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Performance Validation of Large Seismic Response Modification Devices

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Abstract

In the seismic retrofit design of California's Toll Bridges, seismic isolation is used in several bridges to limit the seismic force input into the superstructure and to avoid costly superstructure retrofit measures which would require partial lane closures and traffic interruptions. Isolation bearings designed for these seismic bridge retrofit projects can have ±1.2 m horizontal design displacements while carrying up to 50 MN of axial load from gravity and seismic overturning effects. Viscous dampers to provide energy absorption and deformation control at movement joints are designed with up to 5 MN capacity. Seismic Response Modification Devices (SRMDs) with these capacities have not been manufactured or tested to date and questions concerning scale-up effects for these response modification devices become critical since the safety of the retrofitted bridge relies on well defined friction and energy absorption characteristics. Only full-scale real-time dynamic testing of these new SRMDs can verify the actual response characteristics and thus validate the structural retrofit concept.

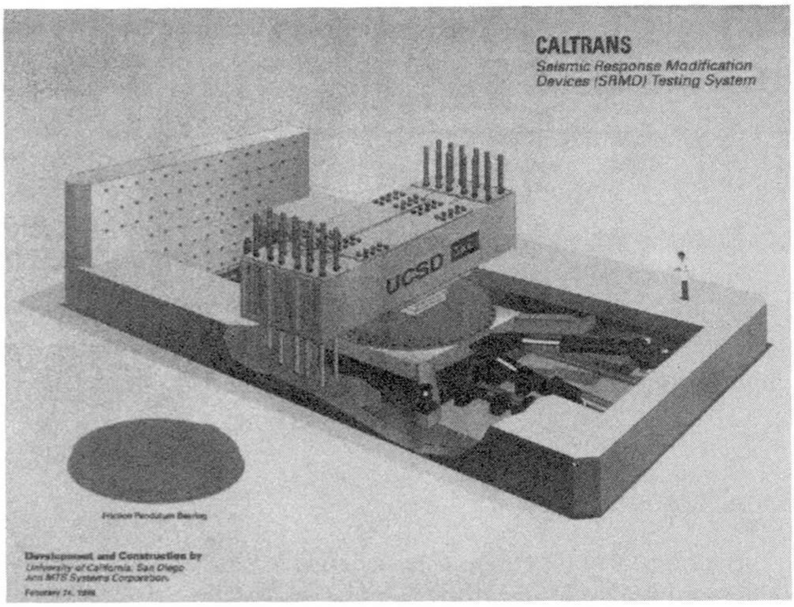

Fig 1 SRMD Test System

Table 1 Technical Specifications

Vertical Force	53,400 kN
Longitudinal Force	8,900 kN
Lateral Force	4,450 kN
Vertical Displacement	±0.127 m
Longitudinal Displacement	±1.22 m
Lateral Displacement	± 0.61 m
Vertical Velocity	±254 mm/s
Long. Velocity	±1,778 mm/s
Lateral Velocity	±762 mm/s
Height of Specimen	Up to 1.52 m
Relative Platen rot.	±2°

The Caltrans Seismic Response Modification Device Test System (SRMD), developed jointly by Caltrans, UCSD, and MTS, requires an exceptional hydraulic power, equal to about 19,000 liters (5,000 gal) of oil storage and pressurization through nitrogen gas up to 34 Mpa (5,000 psi), in order to achieve the technical specifications indicated in Table 1. The machine performance, the different types of isolating devices and dampers to be tested, and the testing objectives and procedures, drove the overall design approach. The isolating devices considered were the Friction Pendulum System (FPS) and high damping rubber or lead core elastomeric isolation bearings, proposed solutions for the Benicia-Martinez and Coronado bridges, respectively, as well as viscous dampers and lock-up devices, common to almost all the toll bridge retrofit projects. Testing objectives ranged from slow speed uni-directional testing for basic performance characterization to high speed, 3-D testing for energy based analysis. The investigation of the effect of wear and aging was also an important issue in the proposed test program, through re-characterization of the performance of the prototype SRMDs already exposed to the actual bridge loads, deformations and environmental conditions. The testing system consists of a horizontal prestressed concrete reaction frame (concrete box), and of a moving platen, connected by four horizontal actuators to the concrete box. The platen slides over four hydraulic hydrostatic low friction bearings attached to the floor of the concrete structure. The platen also extends with four steel outrigger arms that support four low friction-sliding actuators at their tops. The testing system is completed by two additional reaction structures: a steel cross beam, removable and linked to the concrete box through a tie-down rod system, and a heavily prestressed reaction wall on one end of the machine. Due to the large displacements of the test specimens in the longitudinal and transverse directions, the traditional solution of a platen with hinge connection to horizontal and vertical actuators was not practical. This configuration would have required very long stroke vertical actuators, with deep excavation inside the existing building. Space limitations, difficulties of access for tall excavating equipment and the need to maintain the rest of the existing laboratory in working condition during construction made this solution impractical. The adopted solution was the use of 4 vertical hydraulic sliding bearings which support the moving platen, apply the vertical load, and allow horizontal motion and swivel capacity with very low friction (less than 0.2% of vertical force). The four horizontal actuators have a 2.5m stroke, 800 ton capacity and dual 20m^3/min. servo-valves, and the 4 vertical low friction bearing actuators have 0.25m stroke, 2,000 ton capacity and 11m^3/min. servo-valves each.

This paper describes the design, construction and performance characterization of a full-scale testing facility (Fig. 1) which will allow the real-time 6-DOF dynamic characterization of these new generation of seismic response modification devices for long span bridges.