Shaking table experiments for assessing the impact of foundation scour on the dynamic response of bridge piers

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Foundation scour is a primary cause of bridge collapse worldwide, reducing foundation capacity and stiffness (e.g., Foti et al., 2023) and thus affecting the seismic performance of bridge structures. This study describes a comprehensive experimental campaign carried out at the UKCRIC Soil-Foundation-Structure Interaction Laboratory (SoFSI), University of Bristol, as part of the EU-funded project 'Structural Performance monitoring and evaluation of scoured bridges under dynamic actions' (SCOUR&SHAKE), within the EU-ERIES transnational access initiative.

The tests examined the transverse dynamic response of scaled pier-caisson systems that are representative of two types of multi-span roadway bridge. These two configurations were selected to evaluate the impact of scour on typical bridge configurations with different degrees of deformability compared to the soil deposit, which is a 50 m-thick dense sand layer over rock. The systems were excited using white noise and natural seismic motions of varying amplitude in order to evaluate vibration-based monitoring techniques and investigate the impact of scour on seismic performance.

The physical model of the bridge pier-foundation-soil system was defined based on the similarity rules for 1*g* model tests (Iai, 1989) with a length scaling factor of 22. This was done under the assumption that the mass and relative densities of the model were equal to those of the prototype sand. The specimens were constructed to match the desired mass and stiffness properties at the model scale (Figure 1a), and they were installed inside a 4.8×1.0×1.2 m shear stack. This was filled with 950 mm of dry silica sand (Huseynli et al., 2025), over a 20 mm-thick rubber layer, with an estimated shear modulus of 0.78 MPa (Gent, 1958). The rubber layer was added to reproduce the target natural frequency of the soil deposit, mitigating the geometric constraints of the shear stack.

Each specimen was tested in a fixed-base configuration and with three embedment conditions (Figure 1b-c): fully embedded caisson, and two local scour scenarios with realistic geometry and depths of 40% and 75% of the caisson height, respectively. In both scour scenarios, sand was removed using a controlled suction system, and the geometry of the scour holes was verified using a laser distometer. For one specimen, the scour hole was then filled with gravel partly glued to simulate partially grouted riprap, a common low-cost mitigation strategy (Figure 1d; Lagasse, 2007).

As shown in Figure 1, the instrumentation layout included 18 horizontal uniaxial accelerometers arranged in three vertical arrays along the shear stack wall, within the sand at 1200 mm from the model, and beneath the specimen. Additional accelerometers were placed on the caisson and at the centre of the top mass. Two arrays of four strain gauges were installed along the pier to monitor bending. Displacements of the caisson and top mass were measured using an Imetrum Flexi Extensometer and two LVDTs.

Preliminary results indicate that an increase in scour depth reduces the system's dominant frequency and decreases deck accelerations, whereas remedial measures restore the original configuration. These trends reflect increased foundation deformability, which lengthens vibration periods and enhances energy dissipation, thereby reducing superstructure demand but potentially increasing foundation displacements. Future work will therefore include a detailed analysis of the response to ambient noise and seismic motion, focusing on the effects of soil-structure interaction. This will inform the development of predictive numerical models and design guidelines for managing scour in bridges, thereby improving their resilience under multi-hazard conditions.

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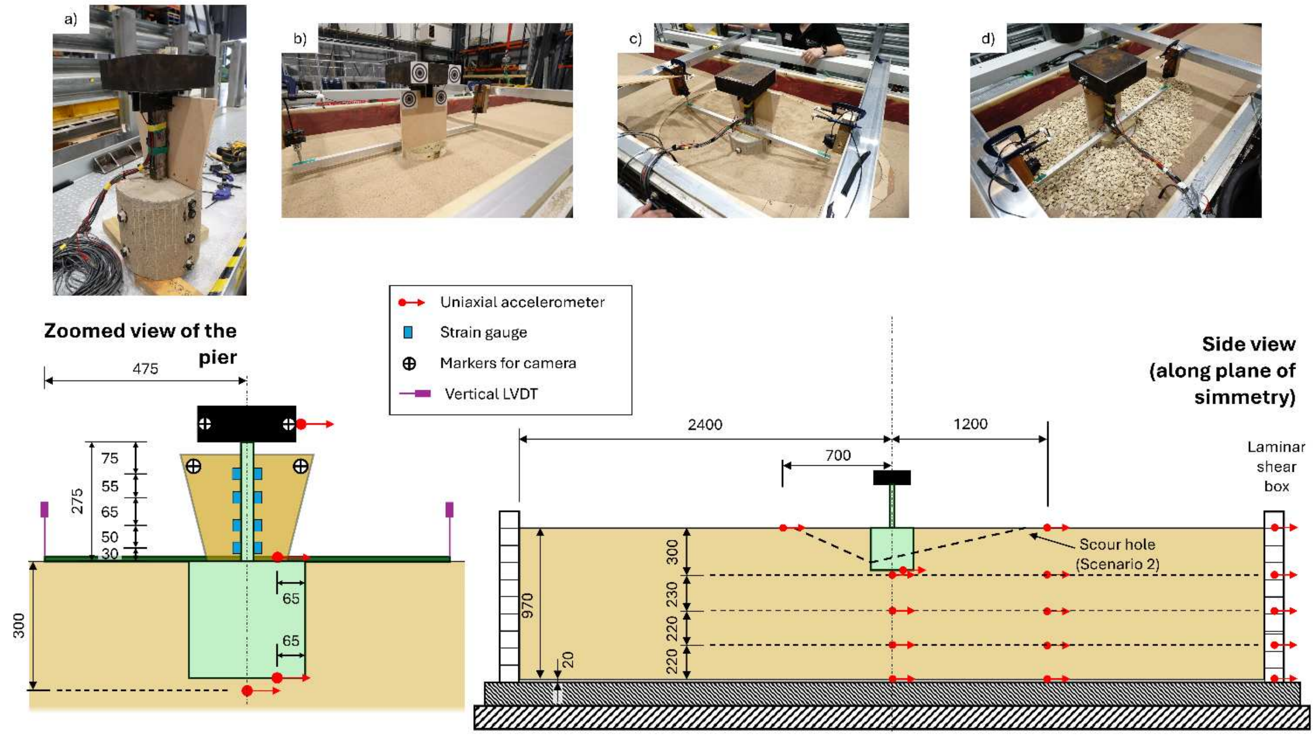

Figure 1. Top: Photos of one pier-caisson taken outside and inside the shear stack at SoFSI, University of Bristol: a) before installation; b) Original configuration (i.e., fully embedded caisson); c) 75% scour configuration; d) configuration with remedial measure. Bottom: Layout of the instrumentation placed in the shear box and on the specimens (all dimensions are in mm).

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