

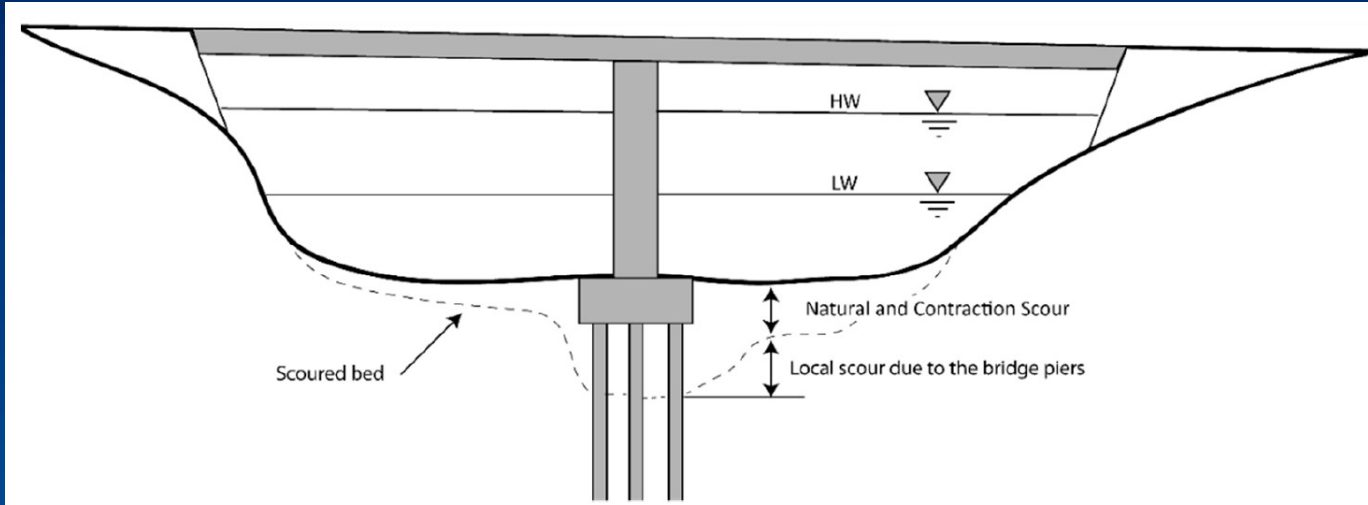
5th International Bridge Seismic Workshop

Influence of Scour on the Seismic Response of a Cable-Stayed Bridge

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Changsha, June 2026

Introduction – The Importance of Scour



Source: Pizarro, A., Manfreda, S., & Tubaldi, E. (2020).

The science behind scour at bridge foundations: A review. Water, 12(2), 374.

Scour (gradual erosion of soil around the bridge foundations) is the leading cause of bridge failures worldwide (close to 50%).

Climate change

- Frequency and severity of flooding events will increase;
- Vulnerability of bridges to scour will also increase.

Introduction – Current Research Trends

- Numerical and data-driven approaches to quantify scour effects (scour depth, etc.)
- Update appropriate Codes of practice to most recent climate change scenarios
- Innovative methods to monitor scour on existing bridges
 1. Underwater inspection (direct assessment but unsafe during floods)
 2. Direct scour monitoring (direct measurements but sensors vulnerability to damage)
 3. Vibration-based monitoring (changes in natural periods but interpretation not straightforward)

