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The E-PILOT container for investigating pile-soil-tunnel interaction in centrifuge

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ABSTRACT: To study the effect of deconfinement that may occur when digging a tunnel, the E-PILOT container was designed to study pile-tunnel interactions. With pluri-decimeters dimensions, the container allows the tunnel working face to be positioned at different depths. Based on the 'trap door' concept, the movement of the working face is controlled by a hydraulic jack. With a diameter of 100 mm, the rigid working face can move horizontally inside a tube. The E-PILOT container is presented in detail with its instrumentation. An example of test results illustrates the in pile-tunnel interaction.

1 INTRODUCTION

Increased urbanization can lead to tunnel projects in areas where buildings on piles, sometimes old ones, are already in place. During the tunnel boring phase of construction, changes in the stress field are expected in the surrounding soil supporting the piles. For investigating the pile-soil-tunnelling machine interaction in the framework of the research programme ANR-E-PILOT (2022), a specific container has been developed for centrifuge testing. The main idea was to provide cases of deconfining or over-confining of the underground stresses under controlled boundary conditions. A simplified design has been done for resisting up to 100g.

The concept is based on the "trap-door" mechanism, which is here considered for circular holes, possibly opened vertically or horizontally.

2 EXPERIMENTAL DEVICE

A scheme of the E-PILOT container (Figure 1) shows the possible arrangements of a horizontal tunnel where an inner vertical trap-door is included, and of a horizontal trap-door at the bottom of the container. This includes two possible scenarios: a vertical trapdoor (detailed below), representing a tunnel passing close to the pile, and a horizontal trapdoor, representing a tunnel located deeper beneath the pile.

The diameter of the holes (the trapdoors) is $D_t = 100mm$, corresponding to the inner diameter of the tube (5mm thick and 150mm long) that simulates the tunnel. The depth z_t of the tunnel axis can be adjusted to $2D_t$, $2{,}5D_t$, $3D_t$, or $3{,}5D_t$. The inner height of the container is $4D_t$, when the horizontal dimensions are $6D_t$. Welded external stiffeners (70mm×8mm) ensure the rigidity. The tunnel, made of cylinder barrel extra smooth E370SR steel (elastic limit 345N/mm², yield limit 490N/mm²) is welded onto a ground support plate with a shoulder. To prevent unwanted sand from entering the tunnel, the piston of the trapdoor is adjusted to the same diameter. It is fitted with a nitrile seal and protected by a silicone-free lubricant to minimise friction.

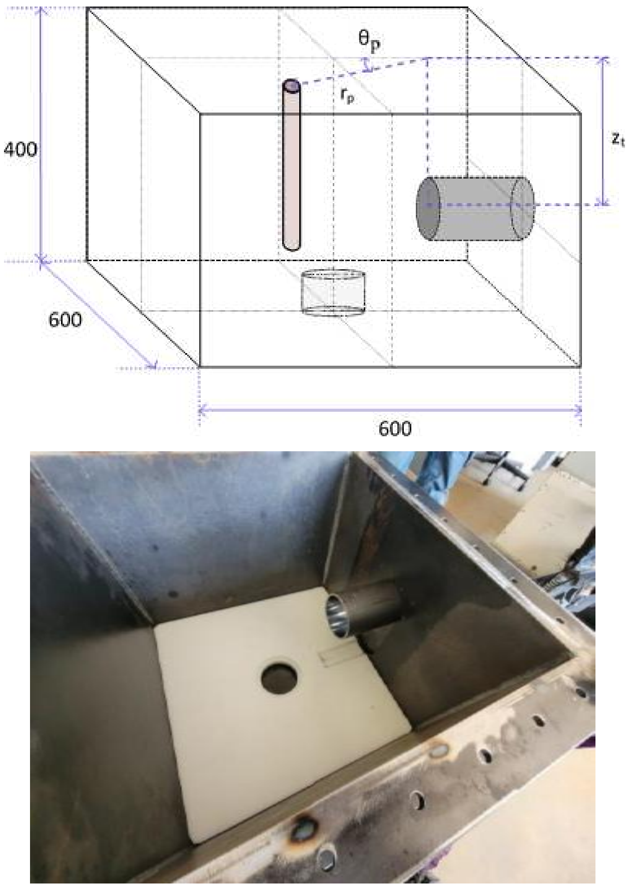

Figure 1. Scheme and dimensions of the E-PILOT container (top); inside of the container (bottom).

The trap door monitoring system consists of a guidance system and a hydraulic actuator (Figure 2).

