

## Upheaval buckling resistance of pipelines buried in clayey backfill

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### ABSTRACT

This paper presents data from a series of Minidrum Centrifuge tests in which the effects of backfill cover (1 m & 1.3 m) and rock-dump (0.5 m) thickness on the uplift resistance were investigated. All the centrifuge tests were carried out at 30g using natural marine clay. The natural clay samples from offshore were characterised and reconstituted before testing. Field backfill conditions were simulated close to reality in the testing. In each of the tests, the resistance of soil cover, the vertical pipe displacement, and excess pore pressure changes at the pipe invert were measured. The results from this study are compared against the current framework of upheaval buckling behaviour in the literature, and are used to provide a better guideline for the design of offshore pipelines buried in clayey backfills.

**KEY WORDS:** Upheaval buckling; pipelines; backfill; clay; uplift resistance.

### INTRODUCTION

Predicting upheaval buckling resistance of buried pipelines has been a challenge as there is a huge uncertainty and randomness in the nature of soil cover created by various pipe burying techniques. Present understanding on uplift resistance of buried pipe lines is based on analysis (Randolph and Houlsby, 1984; Maltby and Calladine, 1995) and experimental work by researchers (Cheuk et al, 2005; White et al, 2001; Bransby et al, 2002; Baumgard, 2000; Dickin, 1994; Finch, 1999; Moradi & Craig, 1998). However, almost all the experimental work on uplift resistance was carried out on granular soils, and there is a lack of experimental work on clay backfill (Cheuk et al. 2007).

This paper presents data from a series of Minidrum Centrifuge tests in which various factors affecting the upheaval buckling resistance were investigated. The factors investigated were depth of burial, time interval between the pipeline burial and commissioning, rate of pipe pull-out, and depth of rock dump. All the centrifuge tests were carried out at 30g on a natural marine clay. The natural clay samples were characterised and reconstituted before testing. Field backfill conditions were simulated close to reality in the testing. In each of the test, the

resistance of soil cover, the vertical pipe displacement, and excess pore pressure changes at the pipe invert were measured. The results from this study are compared against the current framework of upheaval buckling resistance behaviour in the literature, and are used to provide a better guideline for the design of pipeline buried in clay backfills.

A total of 4 tests were conducted on a 1 in 30 scale model. The prototype pipe was 261 mm in diameter (8.7 mm at model scale), and was buried under clay backfill. Tests 1 and 2 were conducted to measure the uplift resistance of clay covers of depth 1.30 m and 1.05 m respectively, after 2 months of backfilling. Tests 3 and 4 were undertaken to measure the uplift resistance of a clay cover of depth 1.05 m overlain by a layer of rock-dump of depth 0.5 m and 1.0 m, respectively. In these tests (tests 3 & 4), the clay cover was allowed to consolidate for one month before rock-dumping was carried out. The clay was then permitted to consolidate for another month under the weight of rock-dump before the pipe was pulled up.

### REVIEW OF LITERATURE

The uplift resistance per unit length of pipe,  $F$ , comprises (i) the weight of the soil above the pipe and (ii) the mobilised shearing resistance of soil. The peak value of  $F$  can be interpreted within an effective stress or an undrained strength framework. The conventional interpretation of pipe uplift resistance involves vertical sliding planes above the pipe, with the geometry and nomenclature as shown in Figure 1.

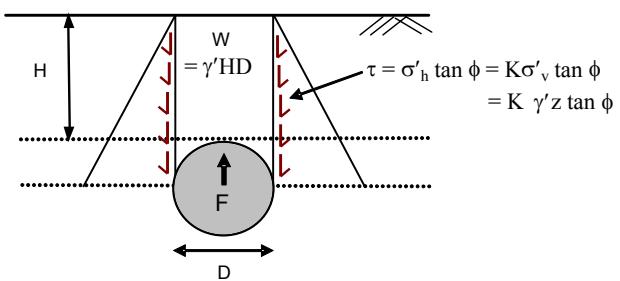


Figure 1. Vertical shear model for pipe uplift resistance.