News Article for RISUD Joint Research Fund

		Name	Department
1.	**Principal Investigator**:	Dr ZHOU Chao	CEE
3.	**Project Title:**	Enhancing the resilience of underground water pipeline systems in Hong Kong	

4. **Annual Progress/Achievement (***in layman's language, no more than two A4 pages, pls attach a few figures***)**

Underground water pipeline systems are vital infrastructure and lifelines globally. However, they often face threats and damage from ground movements induced by landslides, tunnelling, excavations, etc. The occurrence of bursts and leakages in flawed pipelines can lead to substantial water losses, severe traffic congestion, water supply suspension, and catastrophic geohazards like sinkholes and landslides. The above two issues are especially critical in Hong Kong (see Figure 1), where pipelines frequently run alongside or across busy roads and slopes, thereby increasing the frequency and impact of underground pipeline ruptures. Notably, in 2008, a landslide caused damage to the sole water main in Tai O, resulting in a three-day water supply suspension. Moreover, this problem may heighten in the future due to an increased frequency and severity of extreme weather events in a changing climatic scenario, thus exacerbating the challenges faced by soil and underground water pipeline systems.

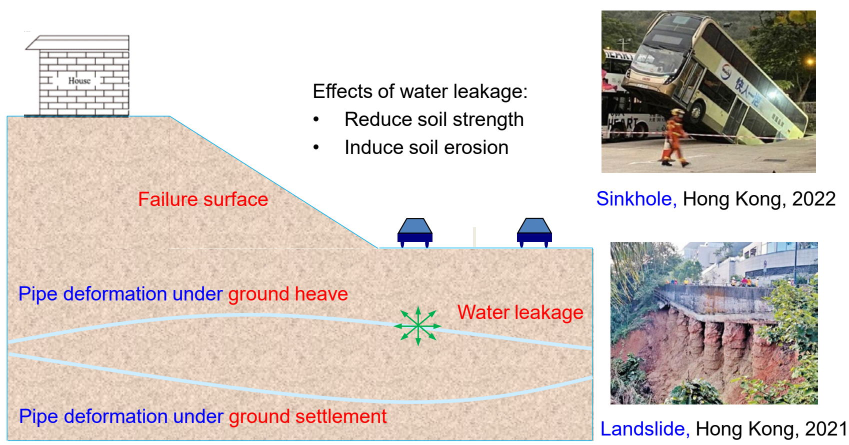

Figure 1. Schematic diagram of soil-pipe interaction and relevant geohazards

This project aims to develop a proactive and multi-pronged approach to enhancing the resilience of underground water pipeline systems in Hong Kong. In the first year, the research team has made good progress, as briefly introduced below. In particular, advanced testing systems and numerical techniques have been developed, based on which more promising results can be achieved in the next stage of this project.

1. Advanced and large-scale testing of soil-pipe interaction

The research team has successfully developed different testing systems for the planned tests in this project. A new and large-scale physical model (1.2 m x 1.0 m x 0.6 m) was developed to study the mechanism of soil-pipe interaction, as shown in Figure 2. Additionally, novel film-like sensors were introduced and modified to measure the contact pressure on the soil-pipe interface and the earth pressure around the pipe, providing comprehensive information on soil-pipe interaction. The effects of crucial factors such as pipe surface roughness, hardness, buried depth, cycling, and moisture conditions were thoroughly evaluated. The obtained test results have great value in understanding the interaction mechanisms between the ground and pipelines and in proposing innovative measures to reduce pipeline ruptures and mitigate the risk of sinkholes and landslides caused by leakage. For instance, a new equation has been developed and validated for the maximum resistance based on the test data.

2. Constitutive modeling of soil-pipe interfaces

Unsaturated soil conditions and temperature fluctuations in the soil surrounding pipelines can significantly impact the strength and stiffness of the surrounding soil, consequently influencing the behaviour of buried pipelines. Therefore, developing an advanced constitutive model for the thermo-hydro-mechanical (THM) coupled behaviour of soil-pipe interfaces is necessary. Such a model is not available in the literature. The research team has developed a cutting-edge thermo-mechanical model that effectively accounts for unsaturated soil behaviour and soil-interface interactions to capture the soil behaviour around pipelines.

3. Simulating soil-pipeline interaction using advanced numerical techniques

The Material Point Method (MPM) has proven to be a highly effective tool for analyzing large deformation problems such as landslides and sinkholes. The research team has developed a state-of-the-art code incorporating temperature and unsaturation influences to accurately simulate the landslide process induced by pipeline water leakage using the MPM method (see Figure 3). The numerical simulations demonstrate a remarkable agreement with the measured data from previous experimental studies.

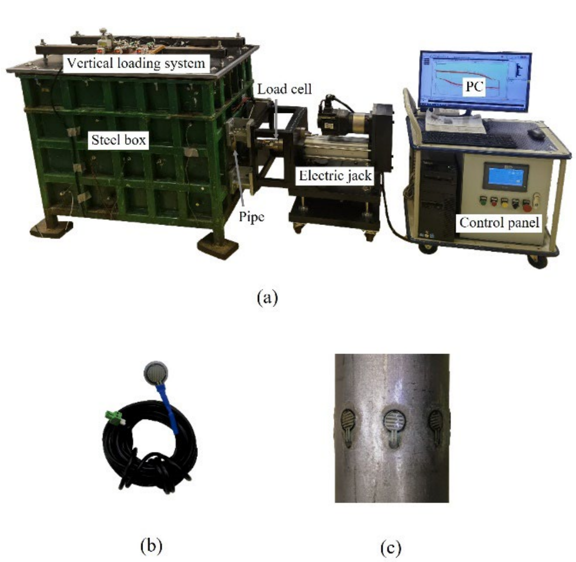

Figure 2. Large-scale physical model and instrumentation setup used to investigate soil-pipeline interaction

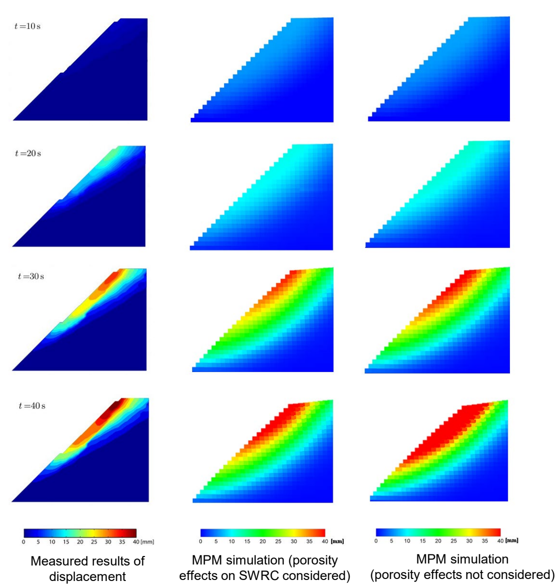

Figure 3. Validation of the proposed MPM formulations using the results of centrifuge tests