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The Geo Engineering Centre

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PENGPENG NI, PHD (2016)

RESEARCH SUMMARY

NONLINEAR SOIL-STRUCTURE INTERACTION FOR BURIED PRESSURE PIPES UNDER DIFFERENTIAL GROUND MOTION

STUDY TO UNDERSTAND RESPONSE OF FLEXIBLE PIPELINES CROSSING GROUND FAULTS

FULL THREE DIMENSIONAL FINITE ELEMENT ANALYSIS OF THE CENTRIFUGE TESTS OF SAIYAR

PARAMETRIC STUDY TO GUIDE DESIGN CALCULATIONS WITH BEAM-ON-SPRING ANALYSES

SUPPORT FOR THE KAPPA METHOD—A SIMPLIFIED DESIGN ESTIMATE OF FLEXURAL BEHAVIOUR

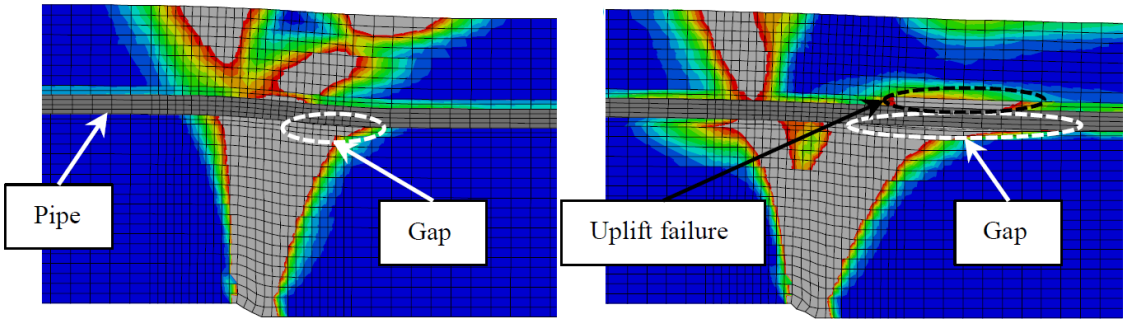
NEW ANALYTICAL SOLUTION FOR AXIAL PIPE RESPONSE DUE TO NORMAL GROUND FAULT

FULL SCALE TESTS ON PVC PIPES TO MEASURE FLEXURAL AND AXIAL STRAINS

It is critical to maintain water supply during earthquake events, to support fire suppression and post-disaster habitation. While design of oil and gas pipelines routinely considers the impact of permanent ground deformations associated with earthquake-induced ground faults, there has been a dearth of studies examining fault impacts on polymer and other water pipelines. Therefore, the objective of this project was to advance understanding of flexible pipe response to normal ground faults.

Firstly, numerical techniques were developed to model the centrifuge tests of Saiyar (2011) using ABAQUS/Explicit. Next, the analysis was used to conduct a parametric study, examining the impact of the flexural stiffness of the pipeline compared to the surrounding soil, the burial depth, the depth of the soil stratum overlying rock, and the characteristics of trench backfill compared to the native soil. This analysis includes the influence of shear failure in the soil, slip along the soil-pipe interface, gap development under the pipe, and mobilization of the uplift resistance of the overlying soil (see the figure).

Theoretical solutions for both flexural and axial pipe responses were obtained, as well as new procedures to estimate extreme fibre strains resulting from axial force and bending moment. Full-scale test data (see below) was used to assess the performance of available design methods, and guide their use.



A. Low stiffness pipeline (e.g. polyethylene) *B. High stiffness pipeline (e.g. cast iron)*

Zones of shear failure in the soil (grey), where gaps develop underneath, and uplift resistance is mobilized

HIGHLIGHTS

- **Three journal papers published or submitted to date and others in preparation**
- **Extended state-of-the-art in 3D computer analysis**
- **Design recommendations for simplified estimates of bending, beam-on-spring analysis, and methods to relate surface motions to those on buried pipe**

FULL-SCALE PVC PIPE EXPERIMENTS IN THE SPLIT-BOX

Working with MASc student Eric Poon, Ni designed and constructed a new test chamber—the *Split Box*. This unique, prototype-scale test facility with length of 7.1m, permits measurement of pipeline response under the influence of a normal ground fault. Testing of four test pipes demonstrated the effectiveness of strain measurements using optical fibres and Rayleigh backscatter analysis, and provided original flexural and axial strain data for PVC pipes of three diameters subjected to differential ground motions.

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Pengpeng and Eric preparing a test in the Split Box