstructure and reduce the horizontal seismic force by sliding against severe earthquake motion. Horizontal springs restrain slide displacement with weak lateral stiffness. They sustain no long-term vertical load.

Two types of sliding bearing are prepared to be used according to the required performance; one is rigid type and the other one is elastic type. As shown in Photo.1(a), rigid sliding bearing is composed of PTFE (Poly-Tetra Fluoro Ethyrene) plate encased in a steel frame. Before sliding, isolation effect can not be expected but stability is maintained by this bearing. Elastic sliding bearing is a laminated chloroprene rubber bearing with PTFE plate attached at its bottom as shown in Photo.1(b). This type of bearing deforms in shear at the rubber section even before sliding occurs. Accordingly isolation effect can be expected under weak or moderate earthquake motions as well as under severe earthquake motions.

Horizontal spring is a cylindrical column made of chloroprene rubber block with attachment steel plates at both ends as shown in Photo.1(c). Both end plates are fixed to the 1st floor and foundation respectively. It deforms laterally in shear and has restraing effect against the horizontal sliding displacement. It also works as a vertical restraint connecting upper and lower structures.

Bearing plate is fundamentally made of SUS(stainless-steel) plate with smoothly finished flat surface like a mirror. In some cases which need lower coefficient of friction, PTFE covered steel plate is used. Bearing plate is fixed on the rigid foundation with exact level. It supports the vertical compressive load transmitted through sliding bearing and also makes sliding surface.

BEHAVIOR AND SUPEORIORITY

Behavior of the isolation devices under earthquake motions is schematically drawn in Fig.2, where elastic sliding bearing is supposed. Under weak or moderate earthquake motions, sliding does not occur but the superstructure displaces by the lateral deformation of rubber. Under strong and severe earthquake motions, sliding occurs in addition to the deformation of rubber.

Sliding-type base isolation system is supposed to have following superiorities.

(1) It never resonates to any type of excitation, because sliding mechanism has no natural period by itself unless extremely strong restoring force overwhelming the friction is applied.

(2) It stably supports superstructure, because bearing devices do not deform excessively due to sliding. It is needless to say that the bearing plate should be wide enough.

(3) It cripples the horizontal seismic force, because no more than friction force is transmitted to the superstructure.

LOADING TESTS OF ELEMENTS

Compression Tests of Isolators Compression tests were conducted on the small size elastic sliding bearing to confirm the vertical stiffness and ultimate strength. It turned out from the tests that the elastic sliding bearing had enough stiffness and sufficient strength. The vertical stiffness was more than 1000 times that of the horizontal stiffness. The yieling and ultimate strengths were more than 700kg/cm^2 and 1800kg/cm^2 respectively, which were determined by the laminated steel plates. Taking the long-term deflection into account, design allowable vertical stress for elastic sliding bearing is chosen σ_{0L}=70kg/cm^2 to long-term load and σ_{0S}=140kg/cm^2 to short-term load. In the case of rigid sliding bearing they are σ_{0L}=250kg/cm^2 and σ_{0S}=500kg/cm^2 respectively.

Shearing Tests of Isolators Bi-plane dynamic shear loading tests were conducted on rigid and elastic sliding bearings as shown in Photo.2 to obtain friction characteristics. Sliding rod with bearing plates on the upper and lower surfaces was penetrated through in between two sliding bearings. Dynamic horizontal load was applied cyclically by actuators under constant vertical load. Hysteresis loops obtained by the tests are idealized as Fig.3. Rigid-plastic bilinear-like loop is for the rigid sliding bearing and elasto-plastic bilinear-like loop is for the elastic sliding bearing, both with the yield forces corresponding to the dynamic coefficient of friction. Static coefficient of friction is a little larger than dynamic one, though the difference is not remarkable. Such quadrangular hysteresis loops absorb very large amount of energy.

Coefficient of Friction Dynamic coefficient of friction varies according to the contact pressure and sliding velocity. Fig.4 shows the dynamic coefficient of friction between PTFE and SUS plate related with the contact pressure. The coefficient decreases as the contact pressure increases. At the design contact pressures of the rigid sliding bearing described previously, the dynamic coefficiesnts of friction lie in μ_d=0.10~0.05. For the elastic sliding bearing, the dynamic coefficients of friction are μ_d=0.15~0.10 for the design contact pressure.