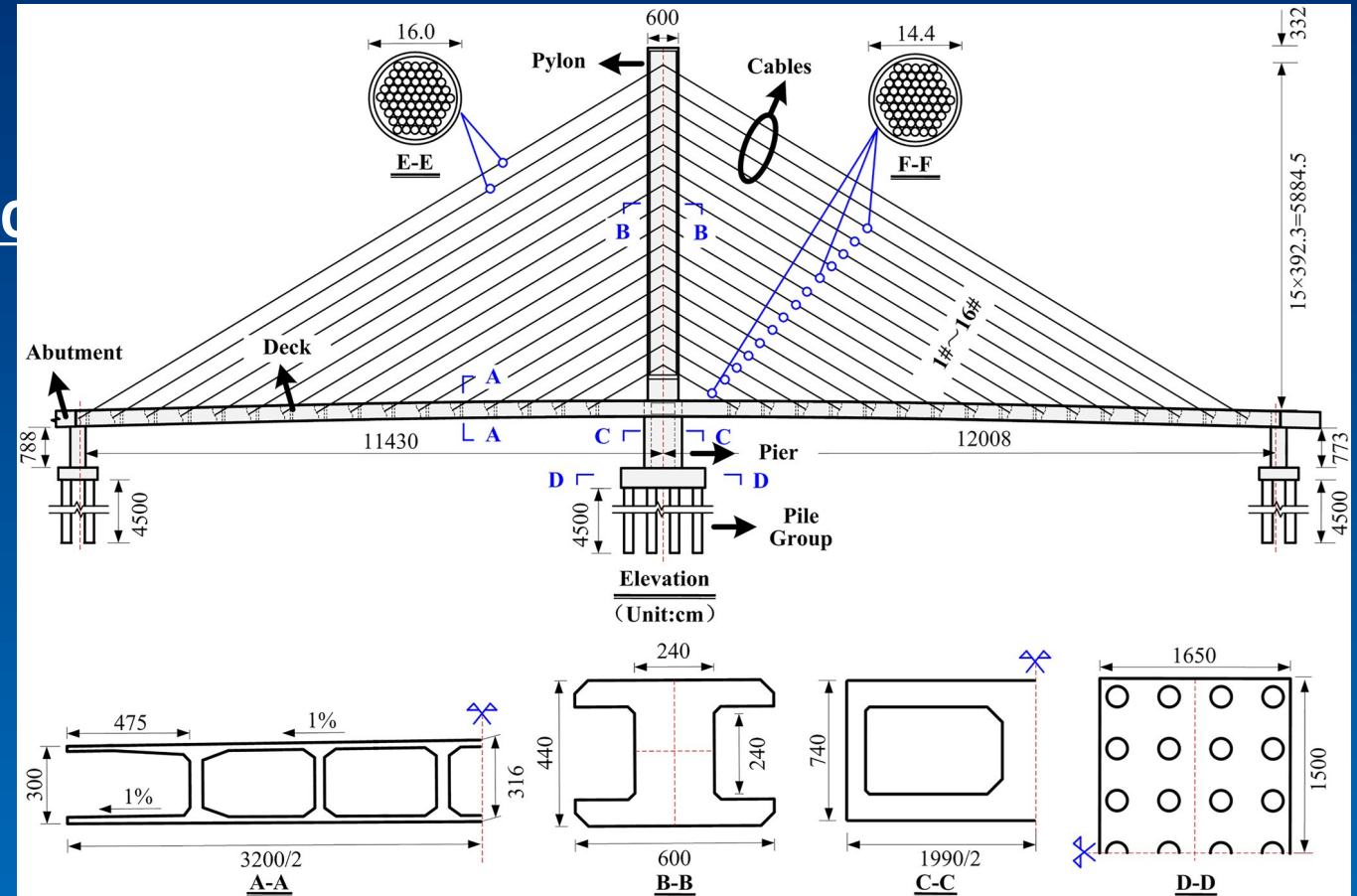
Scour and Seismic Effects

In seismic regions, how does scour affect the bridge behavior?

- Shift in natural properties?
- Increase in structural demand

Case study:

