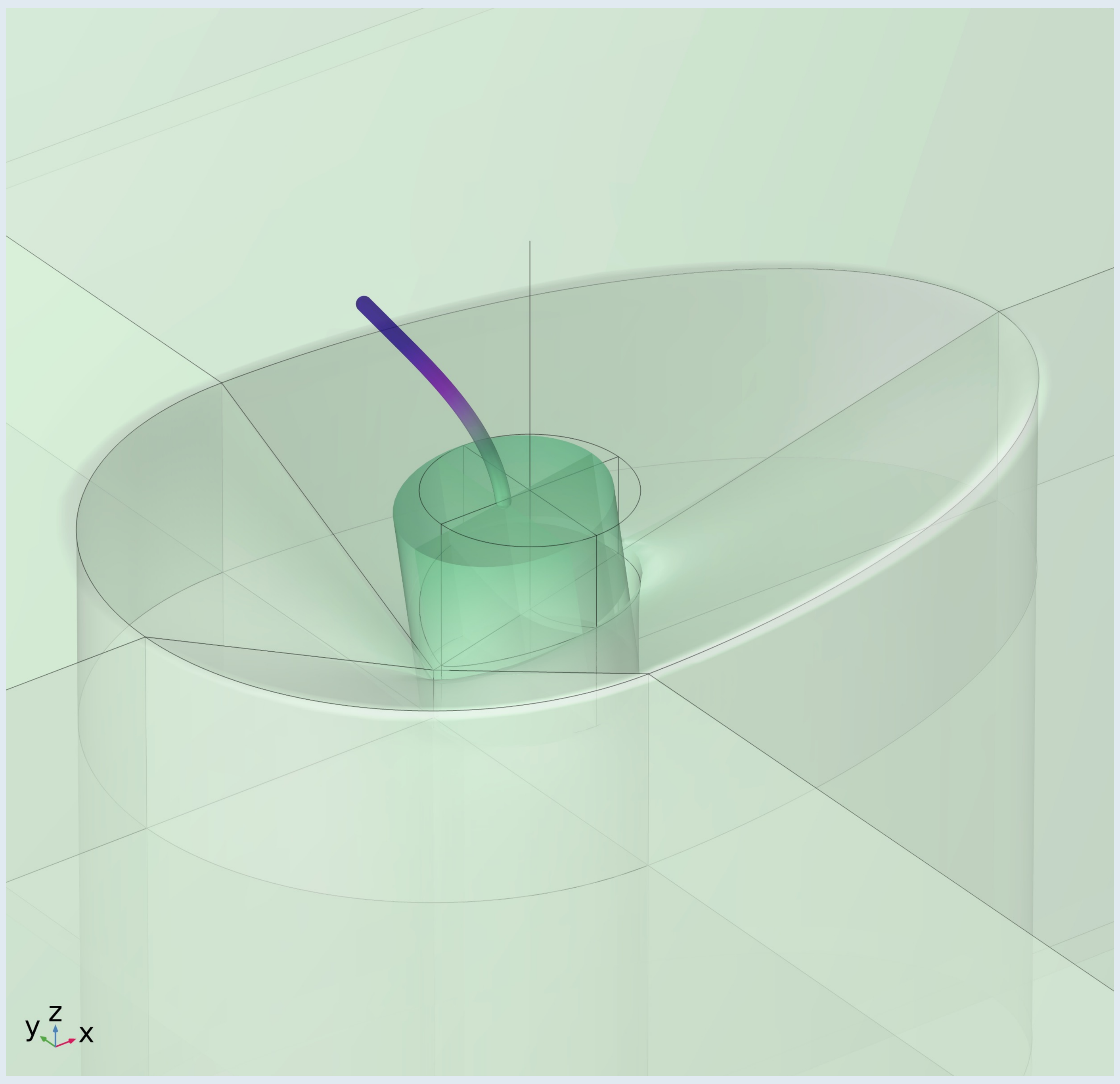

Numerical Prediction of the Eigenfrequencies of an Idealized Bridge Pier Under Local Scour

An insight into the influence of local scour on the dynamic response of bridge piers supported by caisson foundations.

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Abstract

Foundation scour is a major cause of bridge collapse worldwide (e.g., Kirby et al., 2015). Indeed, several studies have demonstrated its detrimental effects on the soil-structure system, both in terms of the foundation capacity and stiffness (e.g., Foti et al., 2023). Furthermore, the difficulty in detection of foundation scour and the budgetary delays in retrofitting increase the likelihood that scour-prone piers will be exposed to events as earthquakes. For this reason, it is essential to investigate the dynamic response of bridge piers before and after foundation scour. This study addresses the dynamic behavior of an idealized reinforced concrete bridge pier supported on a cylindrical caisson foundation embedded in sand, and it estimates the system eigenfrequencies and mode shapes under various scour scenarios.

