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Ongoing Studies of the Foothill Communities Law and Justice Center

Peter W. Clark[1], Ian D. Aiken[2], and James M. Kelly[3], ASCE Members

Abstract

An experimental program has been completed recently to evaluate the long-term performance of the seismic isolation bearings manufactured for the Foothill Communities Law and Justice Center. Two pairs of full-size bearings were tested — one was removed from the building approximately 12 years after installation, and the other pair was from the original set of 4 prototype bearings. This article summarizes the tests of the bearings removed from the building, which indicate that while there are minor differences from the original properties, the isolation system should be expected to perform as designed in the case of a strong earthquake.

Introduction

The Foothill Communities Law and Justice Center (FCLJC) in San Bernardino, California, was the first seismically-isolated building constructed in the United States. The building is a five-story plus basement braced steel frame supported on 98 high-damping rubber bearings, and it was completed in 1985. A thorough summary of the design and analysis of the building is provided in (Tarics, Way, and Kelly, 1984). Details of the prototype test program are provided in (Celebi and Kelly, 1984); the original production test program is outlined in both (Tarics, Way, and Kelly, 1984) and (Tarics, Kelly, Way, and Holland, 1986). This paper describes a series of tests performed on full-size isolators removed from the building, and comparisons between this data and results from the original quality control tests in 1983.

FCLJC Bearing Design and Production

The isolation system in the FCLJC incorporates eight different bearing designs and four different high damping rubber compounds. Each bearing has an outer diameter of 0.76 m (30 in.) and a shim diameter of 0.61 m (24 in.); several different combinations of shim/rubber thicknesses allow a range of axial loads to be accommodated. To verify the original design and manfacturing procedures, Oil States Industries (now the Structural Bearings Division of Furon), Athens, Texas, built four prototype bearings which were tested at the Earthquake Engineering Research Center (EERC) of the University of California at Berkeley in July, 1983 (Celebi and Kelly, 1984). The production bearings were then manufactured and tested between September and November, 1983, and were installed in 1984.

Long-Term Monitoring of the FCLJC Isolation System

The prototype and production manufacturing and testing sequence described above was instituted in part because the use of seismic isolation for the FCLJC represented the first application of this innovative technology. For the same reason, a long-term maintenance program was established that specified that production bearings be removed from the building

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1. Visiting Post-Doctoral Researcher, University of California at Berkeley, Earthquake Engineering Research Center, 1301 South 46th Street, Richmond, CA 94804
2. Research Engineer, University of California at Berkeley, Earthquake Engineering Research Center, 1301 South 46th Street, Richmond, CA 94804
3. Professor in the Graduate School, University of California at Berkeley, Earthquake Engineering Research Center, 1301 South 46th Street, Richmond, CA 94804

and tested ten years after installation. On August 5 and 6, 1995, two bearings were removed from underneath the building and replaced with the two of the prototype bearings.

All of the bearings — both the prototype and production — available for retesting were originally classified as “type A” isolators. This design has a total height of rubber of 0.304 m (11.97 in.) and a layer shape factor of 9.5. The nominal design axial load is 1535 kN (345 kips). The bearings removed from the building were numbered A2 and A5 in the original test sequence. The bearings are connected to the foundation and superstructure via dowel pins, instead of the bolted connection which is more commonly-used today. Analyses for the maximum credible earthquake carried out in during the initial design indicated a maximum displacement of the corner bearings of 0.381 m (15 in.) (Tarics, Way, and Kelly, 1984).

Original Production Tests (1983)

Five tests were performed on each production bearing with minimal instrumentation in place, leading to a single compression stiffness and averaged effective shear stiffnesses at three strain amplitudes. The two bearings that were removed from the building in 1995, numbers A2 and A5, were not tested together in the original production test program. Bearing A2 was tested originally with bearing A4, and bearing A5 was tested originally with bearing A17. Although individual compression stiffnesses are available for each bearing (see Table 1), the configuration of the shear testing set-up prevented individual shear stiffnesses from being calculated. Therefore, only the averaged shear stiffnesses of bearing sets A2-A4 and A5-A17 are available from the original tests, as presented in Table 1. Note that the force values at the target displacements were manually read as the bearing was loaded to a maximum shear strain of 50 percent, and the shear test consisted of only a single half-cycle of displacement. The effective stiffnesses of the A5-A17 pair were as much as 8 percent lower than those from the A2-A4 pair.

