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MODELLING STRATEGIES FOR EVALUATING THE EFFECTS OF PIER SCOUR ON MULTI-SPAN MASONRY ARCH BRIDGES

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INTRODUCTION

The main cause of failure of masonry bridges is flooding, which results to scour. After the Somerset floods of 2015, it is important that the effects of scour are studied. The Computational Structural Mechanics Group has developed an accurate mesoscale representation combined with a hierarchical partitioning approach for modelling masonry. This study uses this approach as a starting point to complete the following:

1. Define scour simulation methodology
2. Define modelling strategies for applying the methodology
3. Identify most efficient modelling strategy
4. Use the best strategy to evaluate the effect of scour on multi-span masonry arch bridges

1 SCOUR METHODOLOGY

Definition: Scour is a natural phenomenon caused by erosion or removal of streambed or bank material from bridge foundations due to flowing water.

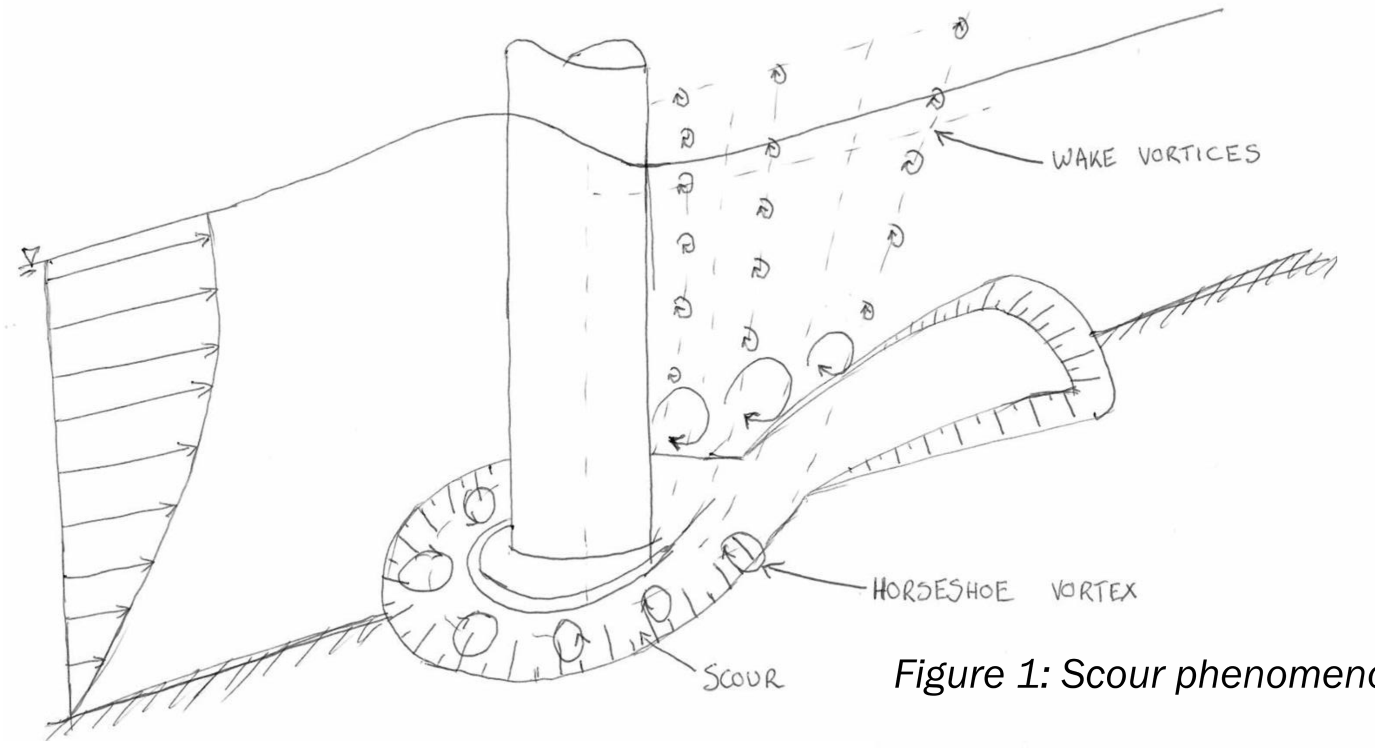

Figure 1: Scour phenomenon

Bed removal occurs due to the wake vortices around the vertical axis and results to the formation of a horseshoe vortex about the horizontal axis.

