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Prediction of Breakout Forces for Deepwater Seafloor Objects

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Abstract

Breakout of objects from soft, clayey seafloors is a common, potentially hazardous and costly task, but there is little information about it beyond results of small-scale laboratory studies extracting decimetre-scale objects from 'model' soils. In this study, a unique dataset is presented, comprising thirty-five immediate breakout events of a seafloor template from very soft clay in 200 m to 2000 m water. The measured breakout forces were compared to operational variables and soil characteristics at the exact location of breakout, which were known because geotechnical soil investigations were performed at each site. Predictions from three existing theories, namely Muga (1968), Rapoport and Young (1983), and Das (1991) were tested. The three theories appear to predict breakout force well, and with comparable accuracy. Predictions from all these methods could be valuable in lifting/extraction risk assessments.

Introduction

Through a variety of marine activities, objects are placed on or come to rest on the seafloor. Many of these objects must also be retrieved. Extracting sunken vessels, manifolds, pipelines, temporary shallow foundations and other objects from soft clay requires greater force than the submerged weight of the objects. The force necessary to pull objects from a cohesive or muddy seafloor, or "breakout force," must be predicted to mobilize appropriate resources for each extraction and to design economic and safe lifting systems.

Fugro operates in deep water, where the seafloors are often very soft clay, and the factor of safety of the lifting equipment becomes a greater concern, particularly as breakout forces increase. To assess factors affecting breakout situations and safety concerns, measurements of forces and other factors that affect the placement and breakout of operational equipment are recorded.

In this study, the relationship of forces measured during breakout of a Seafloor Template (ST) (a Fugro SEACALF[®] system, which is used to perform Cone Penetration Tests (CPTs), Kolk and Wegerif, 2005) to the geotechnical characteristics of the sediments is examined. The goal was to determine what factors predict the level of force (and corresponding time to failure) required to break an object out of soft substrate in deep water. Only very soft clays (undrained shear strength $c_u < 20$ kPa) were considered.

The breakout force is caused predominantly by a 'mud suction' force, or 'under pore pressure', which develops in slow-draining cohesive soil below an embedded object.

The precise nature and cause of the under pressure have been modelled theoretically and investigated in laboratory experiments using different object shapes, including cubes, cylinder, spheres, prisms and flat round plates, and skirted, rectangular grates (Muga, 1968; Roderick and Lubbad, 1975; Foda, 1983; Rapoport and Young, 1985 and 1983; Sawicki and Mierczynski, 2003; Craig and Chua, 1990; Das, 1991; Purwana et al., 2005; Zhou et al., 2007; Kelleher and Samsuri, 2008).

This study's unique dataset provides an excellent opportunity to compare breakout theory and practice. The database contains measurements recorded during breakout from the less controlled environment of real seafloors under 200 m to 2000 m water. The data from 35 actual breakout events can be compared to the soil characteristics at the exact location of breakout, because a geotechnical soil investigation was performed at each site.

Previous Work on Breakout Forces

A search for published measurements of breakout forces during actual salvages from soft clay seafloors yielded no results, but several researchers have published theories and experimental results.