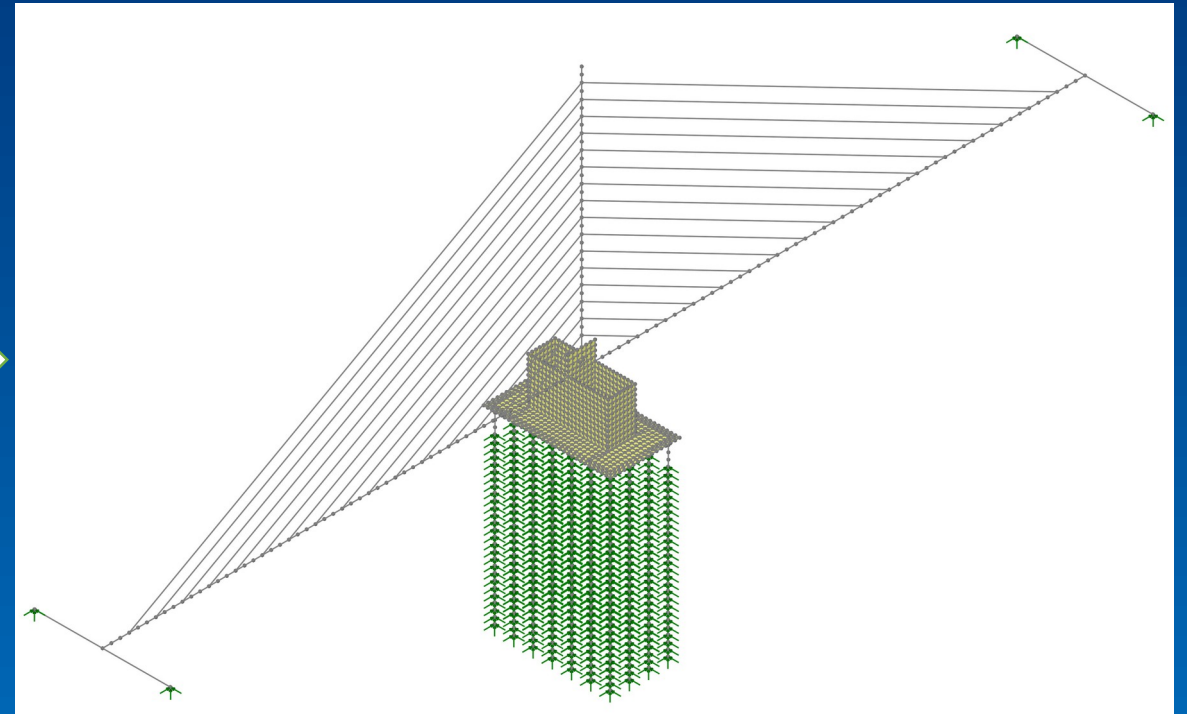
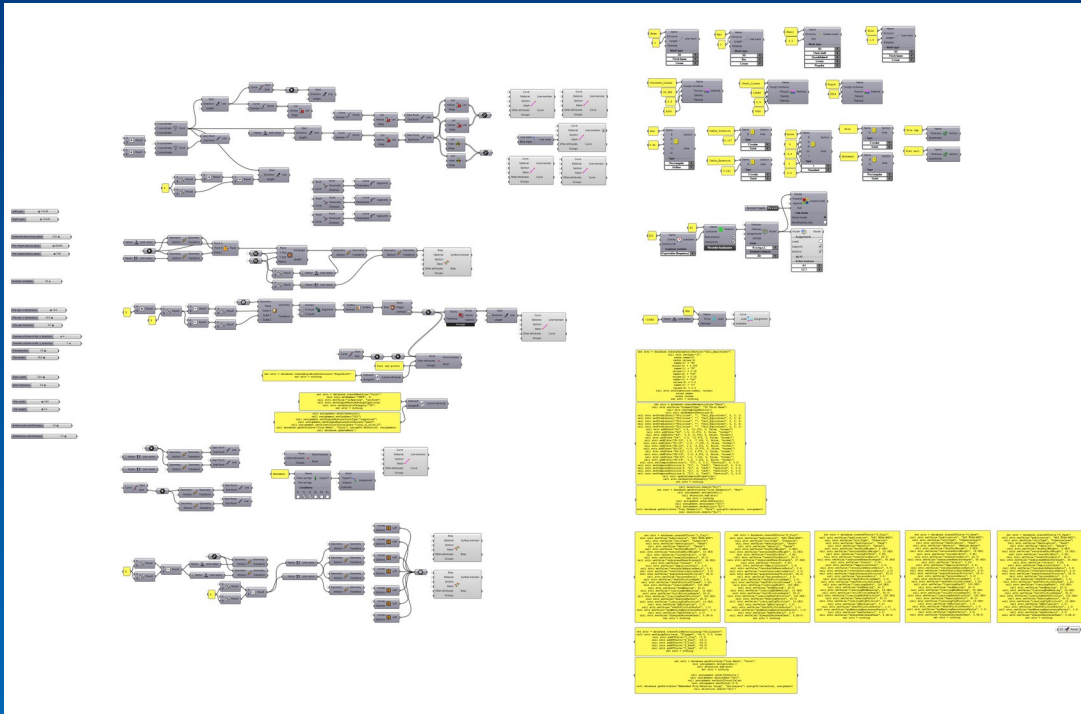
The Longwan Bridge,
Guizhou Province, China



Han, Q., Wen, J., Du, X., and Huang, C. (2019): Seismic response of single pylon cable-stayed bridge under scour effect. *Journal of Bridge Engineering* 24(6).

Parametric Modelling

Parametric definition of the geometry, cross-sections, material properties and boundary conditions in Grasshopper → Automatic generation of the finite element model in LUSAS



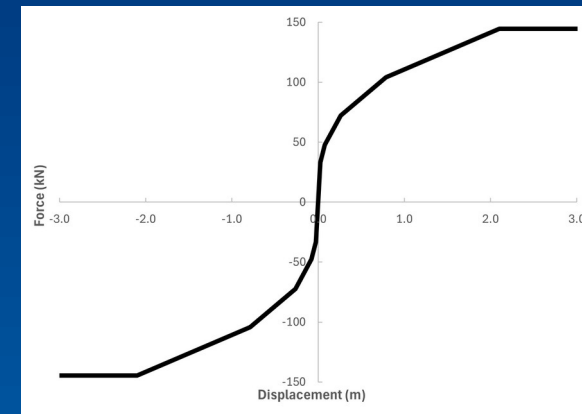
Soil-Structure Interaction

Representation of soil-structure interaction through the definition and assignment of depth-dependent p-y (horizontal), t-z (vertical) and Q-z (vertical) curves, following the soil profile shown in Table 1, with the recommendations of API RP 2A-WSD.

