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Mitigation of hydrogeological instability: blasting demolition of the "Kastenknott" rocky tower (Castelbello-Ciardes, Colsano – Bz)

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In recent years, the village of Colsano in the Venosta Valley has witnessed the recurring phenomenon of rock mass collapse. Large blocks from past landslides are still visible on the edge of the valley. The investigation has brought to light the presence of a strongly disintegrated rocky ridge, within a larger and more complex area, strongly disturbed by the presence of a Deep-Seated Gravitational Deformation of the Slope (DSGSD) still studied and examined in depth. The analysis of the kinematisms, in addition to the geological and geomechanical investigations conducted on site, used extremely detailed morphological surveys conducted with the Laser Scanner technique. The same technique, combined with the topographic measurement of fixed points, has made possible to monitor and detect the slow movement of a large rock mass, of which "Kastenknott" it is the most unstable element. The study of collapse scenarios led to the decision to proceed with its controlled partial demolition in agreement with the provincial technicians and the municipal administration. This decision has been taken after using modelling software considering the hypothesis of an event occurring in an uncontrolled and unexpected way. Due to the extreme proximity of zip-line cables, the rock volume was reinforced with a cortical system, placed by experienced rock climbers, with the purpose to minimise propagation distance of the blocks during the explosion. Specialised operators took care of the control and stringing of the zip-line ropes, moving them further away from the rocky pillar. Small-diameter mine holes limited the invasivity of drilling on a precariously balanced mass of rock. The technicians' knowledge and experience in choosing detonation systems and distribution and depth of the holes provided a further guarantee of minimal invasiveness on the slope. The local volunteer fire-fighters, the Alpine Rescue and police-men ensured a safety cordon downstream the rockfall risky area, also managing the evacuation of the inhabitants outside the pre-established safety perimeter. The controlled demolition was also an opportunity to carry out a Back Analysis study, through it which was possible to relate the evidence found on the slope with the results of the 3D modelling of the rockfall, considering them fully comparable.

***Keywords**: slopestability, geomechanics, blasting, Sudtirol.*

1. Geographical, geological and geomorphological context of the intervention

The Venosta Valley is one of the main valleys within the province of South Tyrol. It develops from the Reschen Pass to the northwestern gates of the city of Meran. The Venosta territory belongs mostly to the Austroalpine domain and in particular, the slope above the village of Colsano (Castelbello – Ciardes, BZ) consists in the lower part of Tessa Unit (extract from CARGbrowser of Autonomous Province of Bozen-Bolzano). This unit includes mainly banded and partially milonitic paragneiss with intercalation of gneisses and schists with amphibolite boudins levels of varying thickness.

The Venosta Valley, like most of the Alpine valleys, due to the succession of glacial – interglacial quaternary cycles, has undergone important slope movements scientifically defined as deep seated gravitational slope deformation (DSGSD) (Agliardi *et al*. 2009). In the area of study, the main hydrogeological instability is now confined within the elevations of 1,300 and 1,500 m a.s.l. where heavily unstructured outcropping rocky areas are located as evidence of large relict deformations. In recent years, very frequent rockfall phenomena threaten the village of Colsano, which is located at the foot of the slope. Because of that, large blocks resulting from past events are observable near buildings. Slope surveys have shown that paragneiss rocks are generally more fractured and degraded, on the other hand, amphibolite rocks are more massive and resistant to meteoric degradation. This inhomogeneous geomechanical behavior implies different types of slope processes, and more specifically, paragneiss lithotype tends to create variable intensity and high probability of occurrence of rockfall phenomena, on the other hand, amphibolite lithotype tends to predispose paroxysmal events by the exhumation of large rock volumes as show in the unpublished geological study "*Zona di pericolo a monte dell'abitato dell'abitato di Colsano, versante Holzgraben-Weittal*" carried out by Alpin Geologie in 2021.

