Seismic Isolation for Extreme Cold Temperatures

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ABSTRACT

The seismic isolation of two structures located in seismically active regions and subject to extreme cold temperatures is presented. These projects used Friction Pendulum seismic isolation bearings because of their ability to maintain their design properties over a wide range of temperatures, including very low temperatures. Results from tests of Friction Pendulum bearings over a temperature range of -68°C to +46°C are reported herein.

INTRODUCTION

Friction Pendulum seismic isolation bearings use the characteristics of a pendulum to provide the desired isolated structure period and avoid the strongest earthquake forces. During an earthquake, the articulated slider within the bearing slides along a stainless steel concave surface, causing the supported structure to move with small pendulum motions (see Fig. 1). The natural period of vibration and lateral stiffness of the Friction Pendulum bearing are determined by the radius of curvature of the concave surface. The bearing lateral stiffness does not change with temperature, as shown by the test results reported herein. Tests of rubber isolation bearings have shown that their stiffness increases significantly at low temperatures, and short-term exposure to extreme cold results in permanent damage to the rubber (Roeder et al. 1987, Mander et al. 1996).

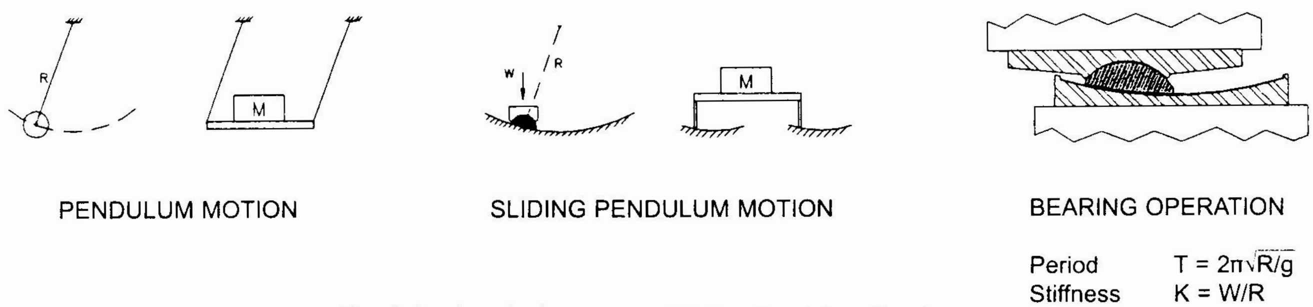

Fig. 1 Basic Principles of the Friction Pendulum Bearing

PROJECT DESCRIPTIONS

White River Bridge, Yukon, Canada

The White River Bridge located in the Yukon, Canada (Fig. 2) is a 590 feet long, steel girder structure supported on 9 Friction Pendulum bearings (Fig. 3). Use of isolation bearings achieved an elastic structure response for the design level earthquake (0.2g peak ground acceleration) at a substantially lower cost than would have been possible without isolation bearings. The Friction Pendulum bearings for the White River Bridge had to maintain their design stiffness and damping over a temperature range of -48°C to +39°C. Figure 4 shows a bearing being cooled with liquid nitrogen for testing at low temperatures. Results of tests over temperatures ranging from -68°C to +46°C showed consistent and repeatable bilinear force-displacement hysteretic loops (Fig. 5). The bearings maintained their design stiffness and damping over the entire temperature range. The tests showed that the bearing's dynamic friction is moderately increased at lower temperatures (Fig. 6), which increases the bearing's effective damping. These changes in temperature and dynamic friction had only a small effect on bridge seismic shear (Fig. 7).