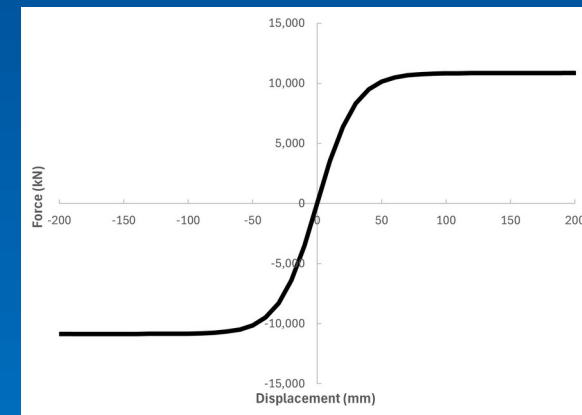
Soil layer	Depth (m)	Type	Characteristics		
Top 3 layers (cohesive soils)			γ (kN/m ³)	S_u (kN/m ²)	ϵ_{50}
1	9.8	Clay	8.6	36.0	0.07
2	7.7	Clay	9.0	47.0	0.05
3	8.0	Clay	8.6	55.0	0.05
Bottom 2 layers (cohesionless soils)			γ (kN/m ³)	K (MN/m ³)	Φ (°)
4	12.7	Sand	9.2	18.4	35
5	6.8	Sand	9.6	20.4	34

Table 1: Soil Profile

Scour depth: 6m (500-year event)



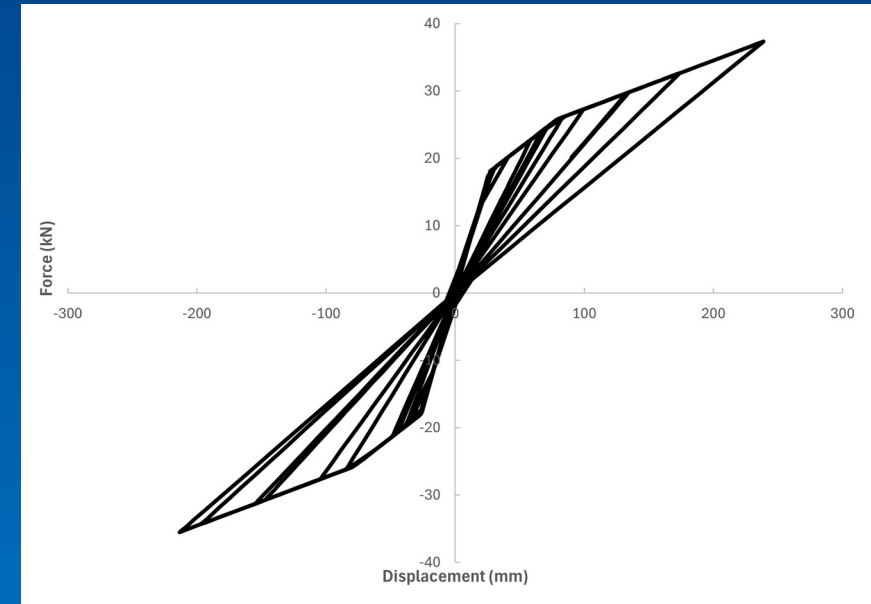
Typical p-y curve
(near mid-depth
of the pile)



Typical p-y curve
(near pile base)

Damping – Three components

- Structural damping: Rayleigh damping coefficients tuned to 2% of critical damping;
- Radiation damping (energy loss due to propagation of seismic waves through the soil): Introduction of viscous dashpots along the piles and at the abutments;
- Hysteretic damping: Adoption of a pinching hysteresis model for the piles. Pinching is able to capture the progressive loss and re-establishment of contact between the piles and the surrounding soil under cyclic loading.

