# Experimental investigation and FEM simulation of a bridge pier with scoured pile foundation from shaking table tests

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## Summary

This study investigated the seismic performance and soil-structure interaction of scoured bridge pier models with pile foundations by shaking table tests and finite element simulations. The model bridge pier with a pile foundation comprised of a lumped mass representing the superstructure, a steel pier, and a footing supported by a single aluminium pile within dry silica sand. The performance of the structure was discussed for different scoured conditions. It is found that the transition of moment demand from pier to pile with increasing exposed length may cause the bridge to failure. A three-dimensional finite element model of the shaking table test was created using the ANSYS program. The soil dynamic property was taken into consideration for the nonlinearity of the soil-pile interface, and an equivalent linear model was used for the soil behaviour. The computational model was validated by the data obtained from the shaking table tests.

**Keywords:** bridge; pile foundation; scouring; soil-structure interaction; finite element method; seismic performance.

## 1. Experimental program and observations

In this study, the dynamic behaviors of a soured soil-bridge-foundation system in earthquake excitations are investigated. A large scale biaxial laminar shear box was used to study SSI. The model bridge pier inside a laminar shear box is shown schematically in Figure 1. The model bridge pier with a pile foundation comprised a lumped mass representing the bridge superstructure, a steel pier, and a footing supported by a single aluminium pile within dry silica sand. The dry sand specimen with relative density of 50% was prepared by using a compaction method in five layers after the placement of the model pile and instrumentations in the shear box. Five cases, SBF-O, SBF-NC, SBF-S3D, SBF-S6D and SBF-WS, represented different scouring conditions as shown in Figure 2. The input earthquake ground motions included the 1940 El Centro earthquake, 1999 Chi-Chi earthquake (TCU068) with the peak ground acceleration of 0.1, 0.15, and 0.2g.

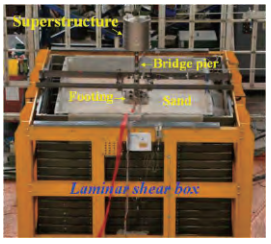


*Fig. 1: Test setup*

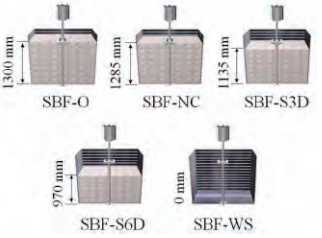


*Fig. 2: test cases*

Based on the test results, the system frequencies were 2.08 Hz, 1.56 Hz, 1.32 Hz, 0.98 Hz and 0.49 Hz for specimen SBF-O, SBF-NC, SBF-S3D, SBF-S6D and SBF-WS, respectively. For the system damping, it is about 5.5% during small excitation in this experimental study. The peak accelerations along the height of frames until sand surface were amplified compared with the laminar box input excitation. Besides, the maximum displacements increased due to the scouring effect, whereas the accelerations varied as the characteristics of the model and the input ground motions changed.

## 2. FEM simulation and comparison of the shaking table test results

To simulate the shaking table tests, a 3-D FEM model of the entire soil-bridge-foundation system in ANSYS was created as shown in Figure 3. Figure 4 presents a flowchart to capture the dynamic behaviour of soil under strong ground motions. The shear modulus of soil first reduced by Shake program, but for those beneath the surface (4 to 6 times the outer diameter of pile) has to be further reduced. The time history responses at the centre of the lumped mass for specimens SBF-O subjected to 0.1g El Centro earthquake excitations are shown in Figure 5. The seismic responses of the model bridge pier with a pile foundation have been reasonably well simulated.

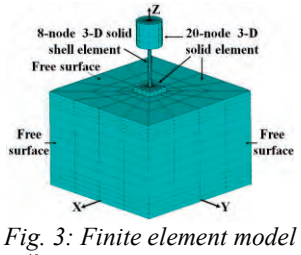


*Fig. 3: Finite element model*

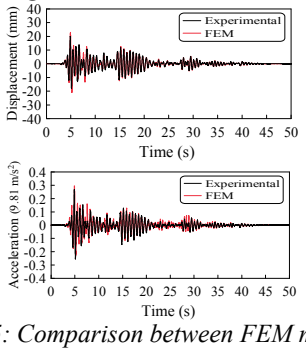


*Fig. 5: Comparison between FEM model and test result*

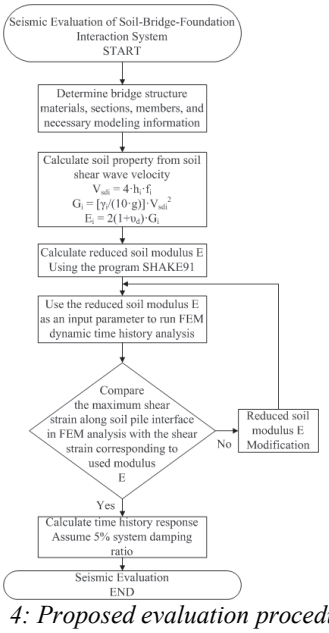


*Fig. 4: Proposed evaluation procedure*

## 3. References

[1] Shiou-Chun Wang, Kuang-Yen Liu, Chia-Han Chen, and Kuo-Chun Chang, “Experimental Investigation on Seismic Behaviour of Scoured Bridge with Pile Foundation,” Earthquake Engineering and Structural Dynamics, Volume 44, Issue 6, pages 849–864, May 2015.