Vulnerability assessment of Sog Bridge´s lead rubber bearing pads

Evan L. Greene, Dr. Ching-Yi Tsai, Dr. Bjarni Bessason

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Objective

The primary goal of this study was to ascertain the current effectiveness and seismic performance of the lead-rubber bearings (LRBs) on the Sog Bridge.

Background

The Sog Bridge, constructed in 1984 (Figure 1) is a vital transit and evacuation link. It was among the first seismically isolated bridges in Iceland. The early lead rubber bearing pads were conservatively designed, resulting in a relatively small total rubber thickness and, consequently, limited flexibility compared to modern isolators. This short height affects the bridge's seismic performance. The Sog Bridge has experienced three major earthquakes (2000 and 2008). Site inspection after the May 2008 event revealed significant concrete spalling at the abutment interfaces and LRBs were permanently deformed inwards. These damages confirm substantial seismic actions at the site.

Figure 1: Sog bridge from the north-east end of the river Sog.

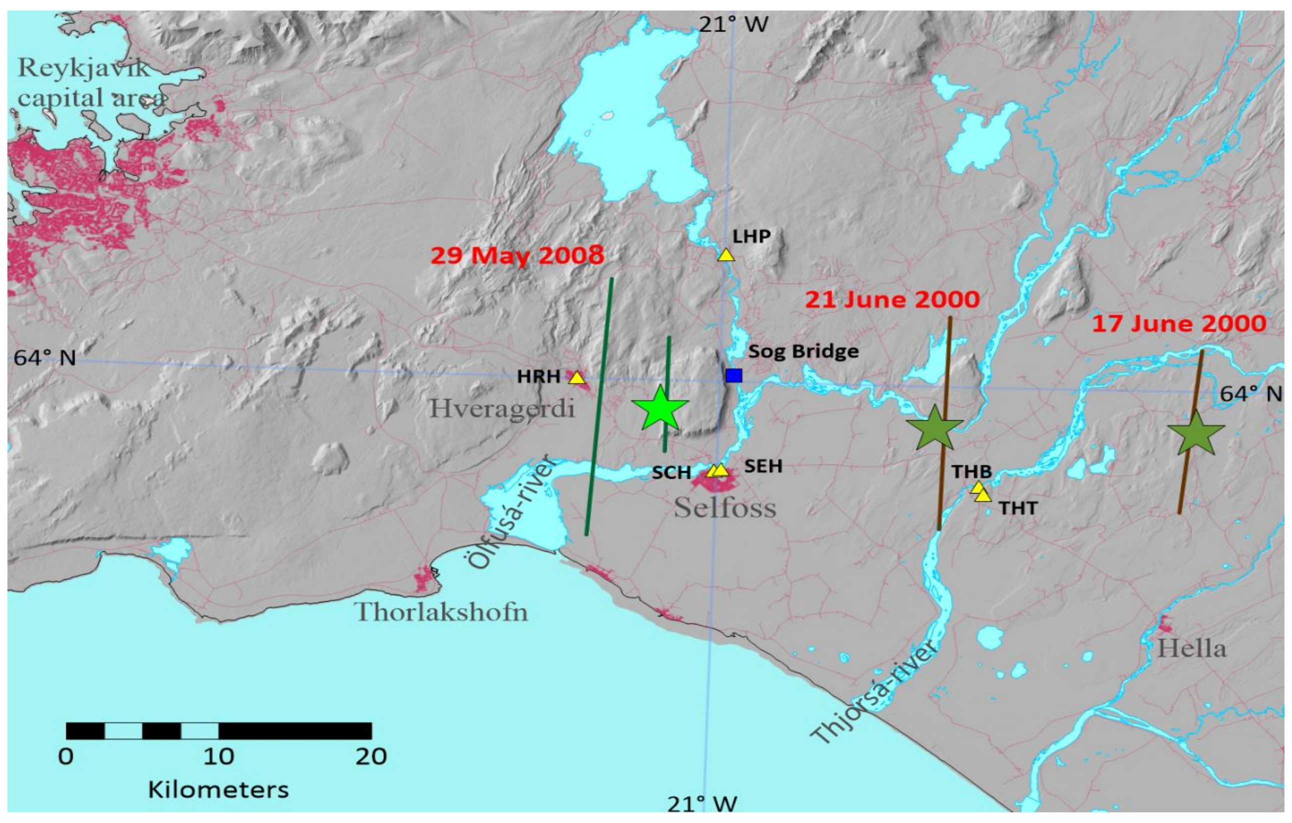

Figure 2: Epicenters (stars) and fault rupture (lines) of the two June 2000 and May 2008 earthquakes. The Sog bridge is labeled as a blue square.