Re-Tests of Production Bearings (1995)

The production bearings were re-tested on August 31, 1995. To allow direct comparisons to be made with the original production test data, the two bearings were subjected to the identical production test sequence. All of the tests were performed in a test machine at the Structural Bearings Division of Furon, in Athens, Texas, that is designed to test two bearings simultaneously under combined compression and shear. Bearing A5 was installed above bearing A2, and compression tests were performed on both bearings (A2 and A5) before starting the shear tests. The production shear test involved a single half-cycle displacement excursion at a constant velocity to a shear strain of 50 percent under the design axial load, P_{des}, of 1535 kN (345 kips).

Compression Test Results

The compression test results are valuable because they represent the only basis on which the long- term performance of individual isolators from the FCLJC can be evaluated. It is felt that the most reliable vertical stiffness is that calculated over the load range from 0.6 to $1.5P_{des}$. The upper portion of Table 1 compares the original vertical stiffnesses with those determined from the retests. The results from bearings A4 and A17 are also included for completeness. The peak-to-peak stiffnesses based on the dial gage readings are used because the original vertical stiffnesses were calculated in the same fashion. The results show that bearing A2 is approximately 1.3 percent softer than before, and bearing A5 is approximately 5 percent softer. Given the uncertainty in the measurement procedure, the load range selected for interpreting the vertical stiffness, and differences in the testing equipment, this represents a negligible change in the bearing compression properties.

Production Shear Test Results

As noted before, the original production tests measured the average stiffness of pairs of bearings at discrete displacements, and the A2-A5 bearing pair was not tested together originally. Although this arrangement prevents direct comparisons with the original tests, a general trend can be revealed by evaluating the shear test results in tandem with the compression test results.

Measured Stiffness [MN/m (kips/in.)]	**Bearing Number**			
	A4	**A2**	**A5**	**A17**
K_V original	589 (3362)	548 (3126)	602 (3436)	491 (2802)
K_V original (2nd run)	—	553 (3157)	—	498 (2840)
K_V 1995	—	538 (3072)	572 (3265)	—
K_H at 2% strain — original	12.3 (70)		11.4 (65)	
K_H at 2% strain — 1995	—	8.7 (49.9)		—
K_H at 10% strain — original	4.9 (28)		4.6 (26)	
K_H at 10% strain — 1995	—	3.5 (19.7)		—
K_H at 25% strain — original	2.8 (16)		2.5 (14)	
K_H at 25% strain — 1995	—	2.2 (12.4)		—
K_H at 50% strain — original	1.7 (9.8)		1.7 (9.5)	
K_H at 50% strain — 1995	—	1.6 (9.4)		—

All vertical stiffnesses computed based on peak-to-peak dial gage displacements in the load range from 0.6 to $1.5P_{des}$, where P_{des} =1535 kN (345 kips).

Table 1. Measured Bearing Properties in Production Tests

Because the production shear test was only a single half-cycle of displacement to 50 percent shear strain, the original effective stiffnesses were determined from force values that were manually read at the target displacements during the cycle to 50 percent. In the production retest, the entire curve was traced, and the forces (and therefore the effective stiffnesses) at the target displacements were determined from the digital data. Figure 1 shows the original derived force-displacement curves for bearing pairs A2-A4 and A5-A17 superimposed on the measured force-displacement curve for bearings A2-A5. It is clear that the re-tested bearings are not quite as stiff as the original two pairs of bearings, but the difference appears to decrease as the shear strain is increased. Unfortunately, no data exists for comparisons at strains larger than 50 percent. The numerical stiffness values are presented in Table 1 and indicate that the stiffness of the A2- A5 pair is approximately 15 percent lower than the mean of the two original pairs at a shear strain of 50 percent. This result is contrary to what would be expected since some studies indicate elastomers may stiffen with time, but such behavior certainly depends on the specific rubber compound, and additional testing is needed before the long-term properties of elastomers can be predicted precisely. However, these results do indicate that over the course of a decade, the relative variations in properties for carefully-formulated compounds can be expected to be small.

