The effect of pipeline-seabed interaction on its response to the strike-slip fault

Mozhgan Asgarihajifirouz, Xiaoyu Dong, Hodjat Shiri.
Department of civil engineering, Memorial University of Newfoundland
St. John’s, Newfoundland and Labrador, Canada

ABSTRACT

Trenched subsea pipelines may experience significant lateral displacement due to permanent ground movements such as strike slip-fault movements, landslides, ice gouging, etc. In shallow depth, using pre-excavated seabed soil as a backfilling material is a cost-effective option to protect pipelines against large deformations. This kind of pre-excavated material usually gets highly remolded and becomes considerably softer than the native seabed soil. The shear strength difference between the backfilling and seabed soil can result in the pipeline-backfill-trench interaction during large deformation and therefore significantly influence the failure mechanism of the surrounding soil and the soil resistance acting on the pipeline. The pipeline-backfill-trench interaction has not been well considered in the present design guidelines, and usually uniform soil has been considered to simplify this issue. In this research, the performance of buried steel pipeline in the strike-slip fault movement is investigated using the Coupled Eulerian-Lagrangian (CEL) method to investigate the failure mechanisms considering strain-softening behavior. This study examined the importance of various parameters, including the geometry of the trench, and the backfill and seabed soil strength on the pipeline-backfill trench interaction.

KEY WORDS: Pipeline-backfill-trench interaction; Large Deformation Finite Element (LDFE) analysis; Coupled Eulerian-Lagrangian (CEL); strain-softening behavior; strike-slip fault; shallow water; soil failure mechanism; p-y responses.

INTRODUCTION

Over the past two decades, oil and gas facilities in the offshore area have been extended from deep water floating production structures to shallow water fixed systems. Subsea pipelines are one of the most efficient, reliable, and safest among these facilities for transporting hydrocarbons. In shallow seas, pipelines are typically buried inside trenches to protect them against any external or internal loads during operation. Moreover, geographic dispersion can severely damage buried pipelines. The structural behavior of buried pipelines subjected to permanent ground displacement (PGD) has been extensively studied in recent years. PGD caused by earthquakes, liquefaction-induced soil movements, or landslides can cause significant damage to underground lifelines. One of the major factors affecting the pipeline's behavior and performance has been recognized as the complex interaction between the pipeline and the surrounding soil in the vicinity of the fault zone. Although earthquake and pipeline engineers have not extensively studied the response of soil to fault ruptures, there have been some significant contributions from Newmark & Hall (1975), Kennedy et al. (1977), Wang & Yeh (1985), Takada et al. (2001), Trautmann & O’Rourke (1985) Ha et al. (2008), O’Rourke et al. (2008), Vazouras et al. (2010), Vazouras et al. (2012), Liu et al. (2016) Zhang et al. (2016) and Özcebe et al. (2017).

In the previously conducted research, the soil domain has been considered uniform (ignoring the trenching effect) and analyzed without dynamic excitation. Also, in current design codes like ALA (2001) and PRCI (2009), the pipelines are designed inside a uniform seabed, and the effects of trenching (the geometry and material properties (see Fig. 1)) have been ignored. Consequently, a proper understanding of pipeline-trenched backfill soil interaction is necessary to safeguard against PGD.

![Fig. 1. Schematic representation of pipeline-backfill-trench interaction.](image-url)