LONG-PERIOD SURFACE-WAVE EFFECTS ON FLEXIBLE BRIDGE STRUCTURES

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Extended Abstract

Long-period ground motions are of particular importance for long-span bridges, tall-pier bridges, and other flexible bridge systems. Compared with early-arriving body-wave components, long-period surface waves usually have longer durations, more concentrated low-frequency energy, and clearer propagation-related features. When the dominant periods of these waves are close to the lower-mode periods of a flexible bridge, they may amplify structural displacement demands, prolong the response duration, and modify the force distribution in girders, towers, piers, bearings, and connection components. Therefore, separating long-period surface-wave components from the complete ground motion provides a useful basis for evaluating their specific contribution to bridge seismic response.

This study proposes a component-based framework to investigate the influence of long-period surface waves on flexible bridge structures, using the Shuanghe Bridge as the benchmark case. The first part of the study focuses on the seismic wavefield at the site. Three-component ground-motion records are examined in terms of low-frequency energy concentration, response duration, and particle-motion characteristics. Because real records usually contain body waves, surface waves, scattered waves, converted phases, and locally mixed wavefield components, simple band-pass filtering or fixed-direction projection is insufficient for isolating long-period surface waves in a physically interpretable manner.

To address this issue, a propagation-consistent time-frequency extraction framework is adopted. The original (N/E/V) three-component records are transformed into complex Stockwell time-frequency fields. A pixel-wise local azimuth field is then estimated in the complex time-frequency domain and used to construct local (R/T/V) representations. Based on local in-plane principal-axis correction, phase consistency, rotational-sense stability, major–minor axis synchrony, envelope co-occurrence, and time-frequency continuity, the PCE Rayleigh-like component is extracted. After subtracting this component from the full

record, a Rayleigh residual is obtained, from which the Love-like transverse component is further identified. The sum of the PCE Rayleigh-like component and the Love-like transverse component is defined as the main extracted long-period surface-wave package. The remaining wavefield contains body-wave-dominated motion, scattering tails, locally mixed components, and unresolved long-period residuals.

In the structural analysis, a dynamic model of the Shuanghe Bridge will be established as the benchmark flexible bridge system. Several input-motion cases will be considered. The first case uses the complete three-component ground motion to obtain the overall structural response. The second case uses the extracted long-period surface-wave package to quantify the contribution of the propagation-consistent surface-wave components. The third case uses the residual motion after removing the main surface-wave package to evaluate the contribution of non-surface-wave or unresolved residual components. If needed, the Rayleigh-like and Love-like components can also be applied separately to the structural model in order to distinguish the effects of in-plane long-period motion and transverse long-period motion.

The structural response quantities of interest include girder and pier/tower displacements, bending moments and shear forces at critical sections, bearing and connection responses, participation of lower vibration modes, peak and sustained response measures, and the contribution of different input components to energy demand. By comparing the structural responses under the complete ground motion, the extracted long-period surface-wave package, and the residual motion, the study aims to answer three questions. First, do the identifiable long-period surface waves dominate the low-frequency response of the flexible bridge? Second, does the removal of the long-period surface-wave package significantly reduce the structural response or shorten the response duration? Third, do the Rayleigh-like in-plane component and the Love-like transverse component correspond to different structural response patterns?

Soil–structure interaction is not treated as the primary focus of the current framework. A fixed-base or equivalent-support bridge model will first be used to establish a clear baseline comparison among different input-motion components. In a subsequent sensitivity analysis, soil–structure interaction may be incorporated through equivalent foundation springs, damping boundaries, or coupled site–bridge modeling. This extension would allow the combined effects of site flexibility, foundation constraints, and long-period surface waves on bridge response to be further evaluated.

The expected outcome of this study is a systematic workflow that links site-specific long-period surface-wave identification, component-based ground-motion extraction, flexible bridge response analysis, and engineering interpretation. Rather than evaluating bridge response only under the complete ground motion, the proposed framework separates the main long-period surface-wave package from the residual wavefield and quantifies their respective contributions. The Shuanghe Bridge case study is expected to provide component-level evidence for understanding how long-period surface waves affect flexible bridge structures and

to support future studies on complex site effects, soil–structure interaction, and seismic input selection for bridge design and assessment.

Keywords: *Long-period surface waves; flexible bridges; propagation-consistent extraction; structural dynamic response; soil–structure interaction.*