SLOPE STABILITY ISSUES IN HYDRATE BEARING SEDIMENTS UNDER SEISMIC LOADING

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While there is debate concerning total gas-hydrate reserves, researchers have suggested boundary surfaces of stable hydrates are far larger than originally anticipated. Recently, a theoretical basis has begun to emerge supporting the hypothesis that pore pressures may increase on hydrate dissociation. Therefore, re-assessment of risk (e.g. earthquake triggers) to seafloor installations is required. Typically, regional seismic assessments exclude site-scale sediment property data. Consequently, the potential for underestimating risk is significant, particularly when shear strengths are reduced by increased pore pressure. This suggests, for example, there is a need for improved geophysical and geotechnical property-models for sediment-hosted methane-hydrates. Typically, seismic hazard assessments utilize only the 'engineering soil' to model the control of local geology on earthquake ground motion. While ground motion amplification caused by the weakest, shallowest sediments is reported widely, similar studies including contributions from deeper geological units are rare. Using a conservative infinite slope model, a methodology is presented for mapping the factor of safety; it is based on modelling sediments on the continental shelf and slope through use of existing geological-lithological models and compatible earthquake time series (Musson et al., 1997; Jackson et al., 1999). Defining lithologies, we derive the soil and rock properties needed in simulating the propagation of earthquake ground motion from bedrock to the seabed through the sediment column. A perceived problem in modelling ground motion amplification in the deeper subsurface is a lack of engineering geotechnical data. However, for such studies we show density and shear wave velocity data from conventional downhole logs (e.g. Ocean Drilling Program and reservoir characterisation) can by incorporated directly, being primary parameters in standard ground motion modelling. Results are presented for synthetic models showing changes in lithology in the deeper subsurface can significantly affect earthquake induced ground motion at the surface. A field example, from the AFEN slide west of Shetland, on the UK Atlantic continental slope is presented where we compare the traditional 'shallow' approach to ground motion amplification modelling with one utilizing geological data to depths of 1.8 km and known lithologies to greater depths. Our results suggest the use of 'soil' properties to depths in excess of 600 mbsf is significant. The use of earthquake time series matching the site are also shown to have a significant impact; we have compiled an earthquake catalogue for the region, developed a seismo-tectonic source model, and used a probabilistic approach to predict effective ground accelerations at required return periods.

From this base we modeled reductions in Factor of Safety to be expected as a consequence of hydrate dissociation. To simulate hydrate dissociation we modeled increasing pore pressures in our physical property models which in turn cause reductions in shear strength and shear wave

velocity, resulting in an increase in earthquake ground motion acceleration (i.e. amplification) and a decrease in resistance to sliding, both reducing the Factor of Safety.

We present results showing the greatest sensitivity to changes in shear strength occur at depths co-incident with the minimum factors of safety. To demonstrate the effect of the dissociation of massive hydrate, e.g. nodules, we present results of laboratory experiments where excess pore pressures generated by melting ice inclusions result in significant strength reductions. To be compatible with the subsurface we demonstrate the necessity to consider drainage as a crucial control, 'undrained' conditions resulting in an almost total loss of strength, which is likely to be unrepresentative of sub seafloor conditions, for example.
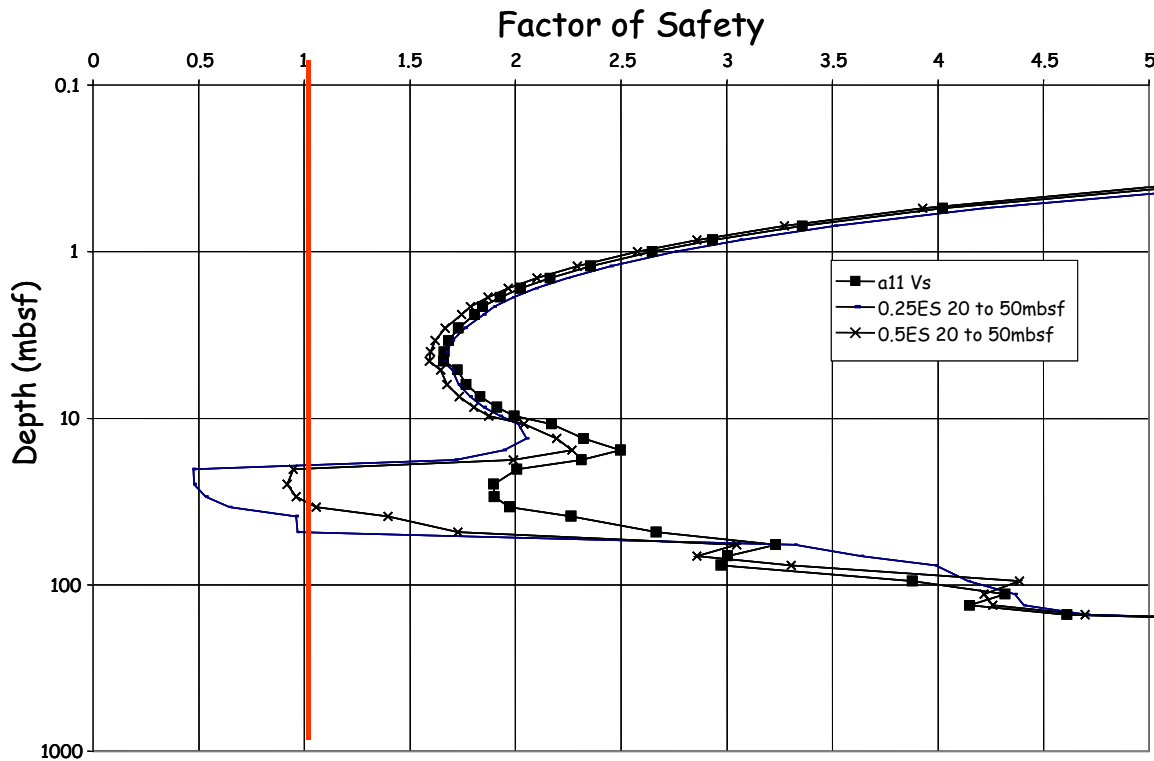