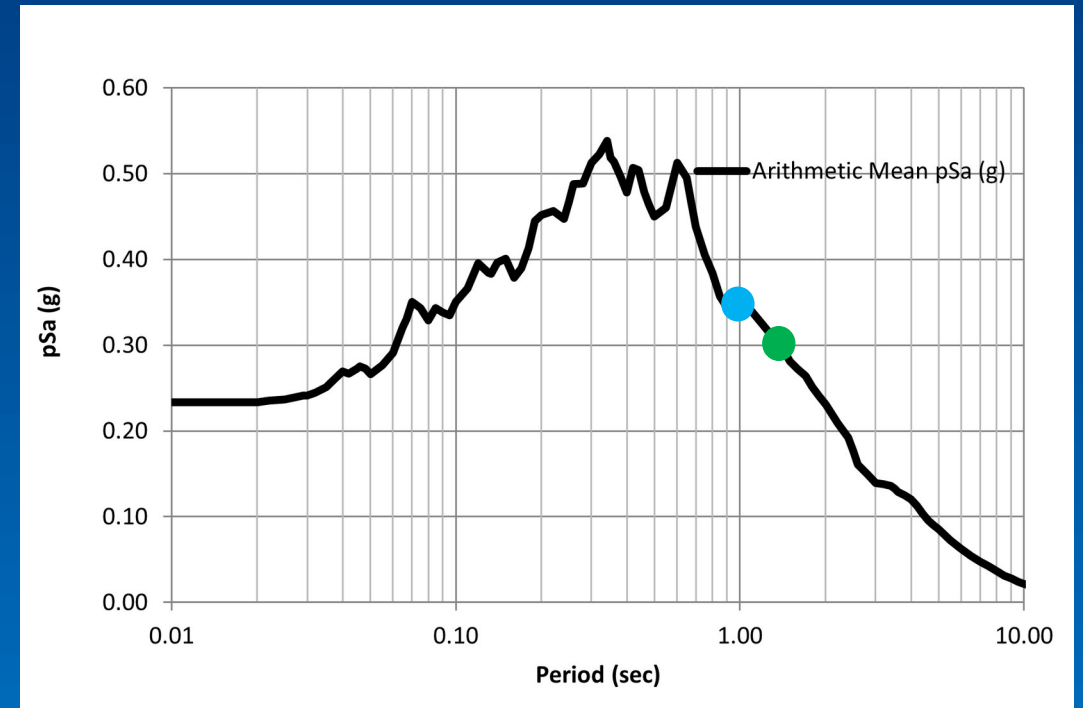


Selection of the Ground Motions

→ Set of 7 ground motions selected from the PEER database: Victoria, Mexico (1980), Kocaeli, Turkey (1999), Chi-Chi, Taiwan (1999), Cape Mendocino (1992), Tottori, Japan (2000), Iwate, Japan (2008), and Darfield, New Zealand (2010).

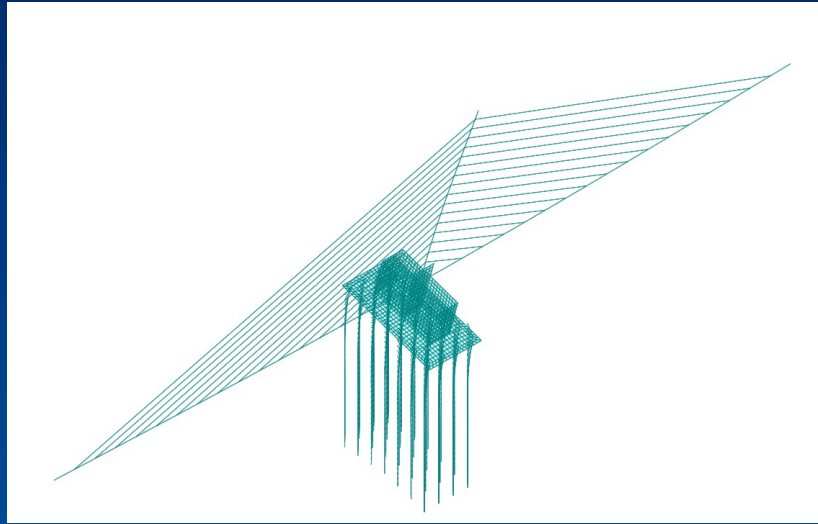
→ Scaled to a spectral acceleration of 0.3g at the fundamental transverse natural mode.

→ Applied in all 3 directions (X, Y, Z).