Methodology & Modeling

The Sog Bridge structure utilizes LRBs on the northeast and southwest abutments. Since LRBs exhibit bilinear hysteresis due to the cyclic nature of seismic loading, approximating their stiffness and stress allows for computationally efficient recording of deformations.

To estimate seismic performance, Incremental Dynamic Analysis (IDA) was applied to a SAP2000 model. Outputs of IDA give a distribution of the response parameter due to incrementally scaled earthquake intensities, using peak ground acceleration (PGA) as intensity measure. The bridge was modeled and validated in SAP2000 using technical drawings and site inspection data. The model includes eight LRBs at the abutments and four rubber bearing at the two piers.

Damage is indicated by determining the PGA from the IDA at which the superstructure begins to pound the abutments during longitudinal shaking. In addition, damage state criteria for the LRBs are defined from their shear deformations, γ, as shown in Table 1 (Furinghetti et al.2023). As an example, when γ=0.5 the shear deformations are 50% of the total rubber height. Exceeding this level means that minor damage can be expected, etc..

Table 1:LRB Damage State Criteria

Bearing response parameters (Furinghetti et al., 2023)		
Response parameter	**Criteria (Horizontal displacement)**	**Damage state**
γ_1	$\gamma = 0.5$	Minor
γ_2	$\gamma = 1$	Moderate
γ_3	$\gamma = 1.5$	Severe
γ_4	$\gamma = 2$	Extreme

The two spans at each end were cast in-situ with varying depth and the midspan is of four precast beams of uniform depth. All features were approximated within a SAP2000 finite element model. Dead loads were considered and calculated through volumetric calculations in a CAD model. Figure 3 shows the extruded SAP2000 model.