Scour leads to hole around bridge pier ⟶ Use equations to define hole geometry

$$if\ z > 0 \quad and \quad d_{max} + |x| \tan\frac{3\theta}{4} + |z| \tan\theta < y$$

$$if\ z < 0 \quad and \quad d_{max} + |x| \tan\frac{3\theta}{4} + |z| \tan\frac{\theta}{2} < y$$

ACKNOWLEDGEMENTS

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2 MODELLING STRATEGIES

STRUCTURE SIMPLIFICATION

Model structure components as beam elements instead of bricks.

These elements are connected with the hierarchically partitioned components using mixed-dimensional coupling.

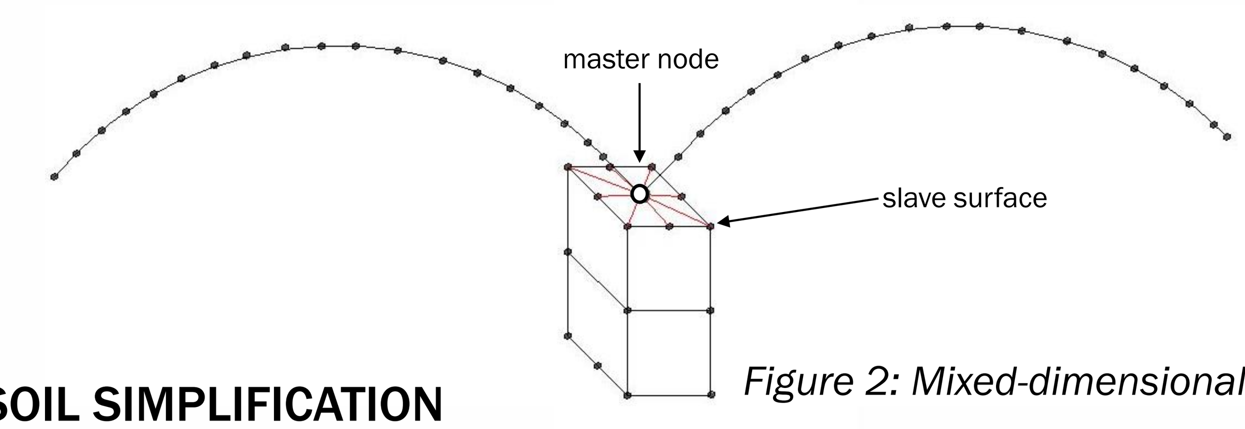


Figure 2: Mixed-dimensional partitioning

SOIL SIMPLIFICATION

Instead of soil elements, interfaces are used for modelling the behaviour of the soil surrounding the bridge foundations.

The characteristic parameter of these interfaces is the stiffness that corresponds to the soil stiffness.

The stiffness varies based on orientation and depth.

