I-609 DEVELOPMENT OF A HYBRID TESTING SYSTEM FOR SEISMIC ISOLATORS

William TANZO Grad. Student Kyoto Univ.
Yoshikazu YAMADA Professor Kyoto Univ.
Hirokazu IEMURA Assoc. Prof. Kyoto Univ.

INTRODUCTION In recent years, there has been a tremendous amount of interests in using seismic isolators as an effective and practical approach to earthquake-resistant design. New rubber compounds and new isolator configurations continue to be developed. For these to be widely accepted for use by the structural engineering profession, their engineering properties and their behavior during earthquakes should be well established. Extensive experimental tests are very much needed to study their behavior and provide data for analytical modeling.

Basically, seismic isolators are horizontally flexible in order to decouple the structure from the destructive horizontal ground accelerations, but should be vertically stiff to support the gravity loads of the structure. Fundamental engineering properties are usually obtained by quasi-static cyclic loading tests. Effects of the horizontal displacement range and axial load level on their damping characteristics are observed.

Effectiveness of seismic isolators are very much dependent on the characteristics of the input earthquake motion. Most experimental testing on dynamic response of seismic isolators have been done on shaking tables. However, the requirement of high vertical stiffness would necessitate a large-capacity table for a full-scale specimen or would require drastically scaled down specimens in order to accomodate them in most shaking tables.

This paper presents a loading system developed for testing both the fundamental engineering properties and the dynamic response during earthquakes of seismic isolators. Tests on a sample specimen are presented to show the versatility of the developed loading system.

A LOADING SYSTEM FOR SEISMIC ISOLATORS A loading system for testing both the fundamental engineering properties and the earthquake response of seismic isolators has been developed at the Earthquake Engineering Laboratory, Kyoto University. The system is capable of testing a wide variety of configurations and types of seismic isolators under different load conditions.

Test Rig and Physical Set-up The test rig and physical set-up of the loading system is shown in Fig.1. The actuator for horizontal motion has a maximum stroke of ±125 mm and maximum load capacity of 40 tonf. Vertical load of as high as 80 tonf can be applied on a specimen. The actuators are normally operated statically in slow quasi-static tests and on-line hybrid tests, but can be operated dynamically to as fast as 1. Hz to test for loading rate effects. The load-transfer beam is controlled to move horizontally without rotation while maintaining the vertical load at a specified value. Specimens under varying vertical loads and rotational deformation can also be tested by this loading system.

Test Modes and Control Software Presently, the loading system has been controlled under three main test modes: (1) repeated cyclic loading with increasing amplitude; (2) on-line hybrid test for resonant response under acceleration excitation with sweeping frequencies; and (3) on-line hybrid test for earthquake response. Future extension considers testing the isolator specimen as an experimental substructure in a substructured on-line hybrid test method.

An interface-rich technical computer controls the load actuators, receives feedback forces, does dynamic structural analysis in on-line hybrid tests, and other data acquisition and recording functions. Digital displacement control values are sent to a digital-to-analog converters while analog feedback signals are received through an analog-to-digital converter. Timing parameters are set within the control program to operate the loading system at the desired loading rate.

TEST ON A SAMPLE SPECIMEN The specimen used in this presentation is a high-damping rubber (HDR) seismic isolator of dimensions 250 x 250 x 48-mm. The high inherent damping in the rubber material itself is rated at about 15% of the critical viscous damping. It has been designed to support vertical loads of 40-tonf. The following tests have been conducted on the newly developed loading system to establish the engineering properties of the HDR isolator and to observe its performance during severe earthquakes.

Repeated Cyclic Loading with Increasing Amplitude Fig.2 shows the static load-deformation behavior of the HDR isolator subjected to cyclic displacements of ±25%, ±50%, ..., ±100% of the specimen height at two repetitions of each cycle. The specimen was also loaded up to ±200% to check its behavior at extreme overload situations. Other tests under this mode include different levels of vertical loads and effects of loading rate.

Resonant Response under Acceleration Excitation with Sweeping Frequencies Resonance response under acceleration excitation with sweeping frequencies is normally conducted on shaking tables. Here, on-line hybrid test procedure is used. The isolator modeled as a 2-sec SDOF system is subjected to acceleration excitation of sine waves at amplitude of 12. gal with frequencies sweeping from 5. sec to 0.5 sec. Fig.3

shows the resonant response. Different levels of acceleration amplitude are also conducted to establish resonant characteristics of the isolator at high and low loads.

On-line Hybrid Loading Test for Earthquake Response Effectiveness of seismic isolators are very much dependent on the characteristics of the input earthquake motion. Two representative types of input earthquake records are used: 1940 El Centro earthquake and the 1968 Tokachi-oki earthquake recorded at Hachinohe. Fig.4 shows the response of the 2-sec SDOF isolator system to the Hachinohe record scaled to 0.1g. Different levels of acceleration amplitude are used to check for isolator earthquake performance at different displacement range.