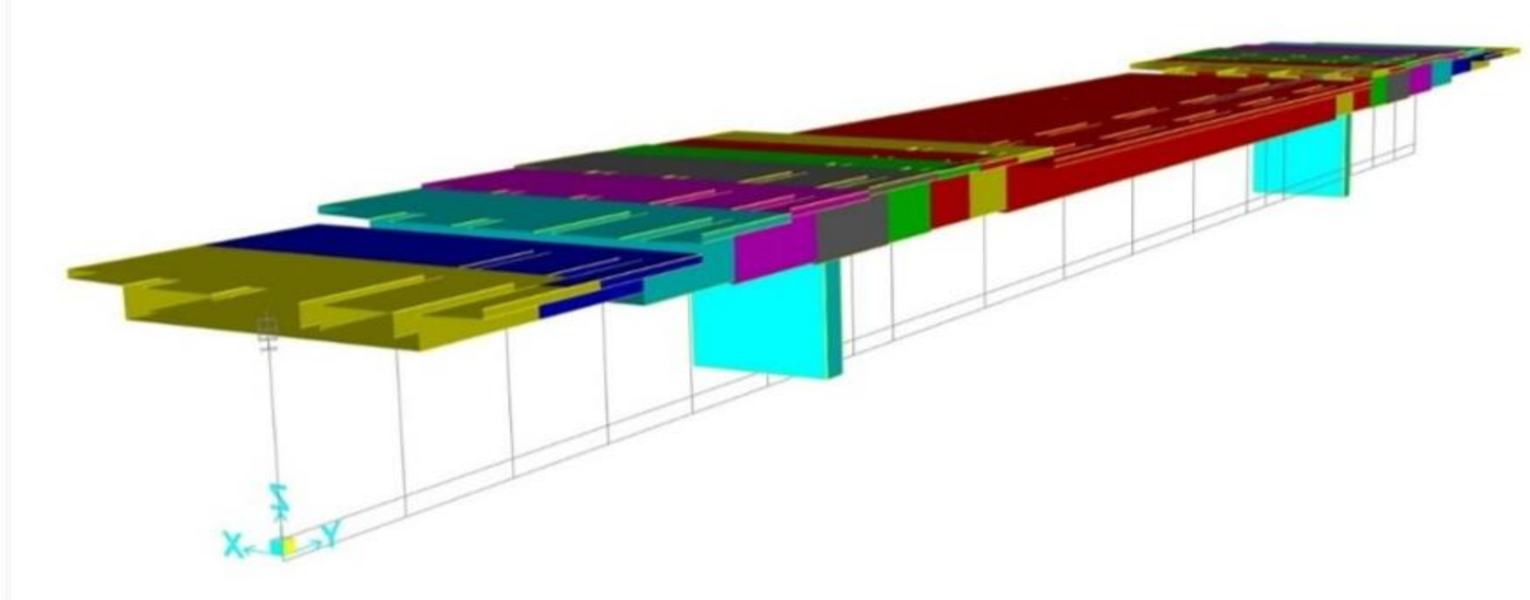

Figure 3: Extruded SAP2000 model outlining the approximation of the change in depth of the Sog bridge.

Results and conclusions

The results of the structures deformation and potential damages are presented in lognormal, otherwise referred to as a fragility curve. Where the inputs are LRB deformation through SAP2000 dynamic analysis of the bridge undergoing scaled intensities of motion based on time-histories. The results for the transverse and the longitudinal direction are shown in Figure 4 and 5, respectively. The results show very little deformation and thus very little seismic energy dissipation through the LRBs. Pounding of the superstructure almost certainly occurred in the May 2008 earthquake and this is reinforced by the presence of concrete spalling at the interfaces. Prior studies of similar structures indicated more deformations and thus more energy dissipation than the Sog bridge in similar intensity earthquakes. Due to the low height of the LRBs high stiffness is preventing their effective implementation. Mitigation strategies could include the increase in spacing between the abutments and superstructure, however this would involve invasive cutting into the existing structure. A less invasive alternative could be the implementation of fluid viscous dampers (FVDs) at the interface. FVDs could be easily bolted in between to increase the damping action in either directional axis.

