The Fifth International Bridge Seismic Workshop (5IBSW)
Hunan University, Changsha, China, June 5-7, 2026

SEISMIC DESIGN AND UNSEATING PREVENTION PERFORMANCE OF SHEAR KEYS FOR HIGHWAY BRIDGES

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Extended Abstract

Small-to-medium span highway bridges equipped with laminated rubber bearings are highly susceptible to girder unseating during earthquakes. Shear keys can be installed at the bottom of girders to prevent such unseating along the longitudinal direction of the bridge through collision with the substructure.

Shear keys are widely used on cap beams to limit relative displacements between superstructures and substructures perpendicular to the bridge axis, referred to as transverse shear keys herein (see Fig. 1(a)). Considering factors such as the position and ratio of vertical steel reinforcement, the volumetric stirrup ratio, and loading height, the simplified mechanical models for transverse shear keys have been developed. A common method to simulate the collision of transverse shear keys in finite element analysis is to connect elements simulating such simplified mechanical model in series with compression-only gap element. The aforementioned studies on transverse shear key can provide references for those along the bridge axis (longitudinal shear key, see Fig. 1(b)), which can be arranged at the bottom of girders to limit longitudinal relative displacement through collision with substructures.

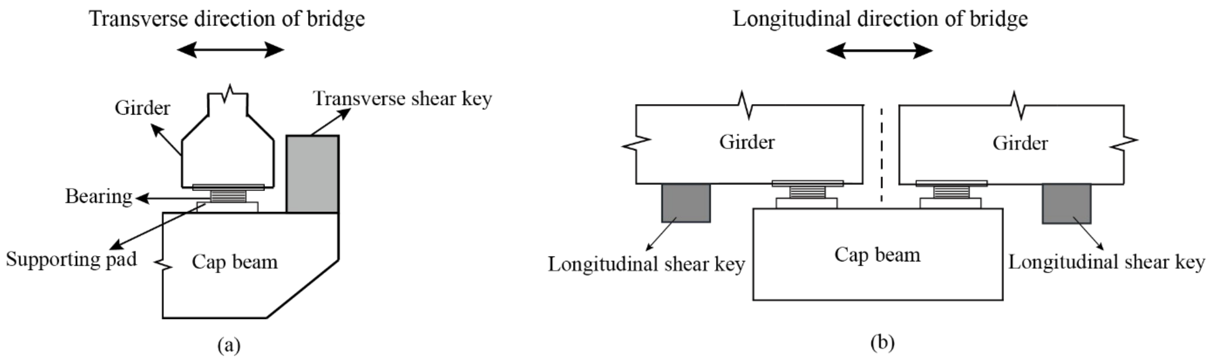

Fig. 1. Schematic diagram of the shear key: (a) transverse shear key ; (b) longitudinal shear key.

In this study, numerical simulation and theoretical analysis are carried out to explore the seismic behavior of longitudinal shear keys. Firstly, the structural form, mechanical model and numerical simulation method of longitudinal shear keys are systematically expounded. On this basis, a targeted design method and technical process for the proposed longitudinal shear keys are established.

In the framework of performance-based seismic design, structures are required to satisfy distinct performance objectives corresponding to different seismic hazard levels, namely multi-level seismic fortification criteria. To achieve the multi-level seismic fortification goal of girder bridges equipped with longitudinal girder fall-prevention systems, this paper proposes a design method for longitudinal restraint-type anti-girder-falling devices. The proposed method is applicable to regular medium- and small-span girder bridges featuring plate rubber bearings, low piers and minor dynamic characteristic differences between adjacent piers.

A four-span simply-supported highway girder bridge is adopted as the engineering case. Nonlinear time-history analysis (NTHA) is implemented to verify the anti-displacement capacity of longitudinal shear keys designed by the proposed method. Furthermore, incremental dynamic analysis (IDA) is adopted to reveal the damage evolution law of each structural component of bridges equipped with longitudinal shear keys under earthquakes with varying intensities. The analysis results indicate that the installed longitudinal shear keys can fully mobilize the

bearing capacity of each bridge component and effectively improve the overall seismic performance of the bridge. In particular, the shear keys designed by the proposed method possess excellent longitudinal anti-girder-falling performance at all key positions of the bridge, and can still maintain reliable restraint effect even under seismic excitations exceeding the maximum credible earthquake (MCE) within a certain range.
Keywords: *unseating prevention; seismic design; longitudinal shear key; highway bridge; incremental dynamic analysis.*