CONCLUSIONS A loading system for both establishing the engineering properties and for simulating the earthquake response of seismic isolators has been developed. The basic isolator characteristics of low horizontal stiffness and high vertical stiffness are considered in designing the physical set-up of the system. The loading system can be operated at quasi-static test mode and on-line hybrid test mode suitable for testing recent and future innovations in seismic isolator system. Compared to conventional quasi-static testing or shaking table testing, the newly developed loading system provides more detailed information on the static and dynamic behavior of seismic isolators.

ACKNOWLEDGEMENTS The authors wishes to express their sincere gratitude to the engineers and management of Toyo Rubber Co., Kawaguchi Metal Co., and Nitto Engg. Consultants for their assistance.

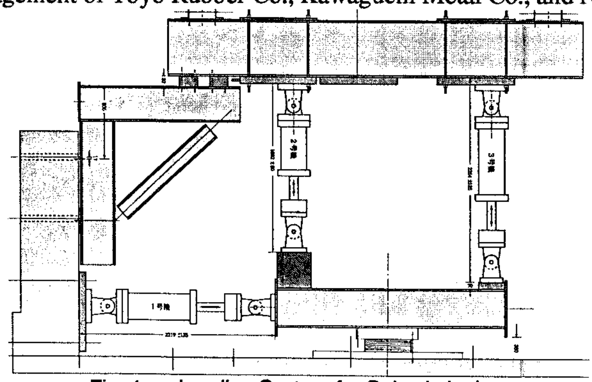

Fig. 1 Loading System for Seismic Isolators

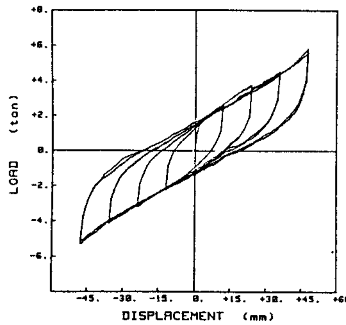

Fig. 2 Load-Deformation Behavior under Cyclic Loading

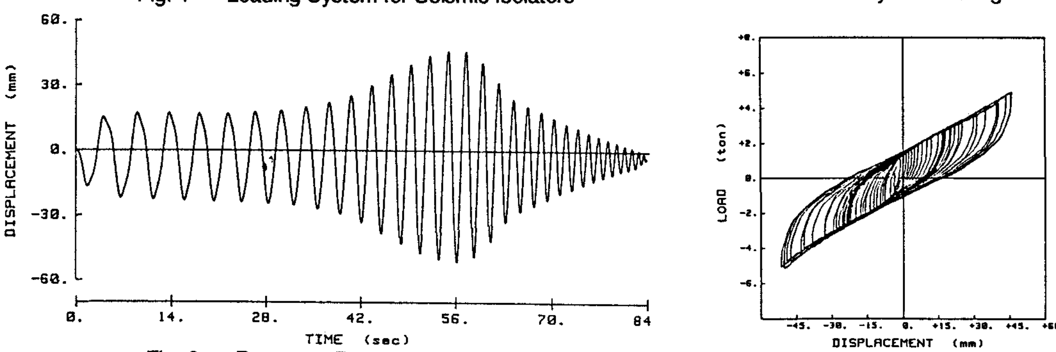

Fig. 3 Resonant Response under Acceleration Excitation of Sweeping Frequencies

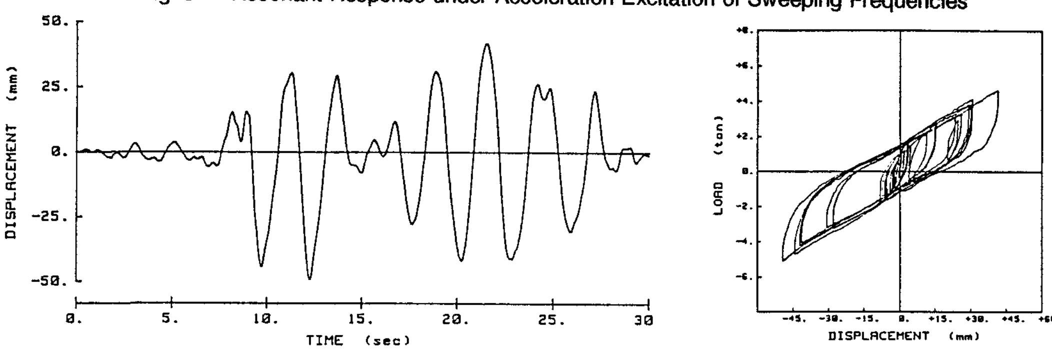

Fig. 4 On-line Hybrid Response under Hachinohe Earthquake