1.1. Monitoring

A large amphibolite tower, 900 m above the village of Colsano, with a volume of 900 m^3 and a total

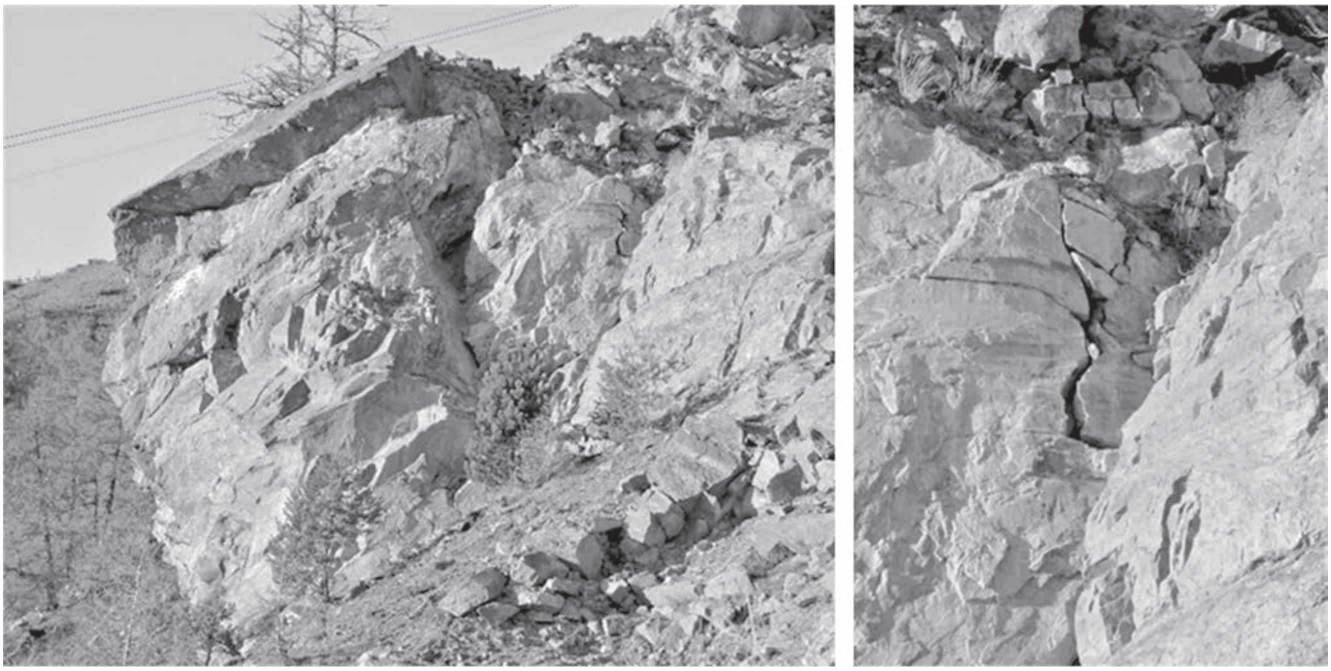

Fig. 1 – On the left an east-side view of the Kastenknott. On the right, recent activity of a back-fracture on the rocky pillar. On the right it's also possible to observe different geomechanical behaviour of fractured Paragneiss rock (above) and massive Anfibolite rock (below).

height of 15 m called "Kastenknott" represents a clear result of rock selective degradation. The considerable size of the rocky pillar, as well as the survey of tensile fracture systems above of the rock body (Fig. 1), led to the decision to implement a monitoring plan to assess magnitude and velocity. No. 8 prisms were placed directly on the rock volume monitored by total station for 15 months (May 2020-August 2021); furthermore, the area was scanned by terrestrial laser in order to compare and certificate three-dimensional movements. Both surveys determined a tilting (block toppling) movement of the rocky mass with an average velocity of 44 cm/y at the top and 28 cm/y at the bottom as show in the unpublished geological study "*Zona di pericolo a monte dell'abitato dell'abitato di Colsano, versante Holzgraben-Weittal*" carried out by Alpin Geologie in 2021 (Fig. 2).

