Monitoring displacement patterns, acceleration and failure (July 2023) at the unstable rock slope Stampa, Western Norway

Thomas Scheiber[a], Alexander Mascher[a], Lukas Schild[a], Paula Snook[a], Stig Frode Samnøy[a], Lene Kristensen[b], Halgeir Dahle[c], Jan Helge Aalbu[c], Helge Henriksen[a]

[a]Department of Environmental Sciences, Western Norway University of Applied Sciences, Sogndal, Norway, thomas.scheiber@hvl.no; [b] Norwegian Water Resources and Energy Directorate (NVE), Trondheim, Norway, lkr@nve.no; [c]Norwegian Public Roads Administration, Leikanger, Norway, halgeir.dahle@vegvesen.no

In early July 2023, a rock section named Block4A failed catastrophically from the unstable rock slope Stampa in Western Norway. In this contribution, we present continuous multi-sensor monitoring data since 2019, provide a timeline of the event chain, and share our experiences with early warning and the handling of the situation by responsible authorities.

Block4A was part of a near vertical cliff situated ca. 725-825 m above the European route E16, which runs along Aurlandsfjord. It consisted of a ca. 5,000 m^3 large rock column resting on a highly fractured base, adding to a total volume of up to 50,000 m^3. The Norwegian Water Resources and Energy Directorate (NVE) identified relatively high deformation rates at Block4A during their InSAR monitoring program in the area. From 2019 onwards, we supplemented the existing monitoring system by several different sensors which made Block 4A probably one of the best monitored unstable rock sections in Norway.

Movement at Block4A from 2019 to2022 was characterized by acceleration phases during late springs/early summers and autumns, relatively low and stable displacement rates during summers and very low to zero displacement during winter. This displacement pattern was clearly influenced by meteorological factors. Rising temperatures combined with thawing ice in rock fractures and enhanced water infiltration due to snowmelt in spring/early summer caused acceleration, whereas drainage combined with reduced water infiltration led to slowing down of the movement. Similarly, high-water infiltration by increased precipitation in addition to high ground temperatures in autumn caused acceleration, whereas winter conditions with temperatures below 0°C had a stabilizing effect. In autumn 2022, Block4A accelerated exponentially until cold air temperatures from the beginning of September completely stabilized the system. End of May 2023, Block 4A started moving again, accellerated and reached velocities of up to 0,1 m h^{-1} by June 30th. Between July 1th and July 3rd, Block4A disintegrated and failed in two main stages: (1) After two days of exponentially increasing movement rates and enhanced rockfall activity, ca. 9,000 m^3 detached from the fractured lower base on July 1st. While most of the debris was deposited high up on the slope, one large boulder with a diameter of ca. 10 m travelled all the way down to the fjord, damaging a power line and the road E16. By this time, guards of the Norwegian Public Roads Administration (SVV) followed the situation closely on either side of the affected road section and immediately closed the road. As a consequence, five houses situated at the toe of the slope, though more than 500 m away from the runout zone, were evacuated. (2) On July 3rd, most of the remaining unstable rock volume of ca. 30,000 m^3 including the rest of the base and the rock column of Block4A collapsed. The debris was deposited in the upper part of the slope despite the larger volume and the much larger drop height, compared to stage 1.