

## LONG-TERM STABILIZATION OF A COLLAPSED SKI SLOPE IN SAN VIGILIO DI MAREBBE, SUD TIROLO, ITALY

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### INTRODUCTION

The April, 22<sup>th</sup>, 2006, early afternoon, a snow-capped ski slope, located just above the village in the famous skiing area in San Vigilio di Marebbe, Sud Tirolo, Italy, collapsed and moved downwards for approximately ten hours. Due to the landslide, the uphill station and upper pier of a new cableway crossing the ski slope tilted and moved tens of meters down the slope scaring the people of the village and the authorities. The moving mass stopped very close to the lower station of the cableway, partially submerging the station and an adjacent garage. Figure 1 shows the mass flow area on the ski slope.

The destabilised volume consisted of a mixture of sandstone boulders and remoulded soil derived from strongly decomposed sandstone rocks with an exceptionally high percentage of water.

The visual inspection of the slope a few hours after the event showed that a pipe of the snow-making system crossing the crest of the landslide at small depth had been cut off.

Short-term stabilization/protection interventions consisting of an earth wall at the base of the slope and a shallow drainage network on the slope were rapidly carried out by the Authority for the Mountain Protection to reduce the risk and avoid possible additional damages.

The catastrophic event has been caused by an unfavourable combination of different factors. More particularly, it seemed that probably some small movements on pre-existing structural weaknesses (Clayey layers - Figure 2) in the upper part of the ski slope damaged the pipe system supplying water at very high pressure to the snow guns in the area. This led to a water seepage, which increased the



**Fig. 1** View of the collapsed ski-slope.

water pressure and weight of the slope hereby reducing the frictional resistance of the future gliding surfaces and increasing the downhill stress component finally exceeding the shear strength of the surfaces. With the sliding started, the water saturated volume partially liquefied and flowed down the slope.

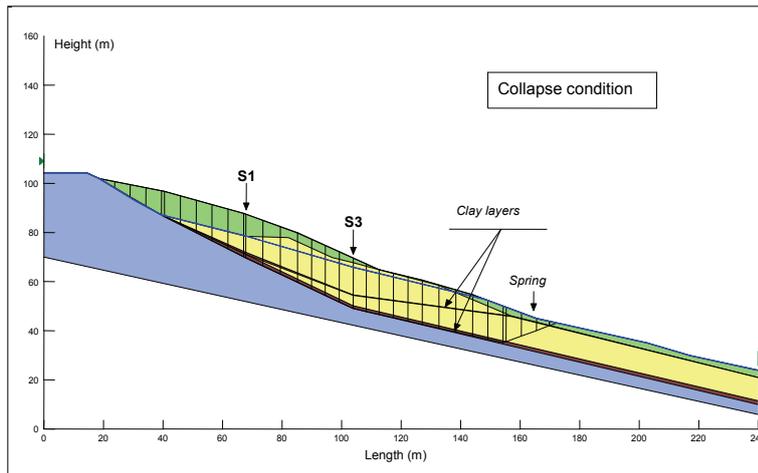
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**Fig. 2** Localization of failure surface in the slope

### LONG-TERM STABILIZATION INTERVENTION

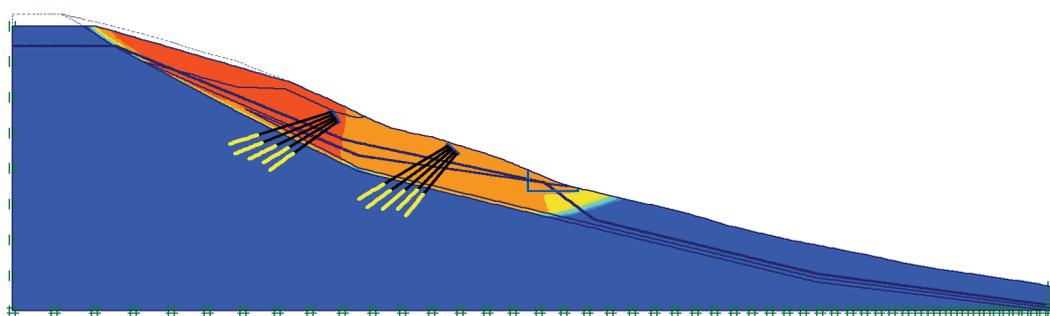
From a geological point of view, the landslide area lies at the border between the crystalline (Bressanone Phyllites) and sedimentary (Val Gardena Formation, sandstone) bedrock, followed by the Bellerophon Formation.

The flow slide involved the detrital cover and the fractured and altered sandstone, sliding on thin layers of non-plastic clayey-silty material down to depths of 15-20 m.

Laboratory measurements of the shear strength of these layers provided a residual friction angle of around  $30^\circ$  and no cohesion. Back analysis of the mass flow showed that the rise of the piezometric surface above the clayey-silty layers was responsible for the flow slide.

In order to avoid the reoccurrence of the slope failure allowing for the reconstruction of the ski slope, three types of stabilization measures, namely a slope re-profiling, a shallow and deep drainage system and a deep soil nailing were selected (Figure 3).

The gained increase of the safety factor FS was proportional to the effects of the three different measures, namely  $FS=1.02$  for slope re-profiling,  $FS=1.12$  including the drainage system and  $FS=1.20$  including also soil nailing. The selected value of 1.20 seemed a reasonable and justifiable compromise between the required reduction of risk level and economical costs of the whole intervention.



**Fig. 3** Localization of displacements in the slope after stabilization from the finite element analysis

**Keywords:** slope stability, ski slope, stabilization system, soil nailing.