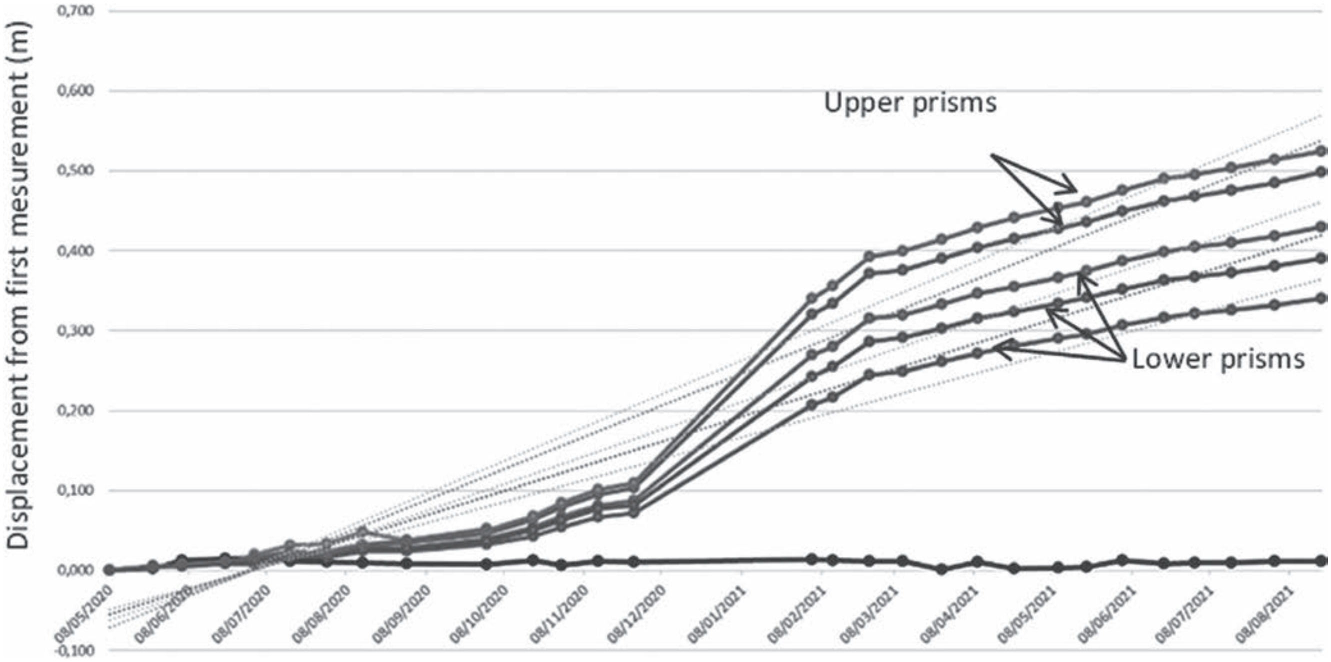

Fig. 2 – 3D displacement trend of Kastenknott monitored points by total station between May 2020 and August 2021 as show in the unpublished "Report di fine lavori di disgaggio parziale" carried out by Alpin Geologie in 2021.

1.2. Intervention choice

The large size of the rocky tower, the predictive analytical uncertainties and limitations of the collapse dynamics and the urgent need to minimize the widespread fears of a catastrophic event among the local population, led to the common decision to proceed with a controlled demolition of the upper part of the Kastenknott (ca. 280 m^3) as shown in unpublished presentation during XXV Geoalp Wintercup 2022 titled "*Dissesto idrogeologico. L'importanza della sinergia professionale nella pianificazione e nell'esecuzione di opere di mitigazione: esempio intervento Castelbello – Ciardes*". To simulate induced collapse scenarios, different modeling was carried out using RAMMS (Rapid Mass Movement Simulation) software.

The primary aim of scaling was to reduce the volume and consequent weight of the rocky block, to prevent any non-artificially induced collapse event and associated mitigation of the rocky titlting dynamics (reduction of the displacement velocity).

1.3. Criticism

The work has been extremely complex due to both the geographical and morphological location of the intervention site and the prossimity of cables way. This interference led to clothe the tower with double twist wire mesh, concatenated ring nets, reinforced and anchored with wire ropes and bolts before the deflagration. To further minimize interference, a specialized firm increased zip line ropes tension, moving them as far as possible away from the ground and the rock pillar (Fig. 3).

Containment activities in number:

- 280 m^2 of hexagonal double twisted wire mesh type 8x10 cm with wire diameter of 3 mm;
- 100 m^2 of ring panels with six points of contact;
- 220 m of galvanised steel strand rope with a diameter of 16 mm;
- 46 m of drilling made by portable pneumatic roto-percussion drilling machine in order to install B450C steel bars with a diameter of 20 mm;
- 250 min of flight was required to transport materials used for site preparation and removal.

