Validation of Rock Berm Cover Design for Offshore LNG Pipeline in Hong Kong

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ABSTRACT

This paper describes results of a testing program using a combination of centrifuge modelling and numerical analysis to obtain design criteria for rock berm protection of a buried pipeline. It provides a discussion of the design approach and test methodology, results, numerical analysis, and combined outcomes leading to the design of the rock berm. The program investigated the effect of pipeline burial depth, the shape and size of the burial trench, and the characteristics and quantity of the rock cover material for protection of the pipeline from dragging of navy stockless anchors of three sizes. Anchor drag load and pipeline loading from both chain and anchor dragging were measured and the anchor trajectory assessed post-testing. While guidelines for successful protection were preliminarily based on minimum vertical clearance between the pipeline and anchor, the main result showed that the lateral extent of rock protection ahead of the pipeline also played a major role in preventing pipeline damage.

KEY WORDS: Anchor, pipeline, rock cover, clay, centrifuge, testing, numerical modelling.

INTRODUCTION

Adequate design and protection of offshore buried pipelines used to connect offshore and onshore infrastructure are critical concerns for continued safety and serviceability, especially in areas with soft seabed soils and shipping activity. Pipelines installed in such multi-use locations have a high risk of damage from the anchoring of large vessels, which can lead to safety concerns, environmental pollution, and significant remedial costs to bring the pipeline back into operation. Anchoring in soft seabed soils often requires significant penetration depths and relatively long drag lengths to achieve adequate anchor holding capacity during initial installation. Additionally, storm loading may cause vessels to further drag previously installed anchors. Common solutions for pipeline protection may include costly burial to depths sufficient to prevent anchor interaction or placement of rock cover to limit lateral displacements, though no formal guidelines exist to assist in these designs.

In addition to the lack of guidelines, few investigations aimed at understanding the effect of anchors forces have been performed. Al-Warthan et al. (1993) investigated the effect of dropping anchors on free-spanning pipelines while Sriskandarajah and Wilkins (2002) assessed the buckling of pipelines due to lateral load through finite element analysis. Although useful, results of these studies are not sufficient to assist in design. Yasseri and Prager (2005) presented a comprehensive probabilistic method for deciding upon the depth of burial of pipelines, accounting for both the likelihood of various levels of hazards and the uncertainty in the response behaviour of the system. However this method does not provide insight into the mechanisms of interaction between the anchor, the chain, and the seabed. The first experimental evidence of the interaction between anchor, anchor chain, and pipeline rock cover was obtained from a series of centrifuge tests investigating the performance of various rock berm protection configurations for anchor dragging for a pipeline project in China (Gaudin et al. 2005). Results of this investigation not only provided data for design, but demonstrated the dominance of the interaction between anchor chain and rock cover in the trajectory of the anchor above the anchor-soil interaction.

The testing program presented herein seeks to expand upon previous experimental investigations of anchor, chain, and rock cover interaction with the specific goal of designing protection for an LNG pipeline project in Hong Kong contracted by CLP Power Hong Kong Limited. The proposed pipeline is 943.3 mm in diameter, 38.8 km long, and its design is divided in five zones that are dependent on water depth (ranging from 2 to 24 m), traffic activity (between 30 to 560 vessels a day), vessel size, and soil conditions.

The design of the rock cover of the pipeline was carried out in two stages. In stage 1, a preliminary design of the rock cover was performed...