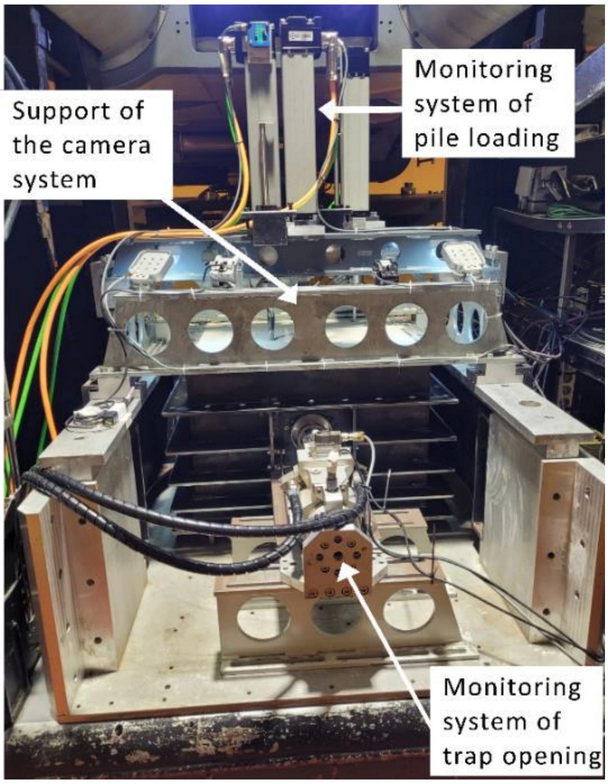

Figure 2. E-PILOT container in the centrifuge basket.

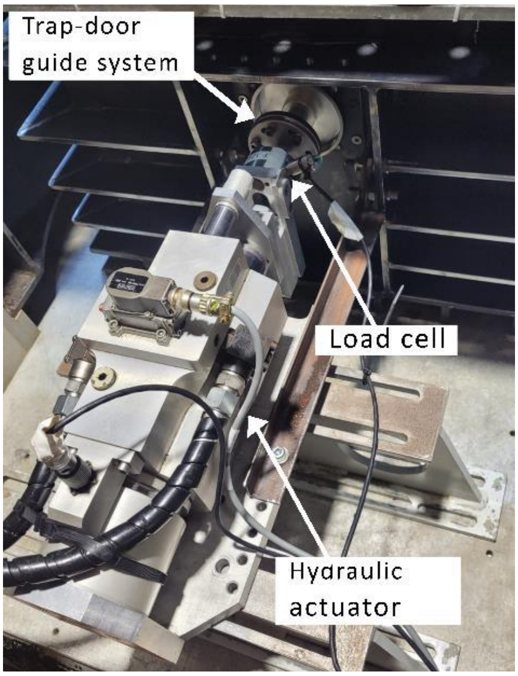

Figure 3. Monitoring system of trap-door opening.

The guide-system (horizontal tube) constrains the trap-door movement to a single direction: the direction of opening, but could also move forward. A hydraulic actuator was connected to the guidance system of the trap door to control and perform the opening (Figure 3) at a controlled speed of 0.01 mm/s, up to a maximum of 5 mm. This actuator was equipped with a potentiometer to measure and control the displacement of the trap door. A force sensor was installed at the head of the actuator and linked to the guidance system to measure the forces applied and generated during operation.

3 EXAMPLE OF RESULTS

In a dense ($I_d = 80\%$) Fontainebleau sand NE34 (Dano et al., 2024), 2 piles (diameter $d_p = 12mm$) pre-installed at 1g and loaded in-flight (60g) to SLS constant load, display different behaviour during the backward movement of the tunnel front (Figure 4). The pile P2 displays almost no settlement, as if it was far away from any soil failure mechanism. The pile P1 is much more affected, showing 3 phases: 1) no settlement up to 1%; 2) progressive loss of bearing capacity up to 3.9% of front displacement; 3) rapid loss of resistance leading to failure over 3.9%.

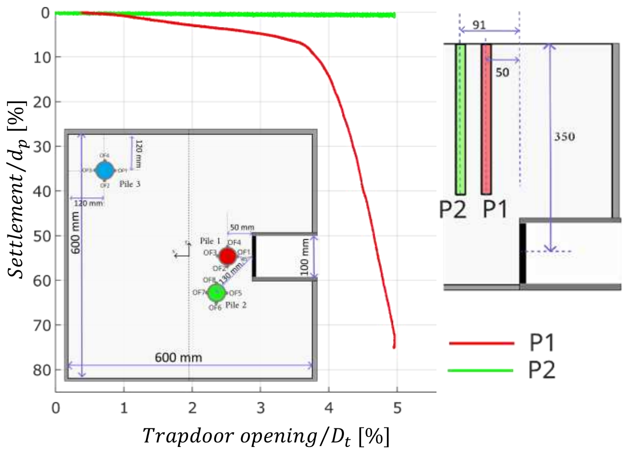

Figure 4. Pile settlement for $z_t = 3.5D_t$.

4 CONCLUSION

The E-PILOT container, developed following the trapdoor concept, is a robust equipment for centrifuge modelling, useful for a better understanding of pile-soil tunnel interaction.

ACKNOWLEDGEMENTS

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