The influence of sliding velocity on the dynamic coefficients of friction is shown in Fig.6. The coefficient increases as the sliding velocity increases, however it saturates in higher velocity. Taking all these varieties into account, the design dynamic coefficient of friction is chosen as μ_d=0.05~0.15 with quite wide range.

Deformability of Horizontal Spring Static shearing test was done up to the ultimate state on chloroprene rubber used for horizontal spring. As shown in Photo.3 at 300% shear strain, cylindrical rubber block was deformed in shear restraining axial deformation. The ultimate shear strain was over 400%. Fig.7 shows shear force-shear strain relationship. Hordening-type restoring force characteristics can be seen, but the residual deformation is scarce even when large deformation is compelled. Equivalent damping factor calculated by the hysteresis loop area is as large as h=5~7%. In the practical design, maximum 250% shear strain is allowed, and the damping factor is underestimated as h=3%.

IMPLEMENTATION

The first implementation of this base isolation system to the actual building is a laboratory building in Technology Research Center, Taisei Corporation, in Yokohama JAPAN. The superstructure is a reinforced concrete building with four stories, whose total floor area is 1173m^2. Its external view and isolation devices set in the underground pit are shown in Photo.4 and Photo.5 respectively. Eight elastic sliding bearings with the diameter of 85cm (maximum bearing capacity 400t) and 75cm (maximum 300t) and with the height of 10cm are placed at the bottom of the columns as shown in Fig.8. Eight horizontal springs 35cm in diameter and 15cm high are placed at four corners.

CONCLUSION

Physical properties of the sliding-type base isolation system named TASS System were evaluated and the system are supposed to have superior performance against earthquakes.

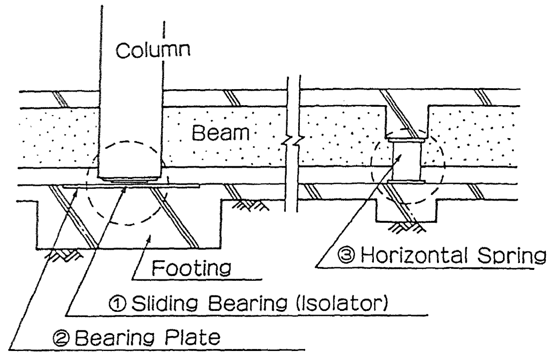
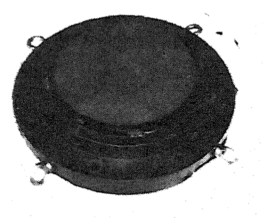
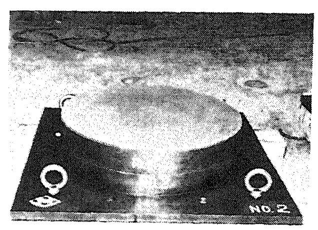


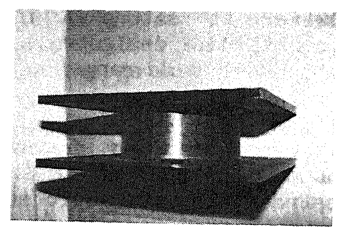
Fig.1 General Composition of TASS System



