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Experiences of a WEB based test site platform for landslide susceptibility and the use of remote sensing interferometric techniques for monitoring landslide movements in Sweden

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Slope stability is a problem of great concern in Sweden. Each year, numerous minor slides occur and every ten to twenty years a major slide develops, often in built-up areas. The landslides are quite deep seated and rapid. Slopes with prerequisites for landslides consists normally either of clay slopes (inclination > 1:10) or rather steep slopes in areas with silt and sand. In Sweden there are guidelines for stability analyses of natural slopes issued by the Swedish Commission on Slope Stability in 1995. The guidelines are structured in such a way that an investigation is carried out in four stages with increasing extent (Sällfors, Larsson and Ottosson, 1996). The different stages, subsequently referred to as the Swedish methodology, are as follows: Stage 1: Overview stability mapping carried out individually for each municipality. Stage 1 is divided in a pilot study and two Sub-stages (Fallsvik and Viberg, 1998). In the Pilot study, sub-areas in the municipalities considered to be mapped are identified. In Sub-stage 1a, the land is divided into areas with and without prerequisites for initial slope failure in clay and silt, while in Sub-stage 1b an overview assessment of the stability under prevailing conditions based on survey calculations is done. The overview stability mapping in Sub-stage 1b forms the basis for decisions on where detailed stability investigations should be performed in Stage 2. The principal aim of Stage 2 is to identify whether there is a real stability problem or not. Based on geotechnical field and laboratory investigations the prerequisites for the calculations are clarified. Slope stability calculations are then carried out with both undrained and combined analysis normally for circular slip surfaces using reliable computer programs. If needed, following the detailed investigation an extended and eventually also a supplementary investigation are carried out.

Within the framework of PREVIEW (EU FP6 Project), Landslides Platform, a WebGIS platform was developed, which comprises two test sites in Sweden, Vagnhärad and Sundsvall, in which the Swedish methodology has been applied. One purpose of the platform was to illustrate the stability conditions for end-users as the municipalities for easier decision making. In addition, within the PREVIEW project, the applicability of resistivity measurements to obtain an overview of the soil profile as a basis for geotechnical field investigations and the use of satellite radar data (differential SAR interferometry (DIFSAR)) for detection of small movements of the ground, as an early warning of a large landslide have been tested for Swedish conditions. In Vagnhärad, a 200 m wide and 50 m long landslide occurred in 1997 which destroyed or undermined seven single-family houses (Andersson et. al. 2000). In the Sundsvall area two minor slides in vegetated areas occurred 2006 and 2007. The Italian private enterprise Telespazio (a Finmeccanica/Thales company) has been responsible for the WebGIS platform and conducted the DIFSAR analyses, while the Italian research Institute for Environmental Methodological Analysis, (IMAA-CNR) carried out the resistivity measurements.

The WebGIS platform for the Swedish test sites consists of one landslides inventory map, three landslides susceptibility maps (1a, 1b and 2) based on the Swedish methodology, DIFSAR displacement maps, 2D Electrical Resistivity Tomographies (only Vagnhärad test site) and a satellite image as a background. The landslides inventory map contains areas with old landslide scars, gullies, ongoing erosion and fill. The intention is that the information on this map could be combined with the susceptibility maps. The susceptibility maps 1a and 1b contains the results from Sub-stage 1a and 1b of the overview stability mapping and these results are presented on the WebGIS

the same way as it is normally done in Sweden. Susceptibility map 1a is a map divided into stability zones including areas with or without prerequisites for landslides. Susceptibility map 1b is a map showing built up areas considered to have unsatisfactory stability. The results from Stage 2 of the Swedish methodology are normally presented as cross-sections representing calculated factors of safety. Within susceptibility map 2, the results have been visualised though stability classes division. The stability classes are based on the calculated factors of safety from the detailed stability investigations in representative sections. In addition to these susceptibility maps, a proposal for the prioritization of landslide susceptible areas has been developed. The proposal is in the form of a table for prioritization. This priority table is based on the stability conditions assessed in sub-stage 1b of the Swedish methodology, i.e. susceptibility map 1b.

The Differential Interferometric SAR (DIFSAR) method for movement detection has not previously been used in Sweden. From a Swedish point of view, participation in the Preview project has given the opportunity to evaluate this method with respect to detecting early movements of deep seated, rapid landslides in clay and silt (typical to Scandinavia). Based on the DIFSAR analysis of the landslide in Vagnhärad in 1997, it has not been possible to detect any movements prior to the actual landslide. One possible explanation is that landslides in Sweden often occur rapidly and are fast moving. However, the analysis indicated other small movements within the Vagnhärad area. The DIFSAR analysis of the Sundsvall area was hindered by the lack of coherent points within the area of the two landslides. This is primarily due to the lack of permanent structures, as radar benchmarks, (e.g. houses or buildings) in the vicinity. The results from the DIFSAR analysis of these landslides exposed the difficulties in detecting the minor movements prior to slides in clay and silt in Sweden. However, the DIFSAR technique has potential in Sweden for applications pertaining to other ground movements.

The resistivity measurements from two areas in Vagnhärad showed fairly good correspondence with the traditional geotechnical investigations that were performed as well as with earlier resistivity measurements in the Vagnhärad landslide area (Dahlin et. al., 2001). Thus resistivity measurements have potential as a tool to estimate the soil profile in general, as a s complement to the production of the map 1b.

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