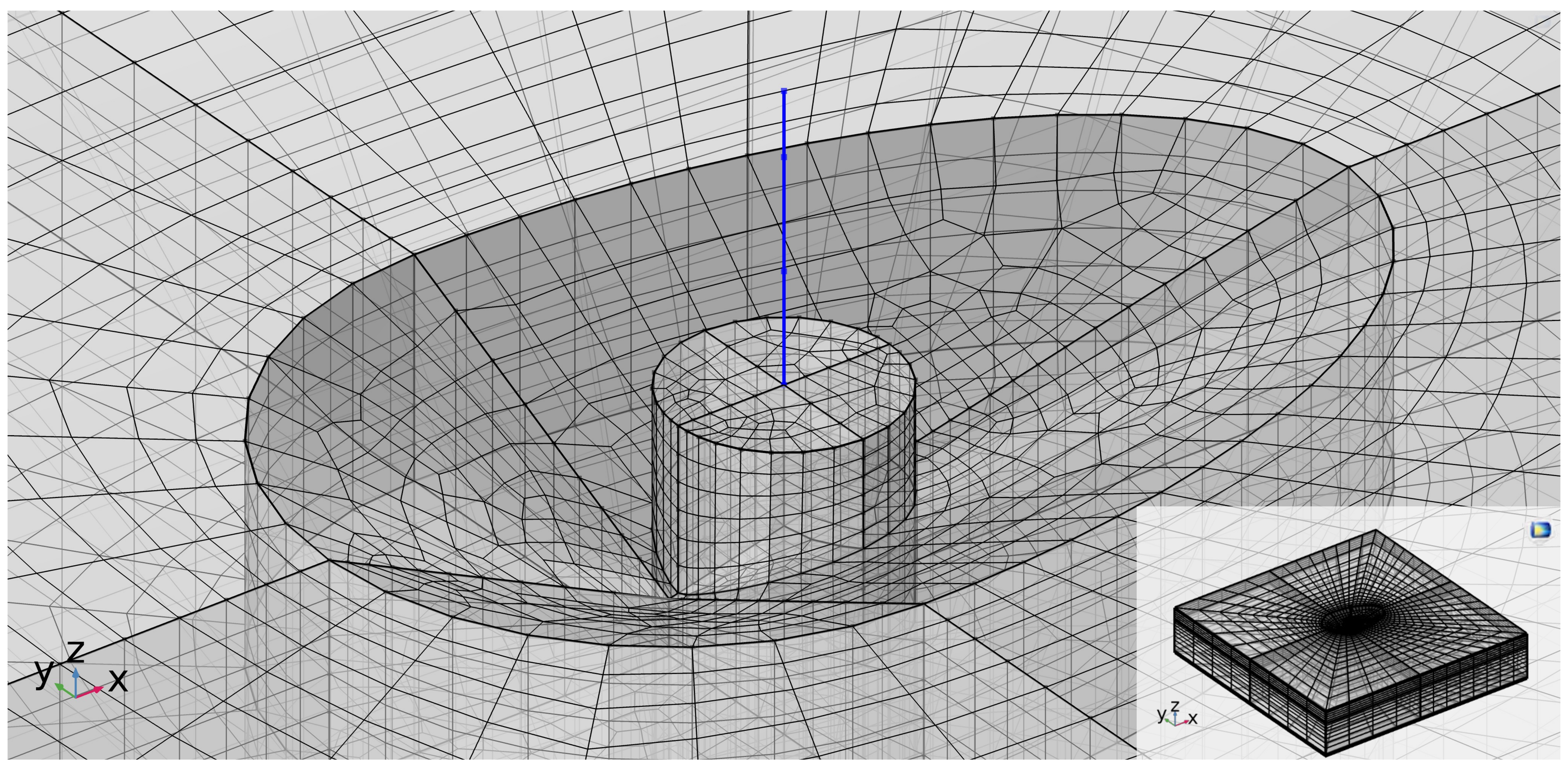

FIGURE 1. View of the FE numerical model, with a focus on the portion including the pier-caisson system and the scour hole.

Methodology

The numerical model was implemented using the Structural Mechanics Module of the COMSOL Multiphysics® software, using beam elements for the superstructure and solid domains for the foundation and the soil deposit. Foundation scour was introduced by removing a portion of the soil from around the caisson, to create an excavation with a shape consistent with experimental observations (e.g., Ciancimino et al., 2022). After a preliminary validation against DEEPSOIL (Hashash et al., 2017) and SAP2000 (CSI, 2023), an eigenfrequency analysis was performed to address the influence of different scour depth scenarios on the first rocking mode of the system.