(a) Rigid Sliding Bearing

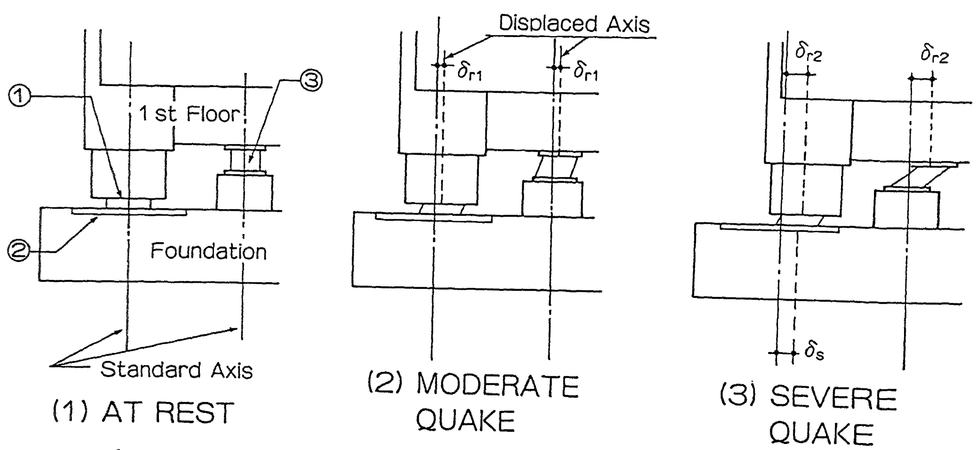


(b) Elastic Sliding Bearing



(c) Horizontal Spring

Photo.1 Elements of TASS System



(δ_{r1}: Relative Disp., δ_{r2}: Total Disp., δ_s: Slide Disp.)

Fig.2 Behavior for Isolation

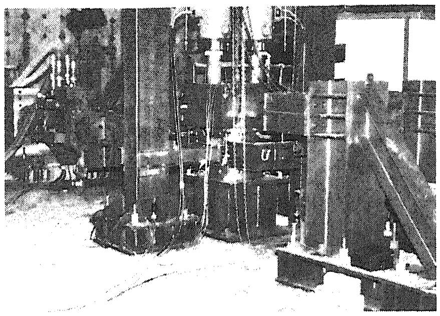
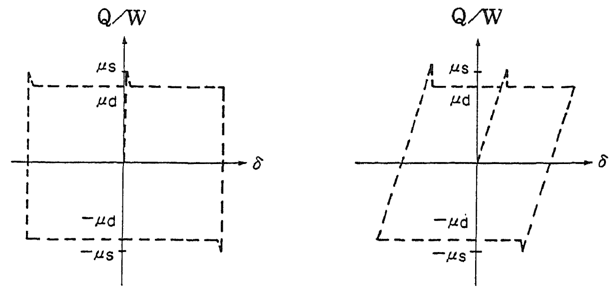


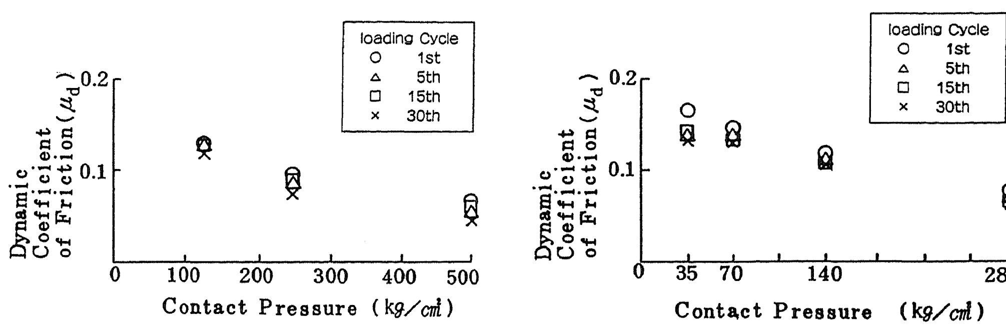
Photo.2 Bi-Plane Dynamic Shear Loading Test



(a) Rigid isolator (b) Elastic isolator

Q : Shear Force, W: Vertical Load
μs : Static Coefficient of Friction
μd : Dynamic Coefficient of Friction
δ : Displacement