1.4. Scaling activity

An interesting aspect of blasting is certainly that isolated rock volumes are the easiest targets to fragment from an explosive point of view. The absence of containments around the perimeter of the boulders or rock fragments facilitates the disruptive action of explosives. Side effects such as dangerous rock fragment launches due to overdosing or errors in the design and/or execution of the drill mesh are not infrequently generated. The speed of detonation using dynamite can overcome 6.000 m/sec and can result in launches up to 300 metres' distance. The height of the blasting point further affects the range of rock shrapnels (Fig. 4). Because of the urgence of the present study-case, it was decided to operate with small-diameter mine holes (approx. 40 mm), in order to allow a minimally invasive drilling operation. The drilling pattern was determined by the

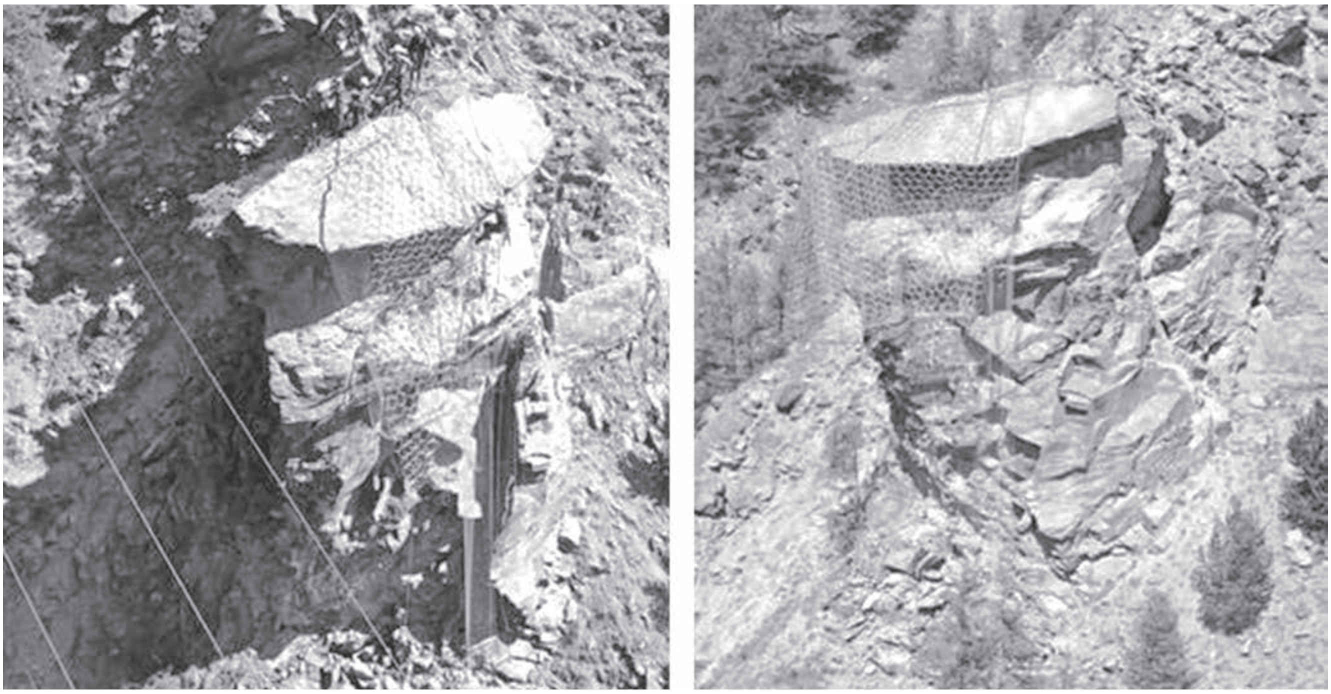

Fig. 3 – Placement of metallic reinforcement on Kastenknott in order to protect zip-line ropes (visible on left figure).