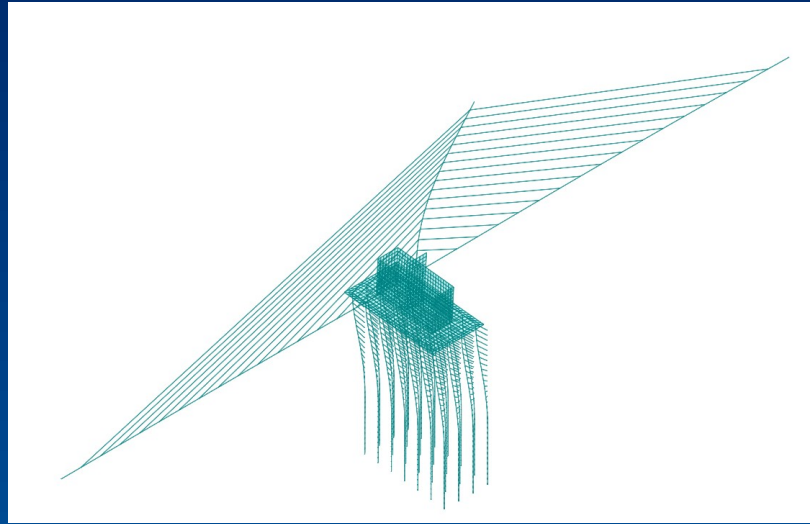


First transverse mode; second transverse mode

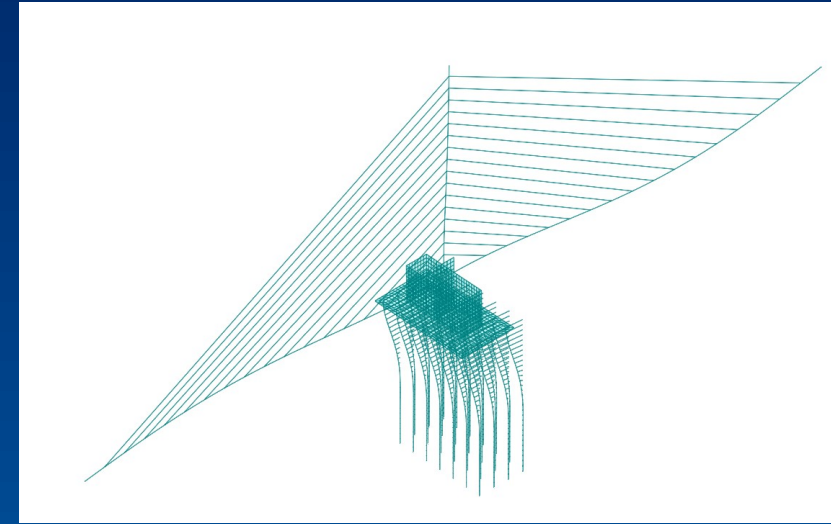
Eigenvalue Frequency Analysis Results: Changes in the Natural Periods