Vertical Orientation: $k_s = \frac{E_s}{B(1-\nu_s^2)}$

Horizontal Orientation: $k_h = \frac{A\gamma}{1.35b} z$

MODEL DEFINITION

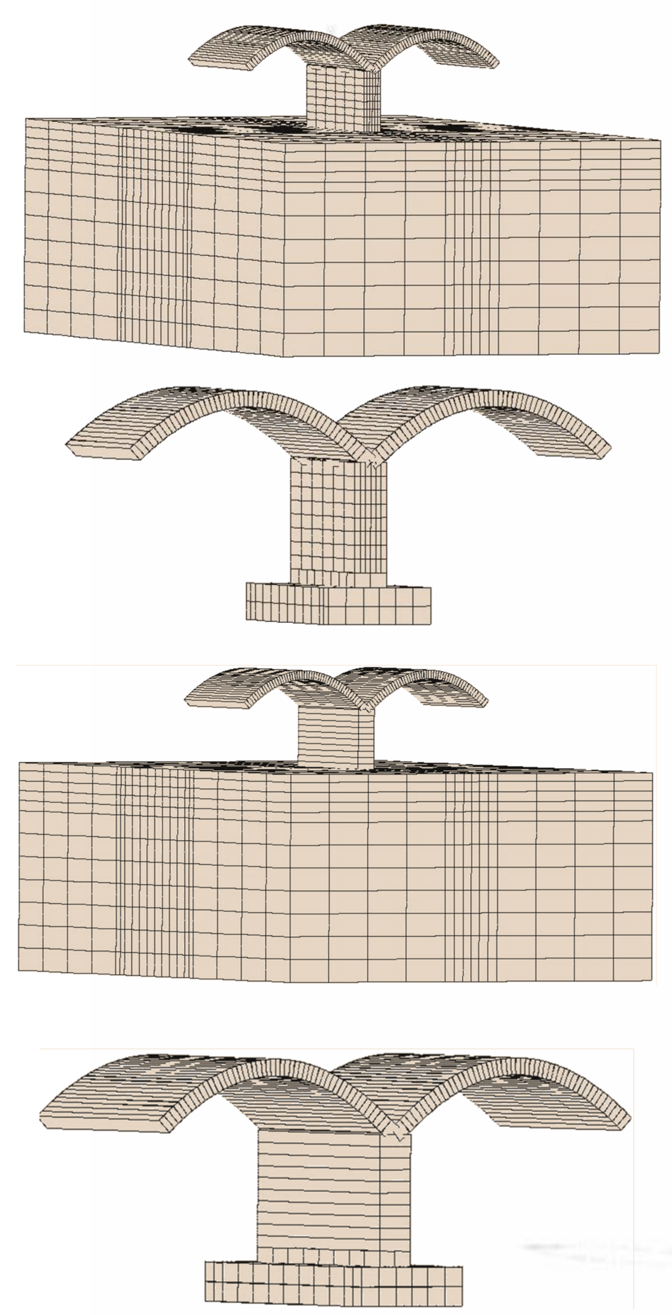
Figure 3: Modelling strategies defined

Model 1: Beam-element arches
Brick pier
Solid soil

Model 2: Beam-element arches
Brick pier
Soil interfaces

Model 3: Beam-element arches
Beam-element pier
Solid soil

Model 4: Beam-element arches
Beam-element pier
Solid interfaces



3 BEST MODELLING STRATEGY

The criteria for choosing the best model are the number of processors and the wall clock time required for the analysis.

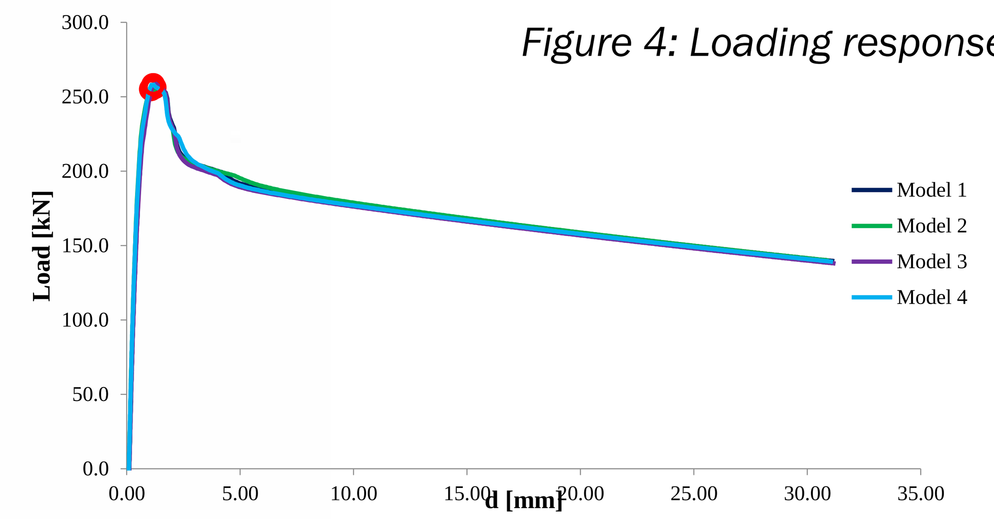


Figure 4: Loading response for all models

The loading response of the models shows high convergence.