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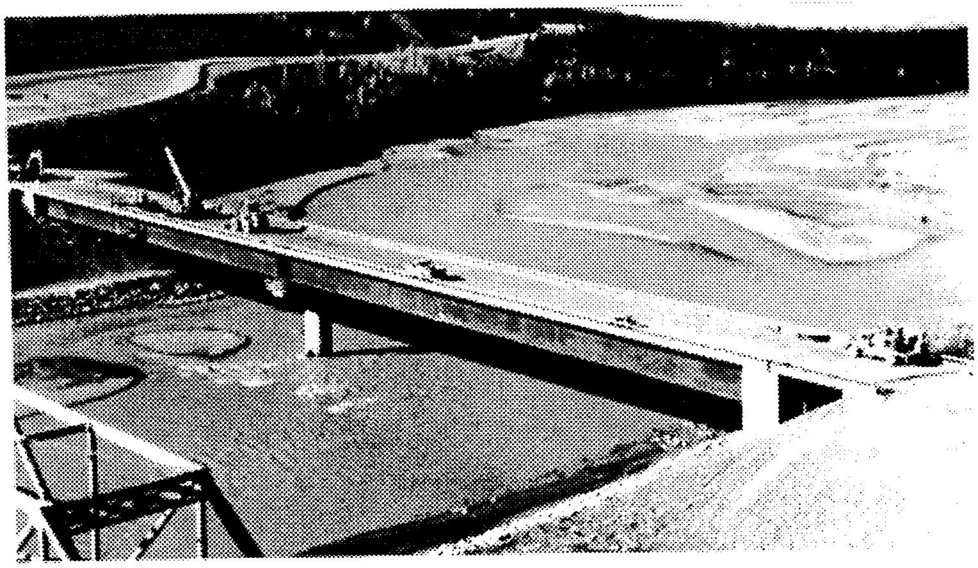

