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Editorial: Landslide hazards in alpine region: Mechanics and mitigation

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Editorial on the Research Topic
Landslide hazards in alpine region: Mechanics and mitigation

Alpine regions refer to mountainous areas with high altitudes, cool climates and large differences in day and night temperatures, which can only be adapted to grow more cold-tolerant crops. The Qinghai-Tibet Plateau is a typical alpine region. Comparing to the low altitude areas, the engineering geological conditions in alpine regions are much more complicated. These include steep mountain slopes (Figure 1), complex geotechnical structures, and severe environmental conditions such as strong earthquakes, drastic change in temperature (for example, the temperature difference between day and night can be up to 50 degrees, in the Qinghai-Tibet Plateau), and extreme precipitation. Besides, the disturbance from human being is also noticeable, like blasting excavation, vegetation destruction, and vehicle loads, etc. The coupling of these unfavorable factors leads to frequent landslides (slope instability and landslide dam, avalanche, and debris flow, etc.), which seriously threaten lives and the safe construction and operation of infrastructures. The Research Topic is to present the recent advances in engineering geological features, landslide mechanisms, and mitigation technologies in alpine regions. This will help us to prevent and control landslide hazards that may be encountered in hydropower projects, highways, railways, and open-pit mining.

Due to strong tectonic movement, earthquake is one of the most common triggers of landslide hazards in alpine regions. For example, in the Qinghai-Tibet Plateau, a total of 5,185 earthquakes of $M \geqq 3$ occurred from 1971 to 2021, including 56 strong earthquakes with $M \geqq 6$ (Liu, 2021). This Research Topic includes two articles on evaluating methods for earthquake-induced landslides. Li et al. examine the critical acceleration for regional seismic landslide hazard assessments by finite element limit analysis. The proposed model improves previous mechanical models for regional seismic landslide hazard assessments. Zhang et al. discuss the upper bound analysis of the stability of 3D slopes in the saturated

FIGURE 1
Steep mountain slopes in alpine regions.

soft clay subjected to seismic loading. It is suggested that the effects of horizontal and vertical seismic forces must be considered simultaneously in the seismic design of saturated soft clay slopes.

Drastic change in temperature is the natural environment often faced by the rock and soil mass in alpine regions. This can lead to deterioration of the physical and mechanical properties of the rock and soil mass, which is detrimental to slope stability. As global warming accelerates the rate of glacial retreat, factors such as thawing rock formations and glacial meltwater weaken the stability of slopes. Then, in the event of a strong earthquake, the chances of an avalanche landslide disaster would be very high, such as the Khumbu glacier landslide (Ding et al., 2018). In this Research Topic, An et al. focus on the shear strength and microstructure of granite residual soil under an extremely low temperature. Fu et al. carry out systematic research on mechanical properties of frozen glacial tills due to short periods of thawing. They find that the difference between peak and critical resistances decreases with increasing thawing time and reflects changes in shear behavior. Zhang et al. note that the stress-strain curves of embankment clay changed from strain hardening or stabilization to softening during freeze-thaw cycles.

Precipitation, especially Extreme Precipitation Events, is commonly believed to be the most important factor triggering landslides, and there is no exception in alpine regions. Extreme Precipitation Events refers to instances during which the amount of rain or snow experienced in a location substantially exceeds what is normal. What constitutes a period of extreme precipitation varies according to location and season. From 1961 to 2017, the annual precipitation of Qinghai-Tibet Plateau showed an upward trend, with a rate of 8.06 mm/10 a, and the average annual precipitation reached 472.36 mm. At the same time, there has been a marked increase in the number of Extreme Precipitation Events (Ma et al., 2020). This Research Topic includes three articles on the assessing method of landslides caused by precipitation. Fu et al. propose an innovative strength parameter estimation method for soil-rock mixture for evaluating the deposit slope stability under rainfall. Zhou et al. describe a predisposed geological emergence of a rainfall-induced soil-rock mixture landslide at Chongqing City, China. Bao et al. note that the slope creeping is a dynamic development process, from stable deformation to unstable failure, and rainfall can accelerate this process. The effect of the disturbance from human being on the stability of slope is also noticeable, *i.e.*, the blasting excavation, as discussed in the articles by Wang et al. and Wu et al.

Due to the development of rivers and the large differences in terrain, a large numbers of hydropower stations are built in alpine regions. Landslide dams are massive blockages of river channels resulting from massive earth movements, which is a special kind of landslide hazard in alpine regions. In this Research Topic, Xie et al. describe the accumulation characteristics and mechanism of landslide debris dam based on physical model tests. The damming process and accumulation mechanism of the landslide dam are found to be changed with slope conditions. Zhou et al. present an experimental investigation of the outburst discharge of landslide dam overtopping failure. They suggest that hydrographs of the breaching flow and outburst flood can be divided into three stages where each stage is separated by inflection points and peak

discharges. Also in this Research Topic, Yang et al. note that the excavation of a spillway can effectively reduce the peak breach discharge, therefore delay the time to peak.

Anchoring frame beam is a very common form of support for reinforced slopes and centrifugal tests have been proved to be an intuitive and effective means for investigating the working mechanism of frame beams. This Research Topic concludes an article by Zhang et al. that explores the application of multi-channel selector in centrifuge model test of anchoring slope by frame beam. They find that multi-channel selector can be successfully applied in varying environments, saving time and reducing the cost of obtaining a single set of data.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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