Fig. 1. Change in Factor of Safety to slope failure for one of the most stable sites we modelled in the near the AFEN slide as a result of increased pore pressures simulated in depth interval 20 to 50 mbsf.
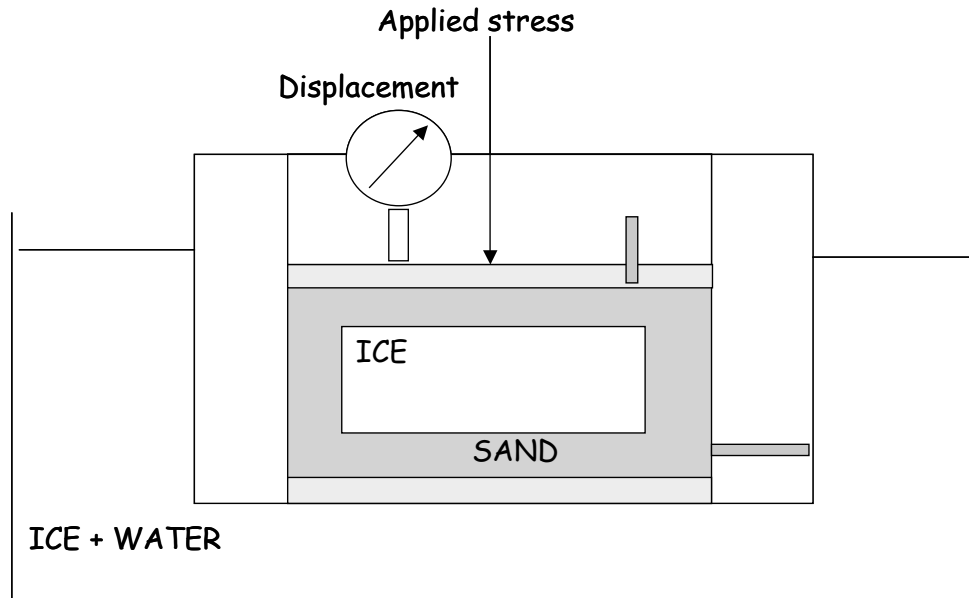
Fig. 2. An inclusion of ice within saturated sand melting in a Rowe cell where pore pressure,
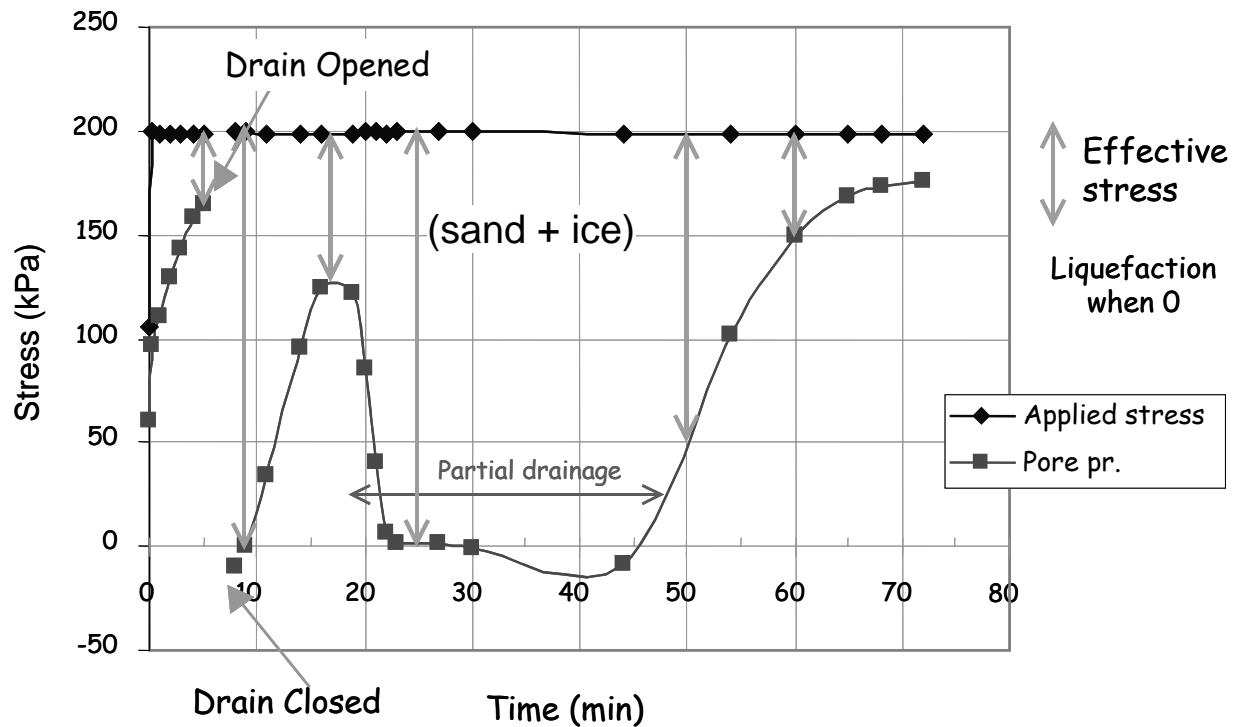applied stress and displacement were monitored

Fig. 3. Effective stress is highly sensitive to drainage during melting, whereas while
undrained, (e.g. at later times) pore pressures rise towards the applied stress and hence
effective stress, and shear strength are reduced to almost zero.

References

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