Fig. 2: White River Bridge, Yukon, Canada

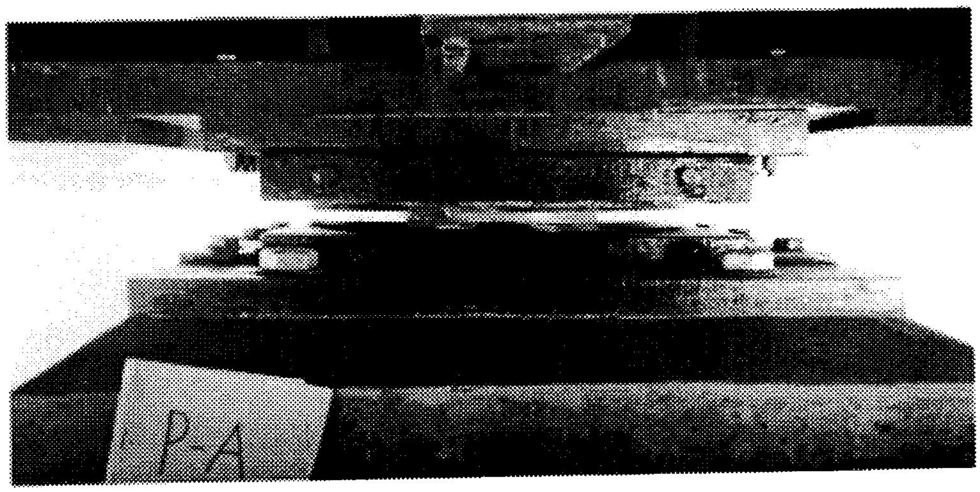

Fig. 3: Installed Bearing at Pier

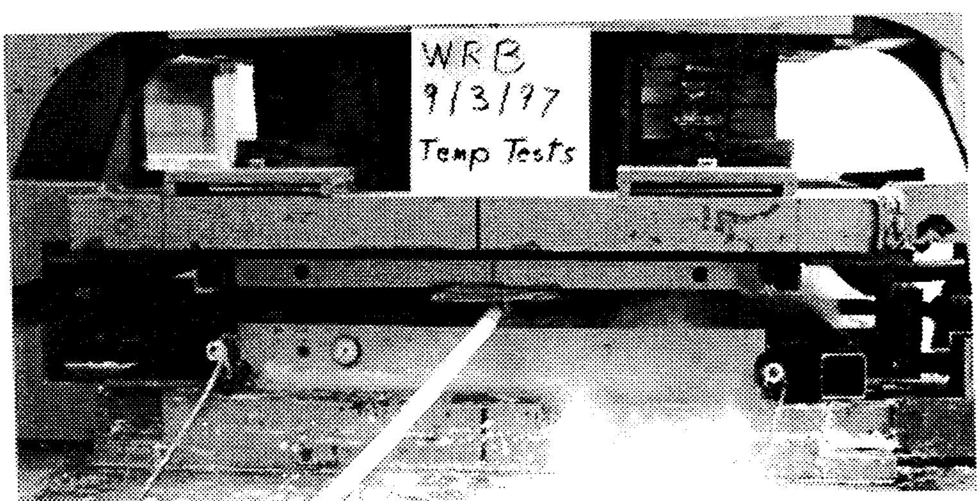

Fig. 4 Bearing Tests at Cold Temperatures

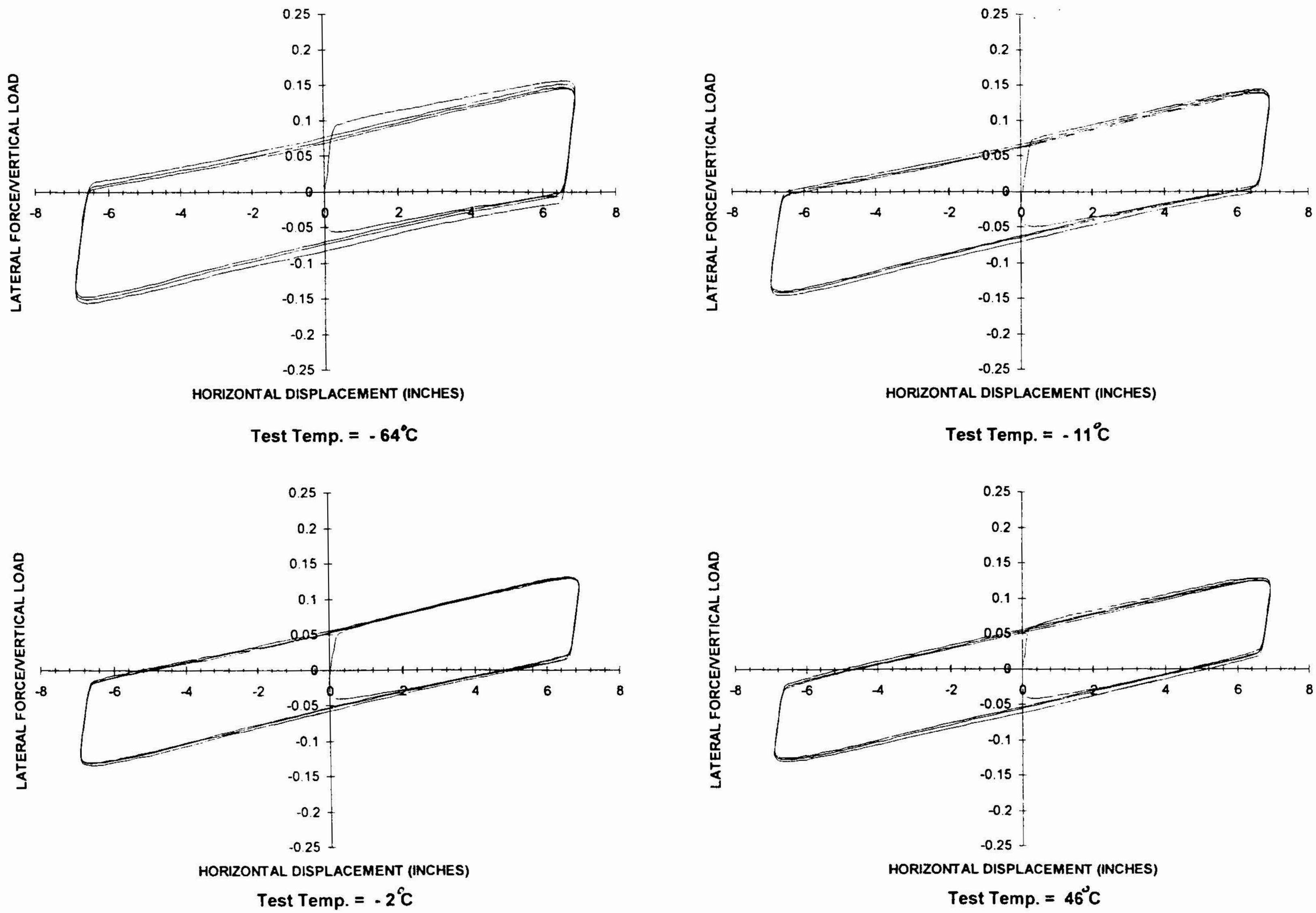

Fig. 5 Bearing Force-Displacement Hysteretic Loops at Different Temperatures

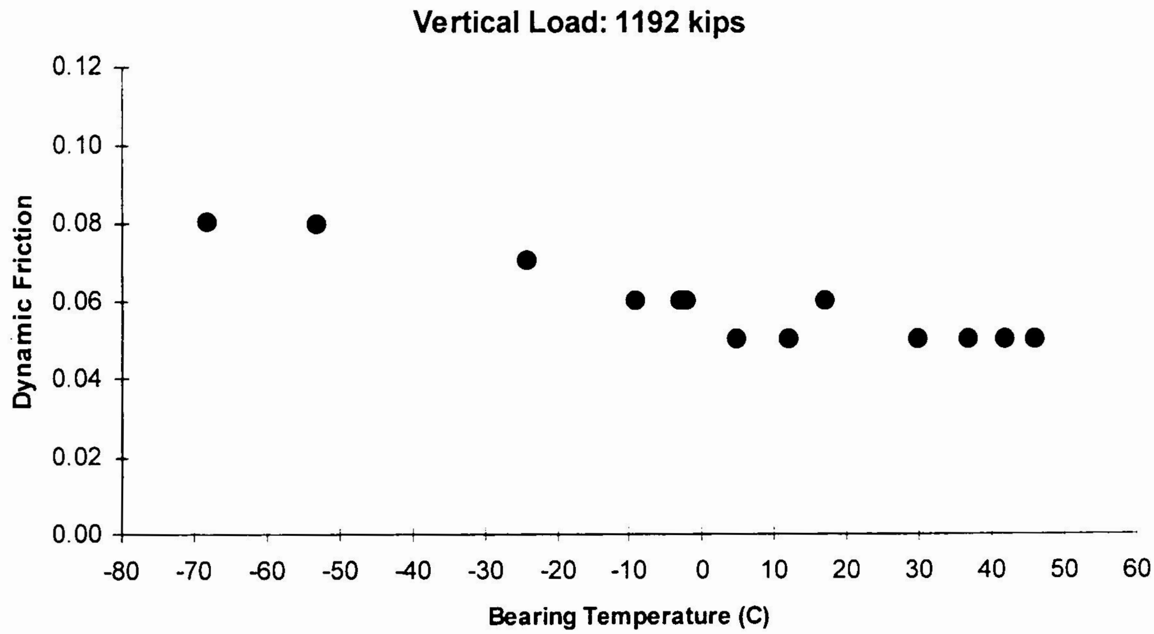

Fig. 6 Effect of Temperature on Bearing Dynamic Friction