Model 4 uses **74%** less computational power → BEST MODEL: MODEL 4

99% faster

4 EVALUATING THE SCOUR EFFECT

Model 4 is used to apply the scour methodology.

CONSIDER 3 SCOUR DEPTHS

With time scour depth increases ⟶ Considering different scour depths, scour evolution is simulated

With increasing scour depth:

- Initial displacement increases
- Response stiffness reduces
- Ultimate load reduces by **26%**

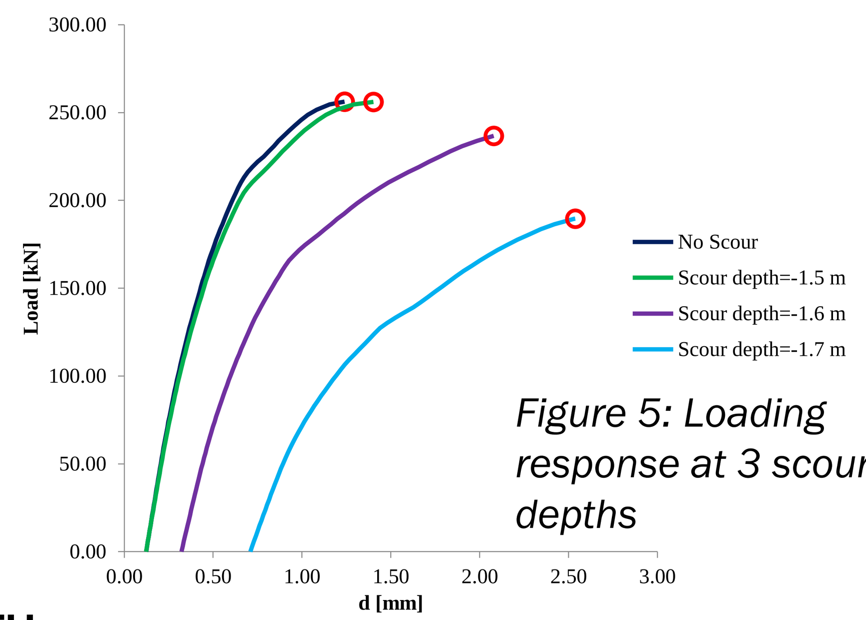


Figure 5: Loading response at 3 scour depths

CONSIDER GREATEST SCOUR DEPTH

- Greatest stress: arch edges
- Asymmetric stress distribution in arches due to scour hole assymetry
- Pier displacement indicates that the pier will rotate

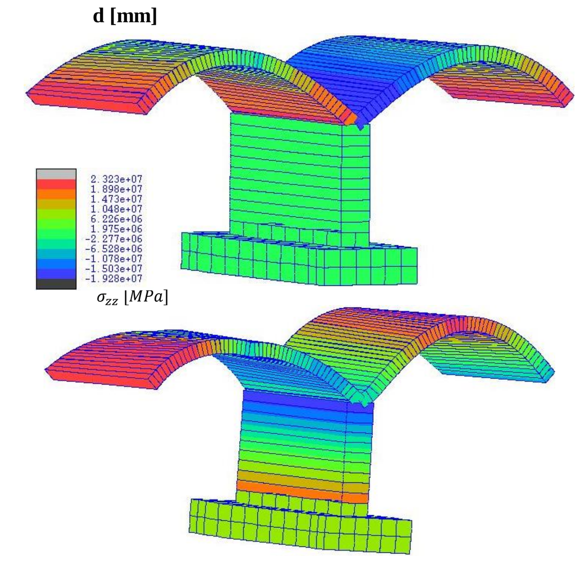


Figure 6: Stress distribution after scour and vertical loading

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Macorini, L. & Izzuddin, B. A. (2014) Nonlinear Analysis of Unreinforced Masonry Walls under Blast Loading using Mesoscale Partitioned Modeling. Journal of Structural Engineering. 140 (8), A4014002 (10 pp.).