Sea cliff instability hazard assessment at regional scale: a case study in the western coast of Portugal

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Sea cliff evolution is mainly produced by mass movements of different types and sizes, which are a considerable source of natural hazard in coastal areas.

For two neighboring counties (Sintra and Cascais) located in the west coast of Portugal, a sea cliff instability statistically based susceptibility assessment was tested in order to analyze the influence of a set of predisposing factors in the prediction of future failures affecting areas located along the cliff top.

The coastal areas of Sintra (length of cliffs 24.8km) and Cascais (length of cliffs 22.0km) are examples of contrasting cliff morphology, height (from less than 6m to more than 120m), and rock mass composition and strength (alternating marls and limestones, sandstones, granite, limestones).

The inventories of past instabilities were performed by a multitemporal study of aerial photographs from different dates, for the period 1947-2007 (Sintra), and 1947-2008 (Cascais), which enabled the detection and measurement of the local maximum retreat at the cliff top, length of cliff affected and horizontal area lost at the cliff top. The aerial photo based data coupled with field surveys enabled the identification of the type of movements. These are mainly of the rock fall and planar slide types.

These aerial photo based studies enabled the identification and measurement of 63 cliff failures at Sintra and 67 at Cascais coasts, with variable spatial density from 0.4 to 20 failures per km of cliff length for the 60/61 years of study period, providing the basis for the division of the cliffs in homogeneous sections in terms of horizontal area lost at the cliff top. Along the different cliff sections, the mean retreat rates varied between 0.0003m/year and 0.025m/year, and the mean values of the maximum local retreat of the cliff top varied between 5m and 17m, with two exceptional cliff failures that caused a net retreat of the cliff top of 70m and 25m.

For the assessment of the susceptibility of cliff failures affecting the cliff top, a set of predisposing factors was studied using statistical bivariate methods, along successive constant length stretches of cliffs. The predisposing factors included: a) major lithostratigraphical units adapted from existing geological surveys; b) rock mass structure based in field observations; c) cliff height measured in 1:2,000 scale aerophotogrammetric surveys; d) general cliff slope angle; e) maximum cliff slope angle; f) presence and type of cliff toe protection (plunging cliffs, fallen blocks, beaches, wave cut platforms); g) land use; h) mean annual wave power computed from calibrated offshore wave data transposed near shore considering actual bathymetric data; i) mean annual rainfall along the studied coastline.

The results obtained, validated with the inventories of cliff failures occurred in the last 60 years, although promising, show that further research is needed to obtain variables with stronger relationships with the actual cliff failures, especially to characterize cliff masses in terms of its susceptibility to failure.