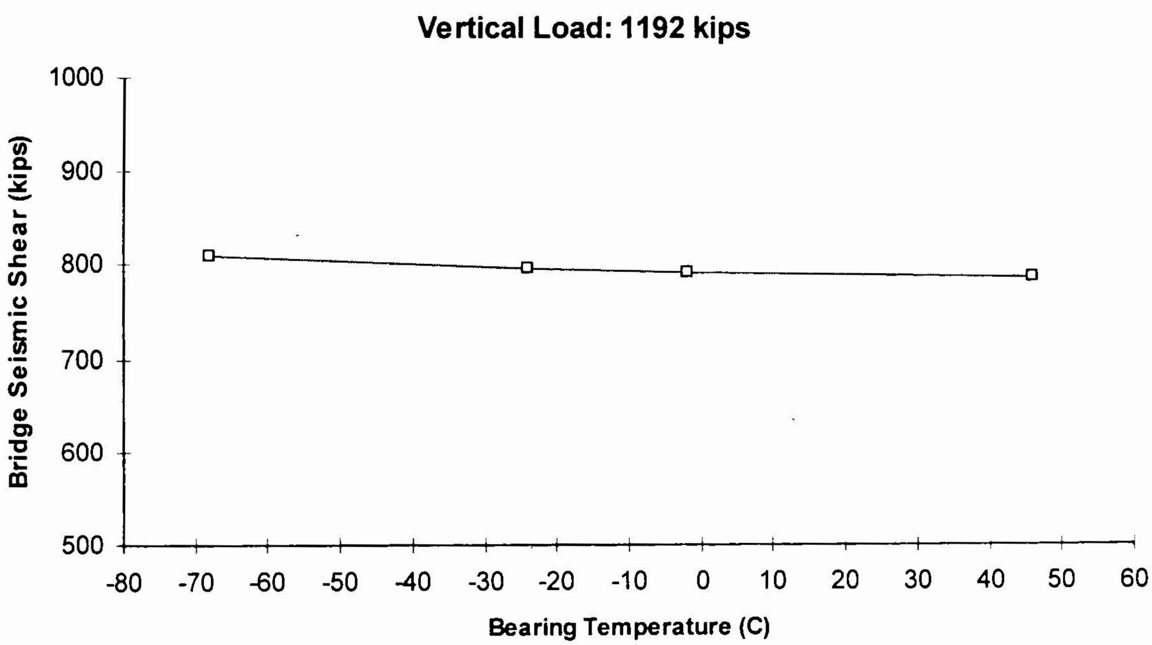

Fig. 7 Effect of Temperature on Bridge Seismic Shear

Liquid Natural Gas Tanks, Greece

Friction Pendulum bearings were used for the seismic isolation of two liquefied natural gas (LNG) storage tanks (Fig. 8) on the island of Revithoussa, near Athens, Greece. The total capacity of the tanks is 38 million gallons. Each tank is supported by 212 Friction Pendulum bearings, enclosed within a large pit (Fig. 9). The bearings were required to be undamaged by short-term exposure to a temperature of -50°C, and to maintain a tight tolerance in design properties over a design temperature range of -7°C to +32°C. Tests of these bearings over the design temperature range showed that the bearing properties remained within specification. The effect of temperature change on the tank seismic base shear is shown in Fig. 10.

