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WEATHERING IN INTERBEDDED MARLS AND CONGLOMERATES - THE 1806 GOLDAU ROCK SLIDE

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Despite improvements in recognition, prediction and mitigation, landslides still exact a heavy social, economical and environmental toll in Switzerland. Recent landslides experienced in the Swiss Alps demonstrate the need for a deeper understanding of the geological and physical processes leading to catastrophic slope failure. Large-scale rockslides (e.g. Randa, Sandalp, Goldau, Elm, etc.), illustrate the destructive potential of these mass movements and the need for further study to improve our comprehension of the mechanisms involved. Advances in rockslide hazard assessment and forecasting will only be made when the mechanisms responsible for the evolution of catastrophic failures are better understood.

To date, the study of mass movements (including rockslides) has been largely descriptive and qualitative. Studies that do focus on some quantitative aspect of large-scale mass movements are often limited to individual mechanisms or triggering processes. Traditional treatments have pursued phenomenological based approaches where a two-dimensional slide plane is assumed or delineated from survey or air photo data, and a back analysis is performed to determine the conditions existing on the surface at failure. In other words, rock slope stability analyses have largely focused on the back-analysis of a static picture of the problem, without considering how the development of the instability evolved with time.

In this paper, we aim to emphasize on the evolutionary failure processes leading to large-scale mass movements in adversely dipping bedded marls and conglomerates. Of key importance are the weathering characteristics of the marl and which tend to rapidly degrade when exposed to weathering processes. The proposed hypothesis contends that rock slope instability, in such geological environments, occurs through 3 primary processes:

(1) weathering of the marls including increases in pore volume (promoting water seepage), decalcification and intact strength degradation;

(2) saturation of the weathered marls and pore pressure build-up during periods of heavy precipitation and snow melt;

(3) progressive development of the slide surface parallel to bedding due to decreases in cohesion and frictional strength as a function of time.

Under these conditions, it is often reported that the slide surface develops along “weak” bedding interfaces between the conglomerates and marls. However, recent investigations of the 1999 Rufi slide in similar rock mass conditions reveal that instead, the failure plane developed along the boundary separating moderately weathered and highly weathered marls.

As an ideal project site the Rossberg/Goldau region was chosen because of the large rock slide event that occurred there in 1806, earlier historic and prehistoric events, and on-going mass movement activity (last event 5’000 cbm in fall 2002).
Weathering In Interbedded Marls And Conglomerates: The 1806 Goldau Rock Slide

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Introduction

Despite improvements in recognition, prediction and mitigation, landslides still exact a heavy social, economical and environmental toll in Switzerland. Recent landslides experienced in the Swiss Alps demonstrate the need for a deeper understanding of the geological and physical processes leading to catastrophic slope failure. Large-scale rockslides (e.g., Pânda, Sandâp, Goldau, Elm etc.), illustrate the destructive potential of these mass movements and the need for further study to improve our comprehension of the mechanisms involved. Advances in rockslide hazard assessment and forecasting will only be made when the mechanisms responsible for the evolution of catastrophic failures are better understood.

New Approach

to date, the study of mass movements (including rockslides) has been largely descriptive and qualitative. Studies that do focus on some quantitative aspect of large-scale mass movements are often limited to individual mechanisms or triggering processes. Traditional treatments have pursued phenomenological based approaches where a two-dimensional slide plane is assumed or delineated from survey or air photo data, and a back analysis is performed to determine the conditions existing on the surface at failure. In other words, rock slope stability analyses have largely focused on the back-analysis of a static picture of the problem, without considering how the development of the instability evolved with time.

Aims Of The Study

We aim to emphasize on the evolutionary failure processes leading to large-scale mass movements in adversely dipping bedded marls and conglomerates. Of key importance are the weathering characteristics of the marl which tend to rapidly degrade when exposed to weathering processes. The proposed hypothesis contends that rock slope instability, in such geological environments, occurs through three primary processes:

1. Weathering of the marl: including increases in pore volume (promoting water seepage), decalcification and intact strength degradation;
2. Saturation of the weathered marl and pore pressure build up during periods of heavy precipitation and snow melt;
3. Progressive development of the slide surface parallel to bedding due to decreases in cohesion and frictional strength as a function of time.

At the Rosberg, the rupture surface also intersects conglomerates in the lower part of the sliding plane.

Process

Under these conditions, it is often reported that the slide surface develops along "weak" bedding interfaces between the conglomerates and marls. However, recent investigations of the 1999 Ruß slide in similar rock mass conditions reveal that instead, the failure plane developed along the boundary separating moderately weathered and highly weathered marls. As an ideal project site the Rosberg/Goldau region was chosen because of the large rock slide event that occurred there in 1806, earlier historic prehistoric events, and ongoing mass movement activity (last event 5’000 m3 in October 1997).

References


The Goldau Rock Slide At A Glance
- Rock slide volume 40’000’000 m3
- Trigger: heavy precipitation over several weeks
- Transport of the slide debris as a rock avalanche = "Sturzstrom"

Main Losses:
- 457 deaths
- 111 farm houses & buildings
- 220 barns with livestock
- 6.5 km² pasture land destroyed
- Total damage 500 million Swiss Francs = 340 million Euro (back calculated in today’s costs).
- 20 m high wave in the Lauerzer See

Fig. 1: The Goldau rock slide ("Brotscher") on September 2nd, 1806 at the Rosberg, Cantone Schwyz, Switzerland. Painting by H. Keller 1806.

Fig. 2: Rock slide engulfing the village of Goldau causing disturbance to the lake of Lauerz. Aquarell by D.A. Schmid 1806.

Fig. 3: Geological situation on the geological map of Switzerland. Scale 1: 500’000. The Rosberg is situated in the subalpine molasse (Lower Freshwater Molasse, brown, dipping at 20°-25° to the south). The Helveticum is following in the south (green).

Fig. 4: The stepped sliding planes at the Rosberg suggest a sliding sequence of prehistoric, historic and recent slide events. Historic events have been reported in the 12th and 13th century. Future events are likely to occur east of the 1806 planes (2) and (3). The village of Goldau reaches out over the rock slide debris and would certainly be affected by a major future sliding event.

Fig. 5: Upper and eastern scarp of the rock slide with conglomerates.

Fig. 6: Conglomerate - marl contact.

Fig. 7: Right: Weathering stages in the Ruß marl. Lower Freshwater Molasse (Luginbühl et al. 2002) with possible location of the rupture surface of the Goldau rock slide.

Fig. 8-10: Strength degradation due to weathering in an alpine marl (Reimnitzmüller 1977).

Fig. 8: left: Effective cohesion drops from 57 kPa in weathering stage W0 to 22 kPa in weathering stage W2 in an alpine marl. Fig. 8, middle: Effective friction drops down from 35° (W0) to as low as 17° (W5) in the same rock type. This behaviour suggests that under these circumstances failure occurs at about 25° in the case of limit equilibrium (= rock slope angle). Therefore - and without taking other causes and processes into consideration - it is likely that failure occurs somewhere between weathering stage W2 (moderately weathered) and W3 (highly weathered).

Fig. 10: right: Weathering stages in the Ruß marl. Lower Freshwater Molasse (Luginbühl et al. 2002) with possible location of the rupture surface of the Goldau rock slide.

Fig. 9: A column diagram representing the lithological log of an alpine marl (Reimnitzmüller 1977).