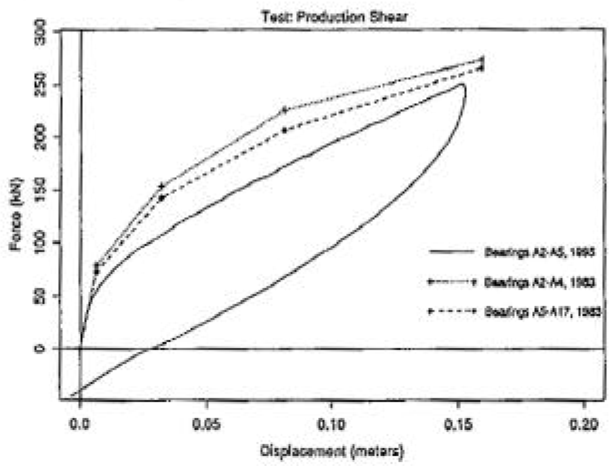

Figure 1. Comparison of Original Force-Displacement Behavior (Derived from 1983 Tests) with that Recorded in 1995 Tests

Large-Displacement Tests

As a validation of the large-strain capacity of the bearings after having been under axial load for more than ten years, the original prototype test sequence was performed after the production sequence was completed. The peak displacement amplitude in these tests reached 0.38 m (15 in.) (loading in the positive direction only), and the bearings exhibited stable behavior through all of these tests. Given that the maximum gap between the edge of the FCLJC and the perimeter retaining wall is 0.41 m (16 in.), it was decided to perform an additional test consisting of three fully-reversed displacement cycles to this amplitude under an axial load of 2589 kN (582 kips). The measured force-displacement behavior in this test is shown in Figure 2. Although the shear dowels are evident in the photograph and it appears that the bearing is approaching a geometrically-unstable condition (roll-out), the stiffness at the peak displacement is positive and does not deteriorate significantly with repeated cycling. This test confirmed the stability of the existing isolation system, and the production bearings were replaced in the building several weeks after the tests were completed.

Conclusions

This article has described the results of a series of tests of high damping rubber seismic isolation bearings from the Foothill Communities Law and Justice Center more than twelve years after their manufacture. The compression stiffnesses of the individual bearings were virtually identical to their original values, while the shear stiffnesses appear to have decreased by as much as 15 percent. Unfortunately, direct comparisons with the original shear data are not possible because a different pair of bearings was tested in 1995 than had been tested originally. Large-strain tests showed that the bearings were able to sustain cyclic displacements equal to the seismic gap around the perimeter of the building.

These results represent the first data on long-term properties of high damping seismic isolation bearings and provide confidence in the stability of the properties of such isolators. Additional testing and evaluation of long-term properties of the prototype bearings and a set of lead-rubber bearings manufactured for the FCLJC is ongoing.

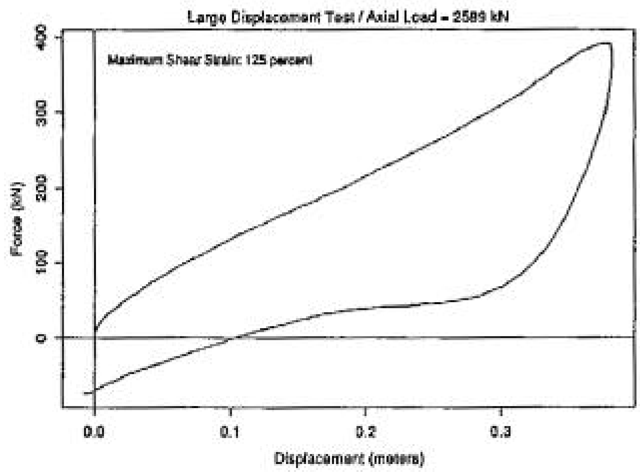

Figure 2. Force-Displacement Behavior During Test to ±0.41 m (±16 in.)

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