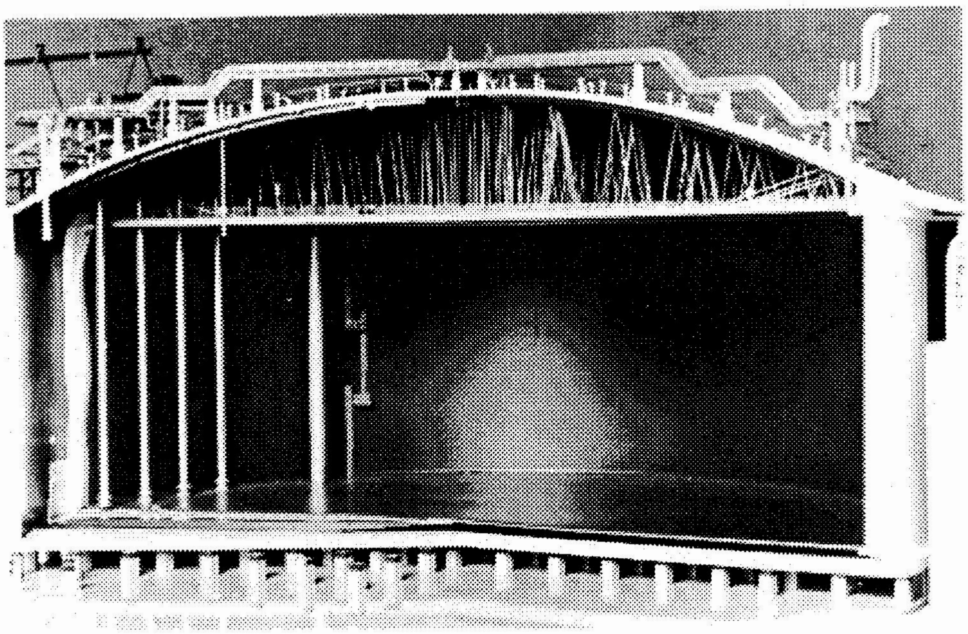

Fig. 8: Liquid Natural Gas Tank

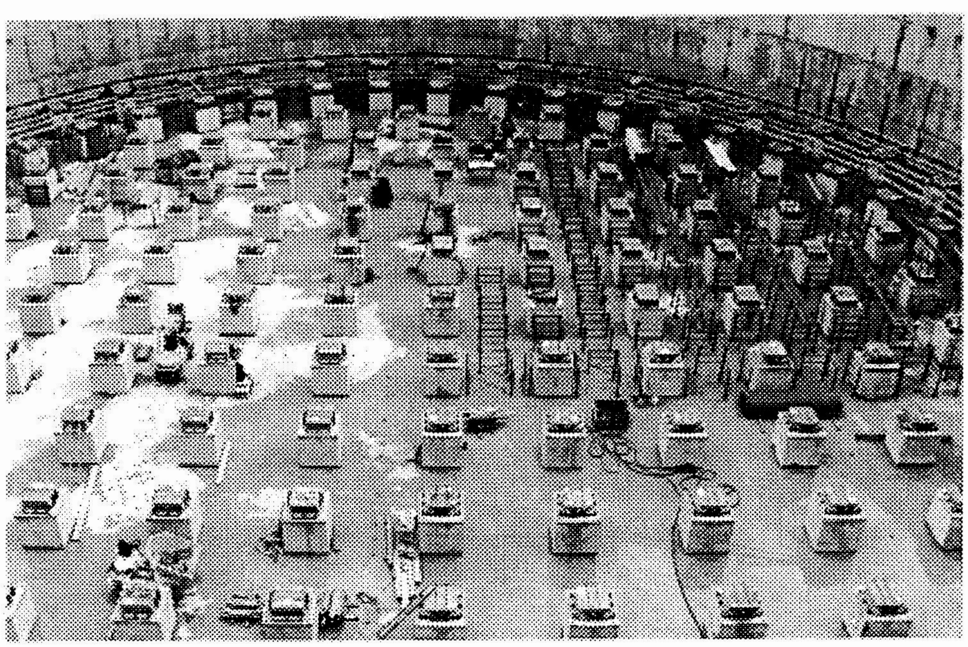

Fig. 9 Installation of Friction Pendulum Bearings

CONCLUSIONS

Tests of Friction Pendulum isolation bearings showed that the lateral restoring stiffness did not change with changes in bearing temperature. These test results are consistent with prior reported test results (HITEC 1998). The consistency in lateral restoring stiffness results in a consistent dynamic natural period of vibration regardless of temperature extremes. Cold temperatures were observed to increase the dynamic friction and effective damping of the bearings. The increase in dynamic friction at cold temperatures, reduces bearing seismic displacements. The reduction in bearing displacement reduces the bearing restoring force, which offsets the increase in bearing force from the higher friction. The consistent bearing stiffness and period, and moderate changes in bearing friction, result in stable seismic responses over a wide range of temperatures.

REFERENCES

HITEC 1998, *Evaluation Findings for Earthquake Protection Systems, Inc., Friction Pendulum Bearings,* Technical Evaluation Report Prepared by Highway Innovative Technology Evaluation Center (HITEC), CERF Report: Hitec 98-07 #40370, September 1998.

Mander, J.B., Kim, D. K. and Chen, S.S. 1996. *Temperature and Strain Rate Effects on the Seismic Performance of Lead Rubber Bearings*, Proceedings of World Congress on Joints & Bearings, Sacramento, California, American Concrete Institute.

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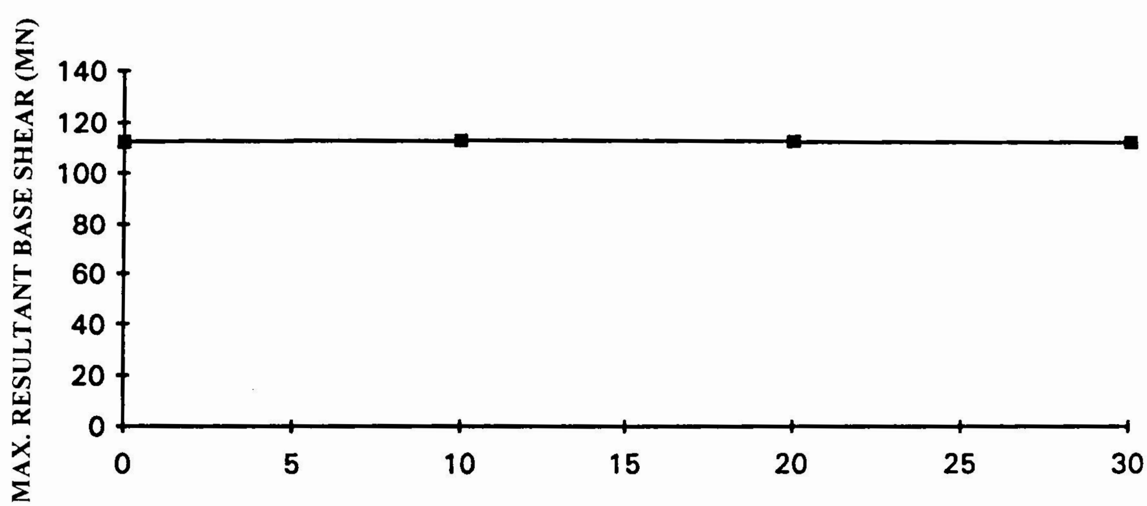

Fig. 10 Effect of Temperature on Tank Base Shear