Fig. 4 – Snapshot of the Kastenknot blasting.

diameter of the holes at approximately 1.2 m, leaving a thickness of rock outside the hole which could reach 1.5-2.0 m in the direction of the cableway ropes. The holes could have lengths between 3 and 4 m, depending on where they were drilled. The explosive charge, 25-mm-calibre dynamite, could vary from hole to hole, depending on their length from 1.0 to 2.0 kg. The large number of holes allow to distribute the total charge in extremely small unit quantities, offering a further guarantee of minimal invasiveness on the slope behind the unstable volume. In order to blast the rock in a successfull way, shockwave detonators were used, which allow the reduction of the cooperating charge and allow each mine hole to be activated in a staggered way.

1.5. Back analysis

The observed, measured and post-event site data allowed to carry out new and more accurate 3D simulations (Back Analysis). The locations reached by the rocky fragments were analysed; identifying the most frequent volumetries (VRU = 0.05 m^3), the most distant volumetries from the point of deflagration (VRU = 1 m^3) and the largest volumetries (VRU = 3 m^3); these dimensional data were included in the new modelling.

The raster maps obtained from the use of the software (reach probability, number of passing and stopping blocks), compared with the data measured post-deflagration showed convergent and matched results, confirming the full effectiveness and reliability of predictive calculation models as shown in the unpublished "*Report di fine lavori di disgaggio parziale del Kastenknott*" developed by Alpin Geologie.

Conclusions

Although three-dimensional modelling is considered the most effective method to simulate and predict collapse events, some geomechanical conditions, such as those of Kastenknott exposed in this work, do not allow faithfully replication of rockfall consequences. In this work, it was presented a study-case in which technological limitations and urgency led to

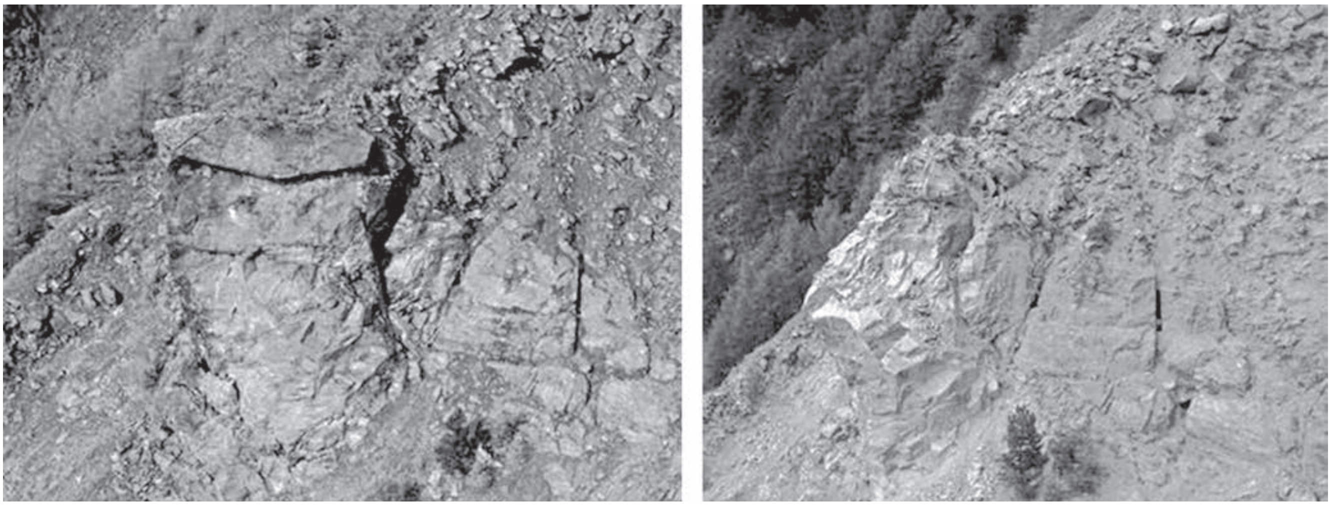

Fig. 5 – Comparison between Kastenknott rocky pillar before (left) and after (right) scaling.

drastic solutions. However, such a decision as blasting was only possible through detailed geological investigation and monitoring. Instead, the success of the operation in an extremely difficult environment was the result of all the professional synergies of all the workers involved. The correspondence between the results of the backanalysis and the post-blasting evidence shows an example of how it is possible to model the effects of explosive demolition on a slope, enhancing this type of intervention in extreme cases.

Unit of measures

m: meter
s: second
y: solar year
kg: kilogram

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