1st Transverse Mode



2nd Transverse Mode

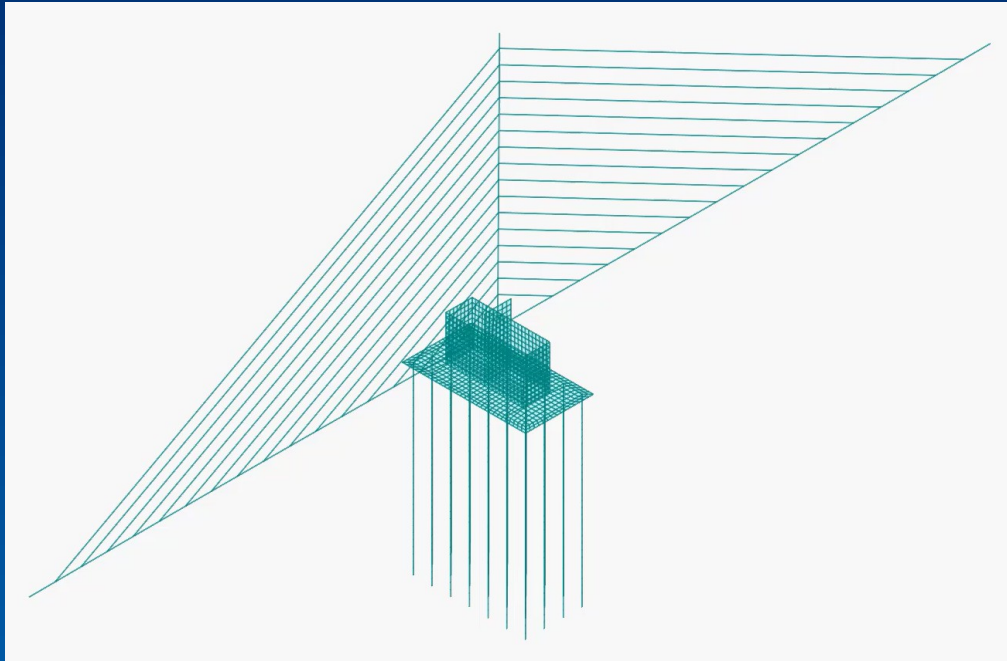


1st Longitudinal Mode

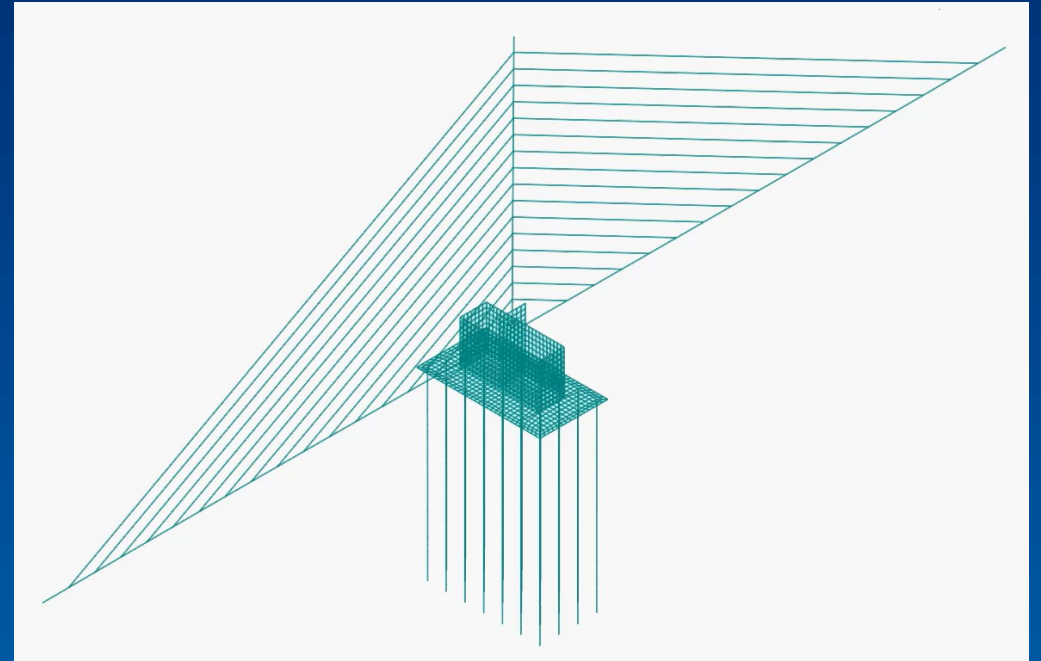
Natural period (s)	1st transverse mode	2 nd transverse mode	1 st longitudinal mode
Without scour	1.36	0.98	1.03
With scour	1.49	1.00	1.10

→ Natural period for the 1st transverse mode increases by 0.13s (10%).

Nonlinear Time-History Analysis Results: Behavior Comparison (Record #1)



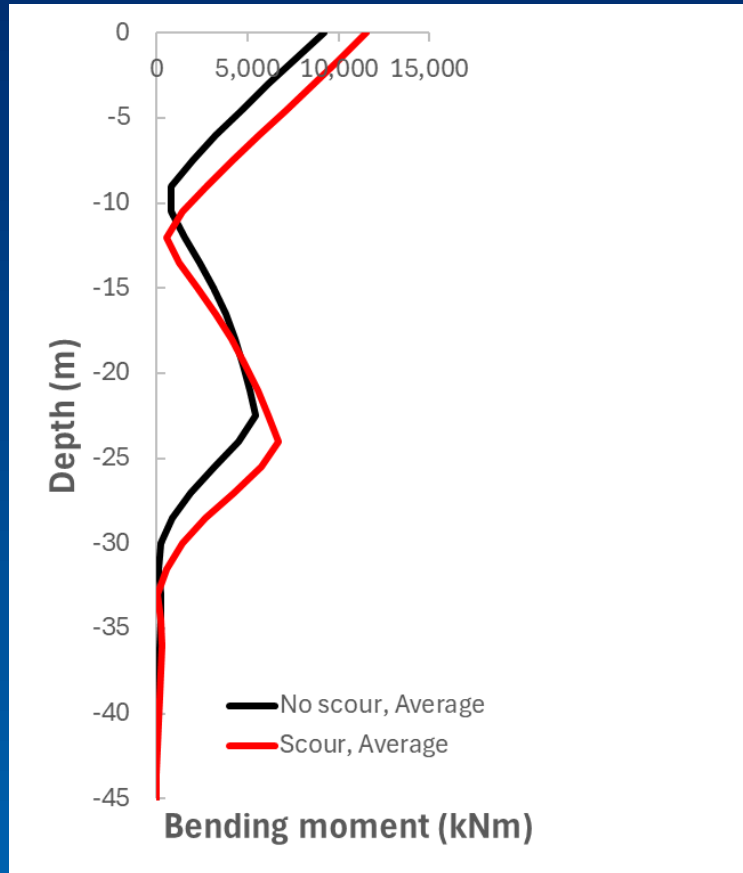
No Scour



6m Scour

→ Slightly longer natural period for the scoured bridge. What about the structural demand?

