Effects of Shear Band Propagation on Submarine Landslide

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ABSTRACT

Interbedded layers of glacial deposits and marine or glacimarine clay layers are a common feature of offshore sediment. Typically, offshore marine clays are lightly overconsolidated sensitive clay. Some case histories on submarine landslides show that the slip surface passes through these marine clay layers. In this paper a model is proposed for post-peak strain softening behavior of marine sensitive clay. The slope failure mechanism is examined using the concept of shear band propagation. It is shown that shear band propagation and post-peak stress-strain behavior of clay layers are two major factors in submarine slope stability analysis.

KEY WORDS: Submarine slope failure; shear band propagation; sensitive clay; limit equilibrium method.

INTRODUCTION

Over the last few decades, offshore oil and gas development activities have rapidly increased with significant increase in demand of energy. For planning and design of offshore facilities, the stability of the seabed is an important issue that must be taken into consideration. The consequences of catastrophic submarine slope failure might be very devastating and could have a significant financial loss, safety and regulatory implications. Numerous failures of submarine slopes have been reported in the literature some of which are small while others are very large, such as Storegga slide in the Norwegian Sea or Grand Banks slide in offshore Newfoundland. Various potential triggering mechanisms have been identified in the past (e.g. sedimentation, earthquake induced pore pressure increase, gas hydrate dissociation) that could weaken a section of a soil layer from where failure might be initiated. Failure might occur from a single triggering factor or could be the combined effect of a number of factors. For example, in case of Storegga slide and Trænadjupet slide, it is believed that initial triggering was developed by excess pore pressure caused by rapid deposition of overlying sediments possibly combined with effects from earthquake loading and/or accumulation of gas (Bryn et al. 2005; Kvalstad et al. 2005; Laberg et al. 2003).

The offshore continental slope has been affected by numerous large scale submarine slides all over the world. The Storegga slide is one of them which have been investigated intensively during the development of the Ormen Lange gas field. Evaluation of possible triggering mechanisms of the Storegga slide, geological and geotechnical site investigations in the slide area and current state of slope stability analysis at Ormen Lange area have been described by Tjelta et al. 2002; Kvalstad et al. 2005; Bryn et al. 2002 and 2005; Solheim et al. 2005 and Yang et al. 2006. Typical seismic profiles of two well-known slide sites are shown in Figs. 1 and 2. It is noted that extensive site investigation has been carried out in these areas through high resolution mapping, field investigation, geoborings up to several hundred meters below the seabed and laboratory testing. By interpreting the field and laboratory investigation results and seismic stratigraphy, it was concluded by previous researchers that such offshore sediments primarily consist of slightly inclined interbedded layers of glacial deposits and marine or glacimarine clay layer. The dashed line BC in Figs. 1 and 2 show two locations of the marine clay layer.

In general marine and/or glacimarine clays have higher water contents, plasticity indices, liquidity indices and clay content as compared to glacial clays. The sensitivity of these clays is in the range of 3 to 6 or more (Kvalstad et al. 2005; Yang et al. 2006). In undrained loading they show contractive and strain softening behavior at large strain. Therefore, the slip surface primarily passes through the marine clay layer, for example as in the case of the Storegga slide.

This paper presents a new method of slope stability analysis considering the strain-softening behavior of marine clay. It is shown that the propagation of shear band through this clay layer could cause the failure of a submarine slope. The limitations of the limit equilibrium method in offshore slope stability analysis are also presented as compared to the results obtained from the present model.