SEISMIC AND SERVICE-LEVEL BEHAVIOR OF BRIDGES SUPPORTED BY SPHERICAL SLIDING BEARINGS

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Abstract

Spherical sliding bearings (SSBs) have been adopted as seismic isolation devices for bridges due to their stable hysteretic behavior, self-centering capability, and relatively low structural height. In these bearings, the frictional response is governed by the friction coefficient and the acting axial force. However, in actual bridge systems, the axial force is not constant and varies during earthquakes, which can significantly affect the load–displacement relationship and the overall performance of the bearings.

This paper summarizes a series of experimental studies on the behavior of bridges supported by spherical sliding bearings under both seismic and service-level conditions. First, the seismic behavior of SSBs is discussed based on large-scale shaking-table tests of a bridge model supported by multiple bearings. The tests demonstrated that axial force variation due to rocking and vertical motion significantly affects sliding stiffness and hysteretic response.

Next, the service-level behavior is presented based on experimental investigations of bridge girders supported by single- and double-SSB systems under live loads. Under live load, the bearings must accommodate the girder's rotation as well as the slider's horizontal displacement. The single-SSB system with a hinge accommodated both smoothly, whereas in the double-SSB system the slider could not follow the rotation, suggesting possible local stress concentration. The concave-plate orientation also affected the horizontal reaction transmitted to the substructure.

Keywords*: Spherical sliding bearing, Seismic isolation, Axial force effect, Service-level behavior, Shaking table test*

1. Introduction

Lead-plugged rubber bearings and high-damping rubber bearings have been commonly used as seismic isolation devices for bridges in Japan. However, damage was reported during major earthquakes such as the 2011 Tohoku and 2016 Kumamoto earthquakes, partly attributed to the aging of laminated rubber. In

addition, because of their relatively large height, replacing existing steel bearings with rubber bearings for seismic retrofitting is often difficult. Spherical sliding bearings (SSBs), which are lower in height and exhibit stable hysteretic behavior with self-centering capability, are a suitable alternative for retrofitting existing bridges. In SSBs, the frictional response is governed by the friction coefficient and the acting axial force at the slider–concave interface. In actual bridge systems, this axial force varies during earthquakes due to rocking and vertical motion and may also redistribute between bearings under service-level conditions. This paper summarizes experimental studies on the behavior of bridges supported by SSBs under both conditions and discusses the unified findings.

2. Seismic Behavior under Shaking Table Tests

A series of shaking table tests was conducted on a three-dimensional large shaking table (table size = 8 m x 8 m) to investigate the seismic behavior of SSBs, focusing on the effect of the acting axial force on the horizontal response [1]. The setup of the bridge model supported by four SSBs is shown in Fig. 1. The specimen had a span of 5.71 m and a width of 1.43 m, with a superstructure weight of 260 kN and an average axial force of 65 kN per bearing. Each SSB consists of a concave plate, a hinge plate, and a slider. The tests demonstrated that the acting axial force on each bearing varies considerably during seismic excitation, primarily due to rocking vibration and vertical motion induced by sliding along the spherical surface. This variation significantly affects the horizontal load–displacement relationship, particularly the sliding stiffness and the hysteretic response.

3. Service-Level Behavior under Live Loads

To investigate service-level behavior, static loading tests were conducted on a steel girder supported by SSBs (Fig. 2). Under live load, the girder rotates at the supports, and the bearings must accommodate this rotation together with the slider's horizontal displacement. The single-SSB system with a hinge accommodated both motions smoothly. In the double-SSB system, however, the slider could not follow the rotation: a gap formed between the slider and the concave plates, and only part of the slider carried the load, indicating possible local stress concentration. The concave-plate orientation in the single SSB also affected the horizontal reaction transmitted to the substructure.

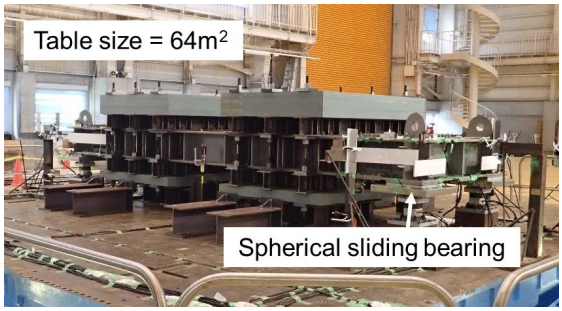

Fig. 1 – Setup of shaking table test

Fig. 2 – Setup of service-level test

4. Summary

The experimental studies summarized above demonstrate that the detailed bearing mechanics significantly affect the performance of bridges supported by SSBs under both seismic and service-level conditions. Under seismic loading, the acting axial force varies due to rocking and vertical motion, significantly affecting sliding stiffness. Under service-level loading, the bearing configuration, the presence of a hinge and the concave-plate orientation, governs the load-transfer mechanism and may cause local stress concentration on the slider. Therefore, the design and performance evaluation of bridges with SSBs should explicitly account for these effects under both loading conditions.

5. References

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