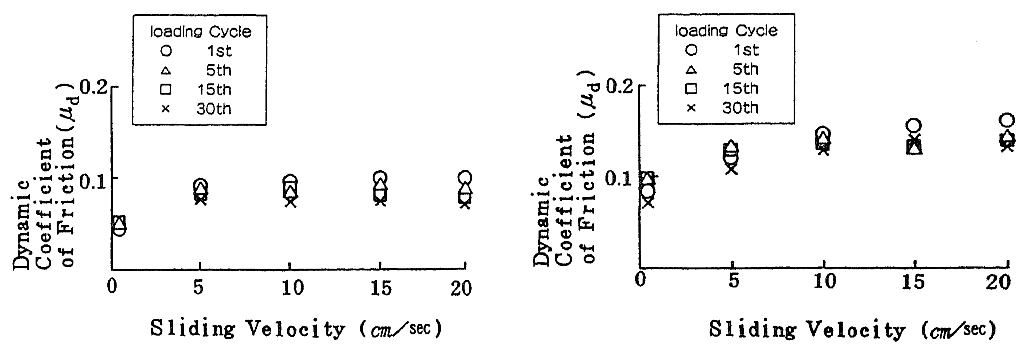
Fig.3 Idealized Hysteresis Loop



V=10cm/sec V=10cm/sec

(a) Rigid Sliding Bearing (b) Elastic Sliding Bearing

Fig.4 Dynamic Coefficient of Friction vs. Contact Pressure



σ_0=250kg/cm^2 σ_0=70kg/cm^2

(a) Rigid Sliding Bearing (b) Elastic Sliding Bearing

Fig.5 Daynamic Coefficient of Friction vs. Sliding Velocity

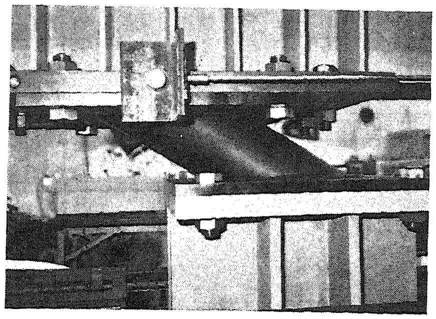


Photo.3 300% Doformation of Horizontal Spring

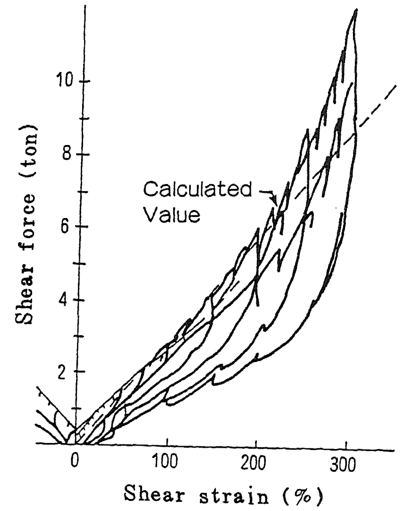


Fig.6 Shear Force-Shear Strain Relationship

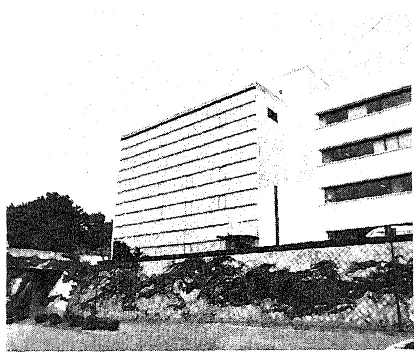


Photo.4 A New Research Building with TASS System

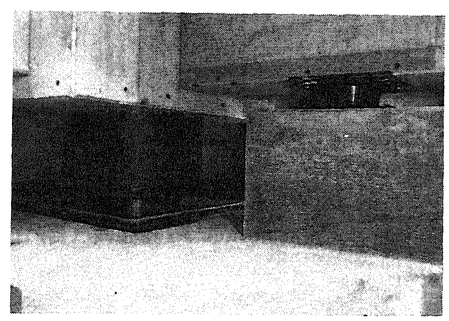


Photo.5 TASS System Actually Set

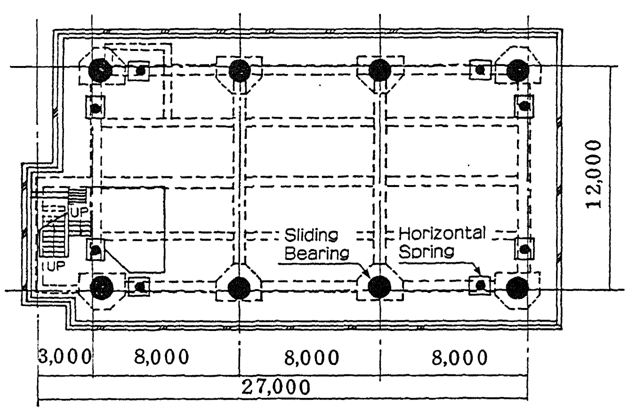


Fig.7 Layout of TASS System