Nonlinear Time-History Analysis Results: Changes in Pile Structural Demands

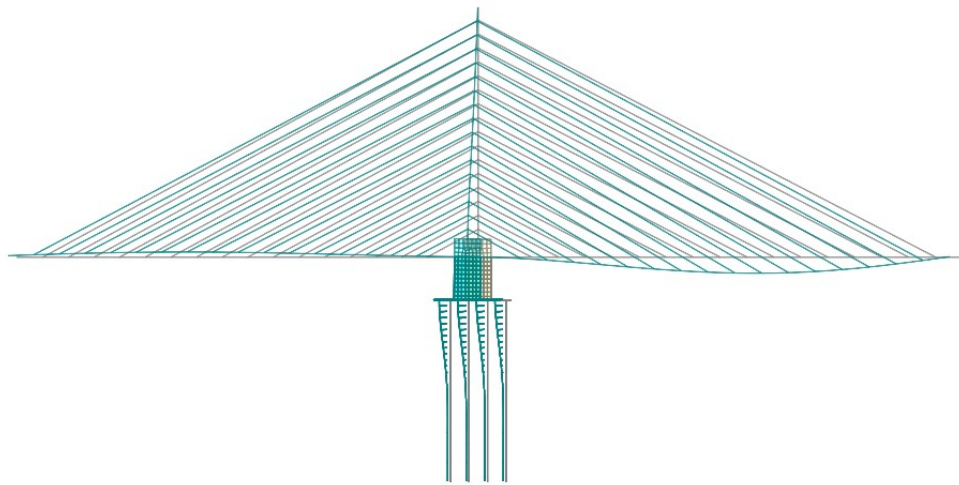


→ Increase in the peak pile head bending moment by approximately 25%

Note: “Bump” in diagram is due to reverse curvature bending of the pile, together with the significant lateral restraint provided by the dense sand layers below a depth of 25m.

Average peak bending moment along pile depth

Nonlinear Time-History Analysis Results: Changes in Pile Structural Demands

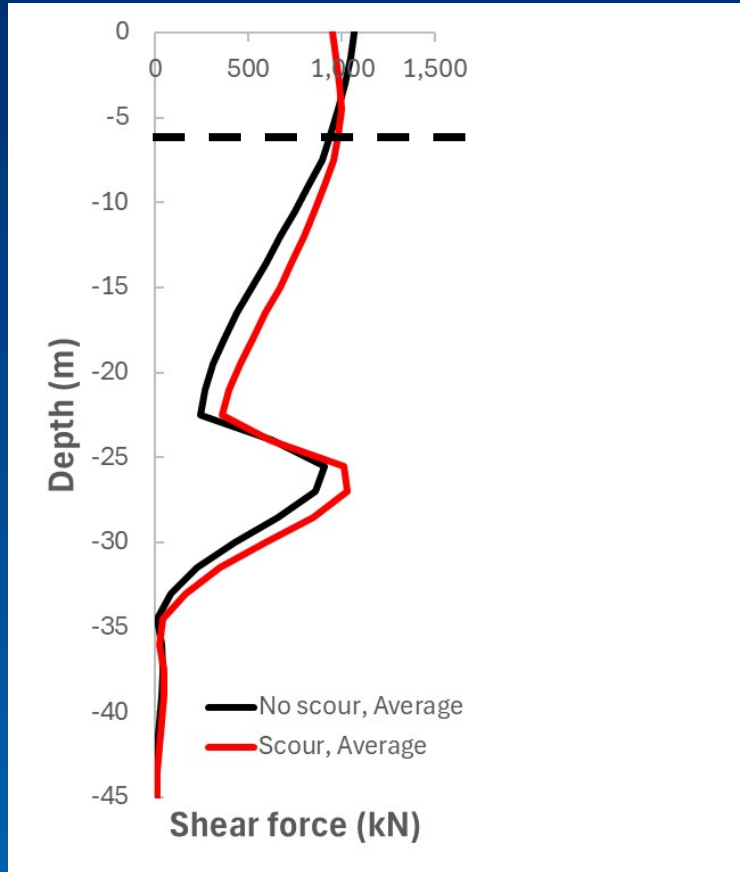


Critical Time Step (6.18s, Record #1), Front View



Critical Time Step (6.18s, Record #1), Side View

Nonlinear Time-History Analysis Results: Changes in Pile Structural Demands



→ Decrease in the peak shear at pile head

Average peak shear along
pile depth

Conclusions

- Step-by-step refined modelling workflow for a representative cable-stayed bridge, including soil-structure interaction, pile hysteretic damping, and radiation damping;
- Scour does affect the bridge natural frequency (1st transverse mode natural period increases by 0.16s or 10%) → Scour detection;
- Scour causes an increase in the peak bending moment at the pile heads by approximately 25% → Pile vulnerability to seismic event combined with scour.

THANK YOU

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