Results

Focusing on the first rocking mode, a deeper scour hole results in a reduced eigenfrequency (Figure 2a) and an increase in the caisson rotation up to 75%, which is partially compensated by a 20% smaller curvature in the pier (Figure 2b). This is the consequence of the increased deformability at the base. Figure 2 also includes a comparison with “general scour” scenarios (simpler model often assumed in the practice), which results in stronger variations of the modal response. Such a discrepancy highlights the importance of properly modeling the hydraulic scenario when dealing with the dynamic response of bridge piers under scour.

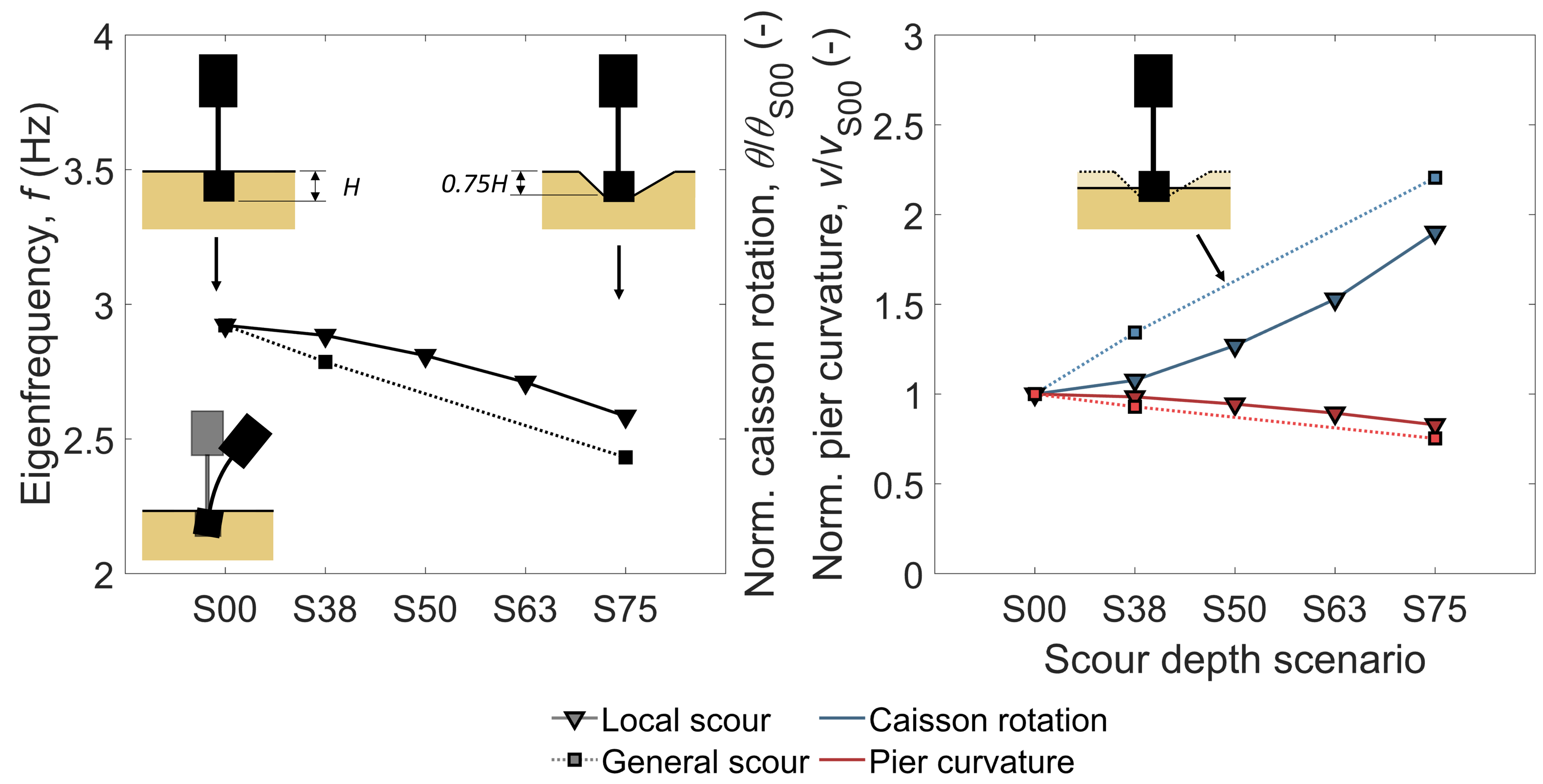

FIGURE 2. (a) Influence of the scour depth scenario on the first rocking mode eigenfrequency; (b) Influence of the scour depth scenario on the first rocking mode shape, in terms of caisson rotation and pier curvature.

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