

Spatial variability of Earthquake Ground Motion

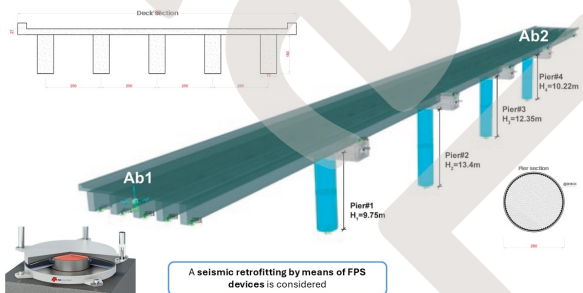
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Motivation

Bridges are among the most vulnerable components within a transportation network during natural disasters, playing a crucial role in the socioeconomic life of modern society. Furthermore, they **often span over long distances with their support points being far away from each other**. Differently to other structures, such as buildings, **spatial variability of earthquake ground motion (SVEGM)** is a critical factor in the seismic design of bridges due to the significant differences in seismic waves characteristics such as amplitude, frequency content, and arrival time when travelling across successive piers separated by long distances. It is now a well-established convention to consider the phenomenon of **spatial variability as coming from mainly three causes**: the *loss of coherence*, the *wave-passage effect* and the *site-response effect*.



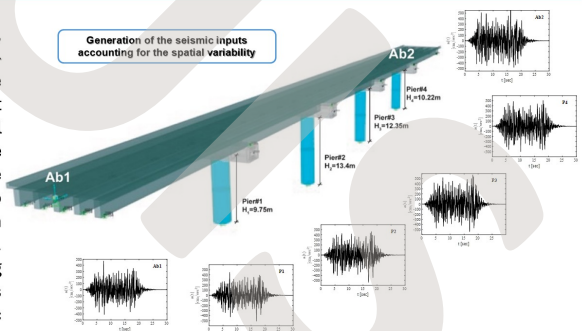
Case study



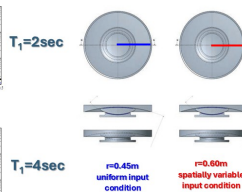
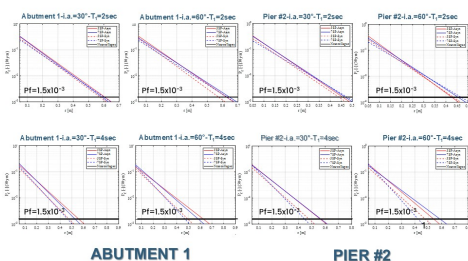
The existing bridge spans over a total length of 163.0m and consists of five simply-supported spans, including 5 RC I-shaped girders and an RC slab of 27.0cm. The substructure of the bridge comprises thin un-reinforced elastomeric bearings (70x50x2cm) placed on each of the girder beams, a cap beam with a hollow rectangular section and four circular RC piers with different heights. The bridge at each end is supported by a seat-type, zero skew-angle abutment with five elastomeric bearings placed on the abutment stemwall.

Methodology

SVEGM is implemented through the spectral representation method, employing a specific correlation function and a NTC2018 spectrum-compatible power spectral density. The generated artificial records are scaled to increasing intensity levels, considering seismic waves at incidence angle of 30° and 60° with respect to the bridge longitudinal axis. The study employs a full-probabilistic seismic analysis to compare bridge responses under uniform input conditions and spatially variable input conditions. Three different radii of curvature for the FPS and two different structural configurations are analyzed, with the sliding friction coefficient at large velocities considered as a random variable. Incremental nonlinear time history analyses (IDA) are conducted using Opensees in order to evaluate the seismic fragility (i.e., the probabilities exceeding different limit states). Ultimately, considering the seismic hazard curves related to the reference site of L'Aquila (Italy), the seismic reliability of the bridge piers is evaluated.



Results



Seismic reliability-based design (SRBD) abacuses for a preliminary design of the in-plan dimension of the isolator as a function of the selected target reliability and of the other structural parameters considered in the analysis, for a geographical area with a seismic hazard similar to the one considered in the study (i.e. L'Aquila).

From the linear regression results, it is possible to observe that across all the isolation periods and structural configurations, the target probability of failure equal to $1.5 \cdot 10^{-3}$ is reached through a in-plan radius that ranges from a minimum value of 0.43m, referred to the uniform input condition to 0.68m under spatially variable input condition.