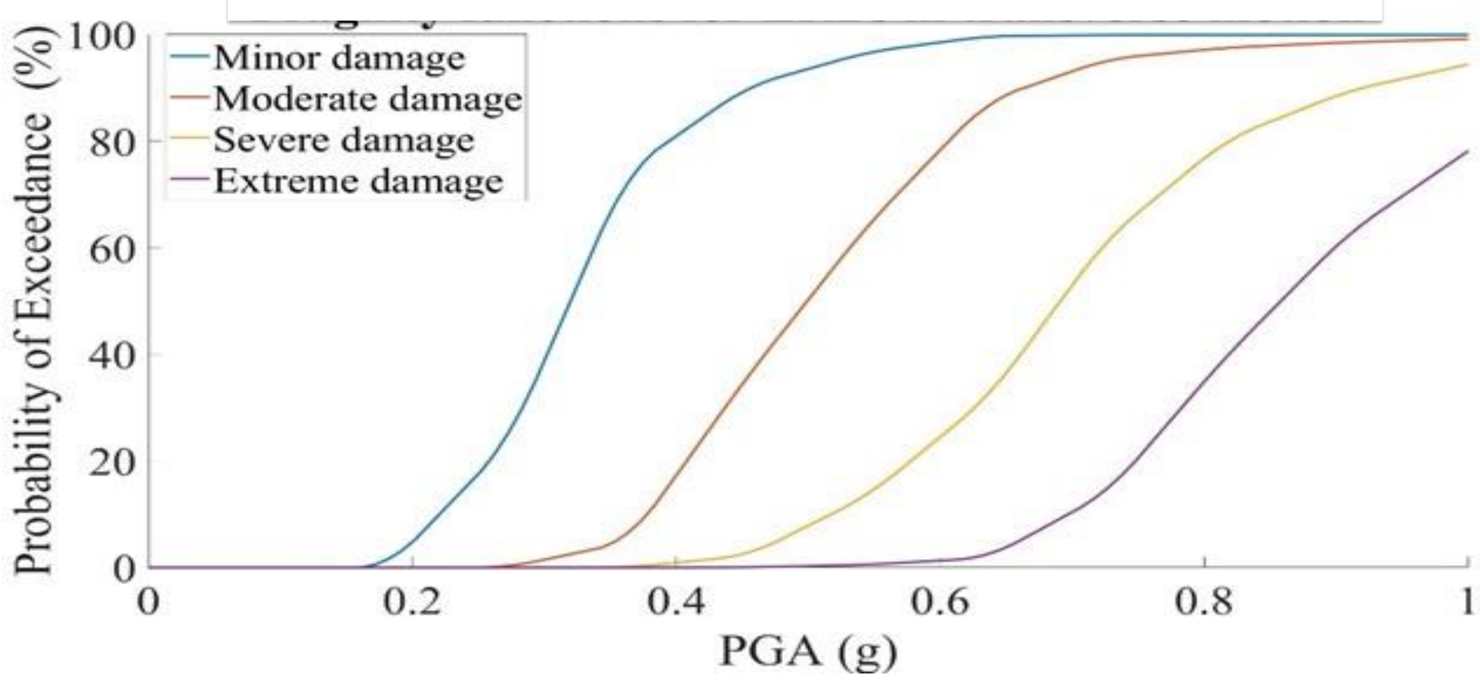

Figure 4: Fragility curves for LRBs in transverse direction.

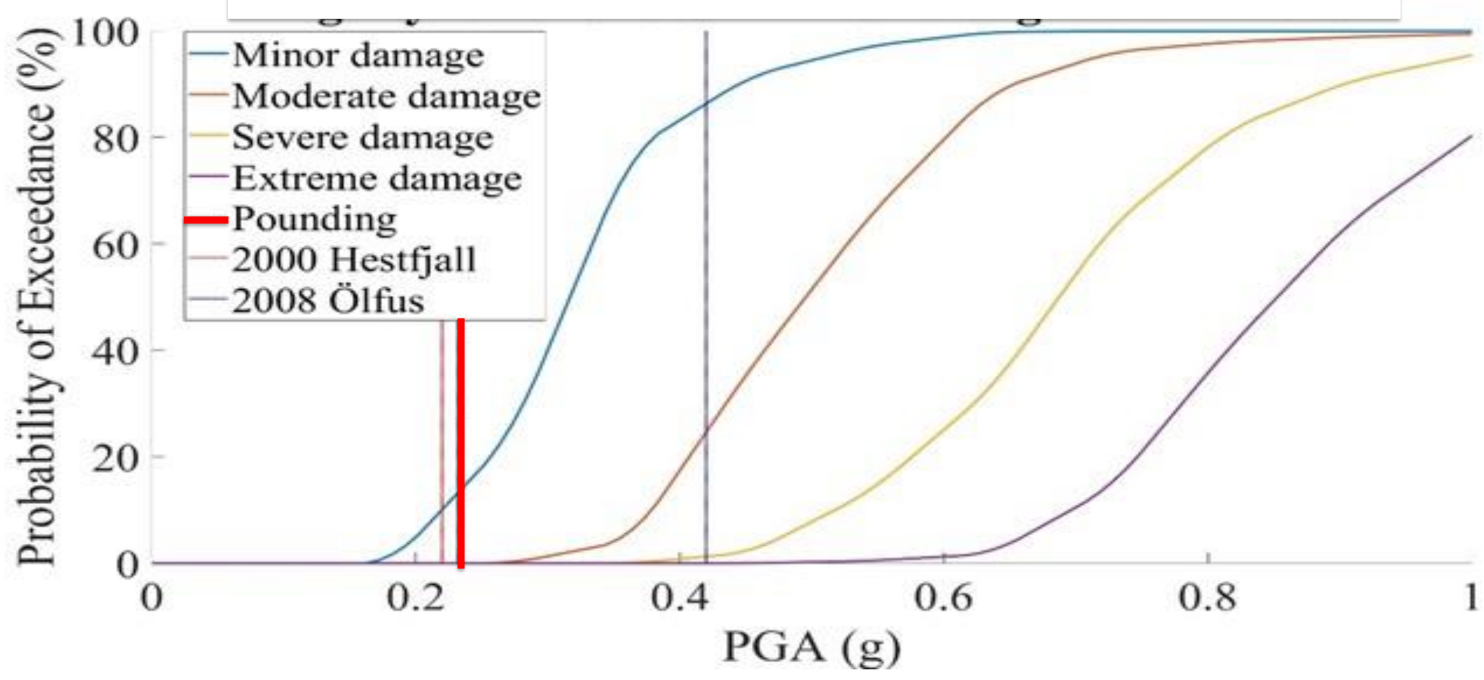

Figure 5: Fragility curves for LRBs in longitudinal direction. Vertical red line show PGA when pounding is expected and for comparison the esti-mated PGA at the bridge site in the 29 May 2008 and 21 June 2000 earthquake.

Acknowledgement

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