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Slope Stability: Factor of Safety along the Seismically Active Continental Slope Offshore Sumatra

Details

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Abstract

Recent papers have documented the probability that turbidites deposited along and downslope of subduction zone accretionary prisms are likely the result of strong ground shaking from great earthquakes. Given the damaging nature of these earthquakes, along with the casualties from the associated tsunamis, the spatial and temporal patterns of these earthquakes can only be evaluated with paleoseismologic coring and seismic reflection methods. We evaluate slope stability for seafloor topography along the Sunda subduction offshore Sumatra, Indonesia. We use sediment material properties, from local (Sumatra) and analogous sites, to constrain our estimates of static slope stability Factor of Safety (FOS) analyses. We then use ground motion prediction equations (GMPE's) to estimate ground motion intensity (Arias Intensity, AI) and acceleration (Peak Ground Acceleration, PGA), as possibly generated by fault rupture, to constrain seismic loads for pseudostatic slope stability FOS analyses. The ground motions taper rapidly with distance from the fault plane, consistent with ground motion - fault distance relations measured during the 2011 Tohoku-Oki subduction zone earthquake. Our FOS analyses include a Morgenstern method of slices probabilistic analysis for 2-D profiles along with Critical Acceleration (Ac) and Newmark Displacement (Dn) analysis of multibeam bathymetry of the seafloor. In addition, we also use estimates of ground motion modeled with a 2004 Sumatra-Andaman subduction zone (SASZ) earthquake fault slip model, to also compare with our static

FOS analyses of seafloor topography. All slope and trench sites are statically stable (FOS < 1) and sensitive to ground motions generated by earthquakes of magnitude greater than 7. We conclude that for earthquakes of magnitude 6 to 9, PGA of 0.4-0.6 to 1.4-2.5 g would be expected, respectively, from existing GMPE's. However, saturation of accelerations in the accretionary wedge may limit actual accelerations to less than 1 g. Arias intensities of 0.4-1.7 to 7.9-33 m/s are estimated for the M = 6 and M = 9 events, respectively, are expected in the source regions of piggyback basins for local slope failures. Typical sites have Dn means of 0.1, 1.6, 7.7, and 16 cm for earthquakes of M = 6, 7, 8, and 9; suggested thresholds for displacement range between 5 and 10 cm. Thus the observed turbidite stratigraphy in the Sumatra piggyback basins can be explained by local ground motions during earthquakes with magnitude greater than ~7, given the static stability and low sedimentation rates. The paleoseismic data to date suggest a repeat time of 240 years, insufficient to destabilize slopes though sediment accumulation alone.

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