Summary and Trend Analysis of Research Progress on Granular Slope Geological Hazards

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Abstract. There are a large number of granular slope mixture geological disasters in the alpine mountainous areas in western China. Their structural characteristics are significantly different from the general slopes. They have the characteristics of poor self-stability, high suddenness and strong recurrence. With the continuous development of the western region of the country, such geological disasters have received close attention from scholars at home and abroad. This article first summarized and analyzed the basic characteristics of the typical domestic granular mixtures slope accidents, and understood the basic characteristics of disaster. Then the domestic and foreign research progress from the aspects of governance measures were summarized. Finally, based on the summary of typical granular mixtures slope disasters and research status, the existing problems in the current research were analyzed, and the key points and difficulties of future research had prospected. The research results have important theoretical significance for the treatment of granular slope.

1. INTRODUCTION
With the rapid development of China’s economy, more and more attention has been paid to the construction of road traffic. The problem of stability of granular slope in the alpine mountainous areas in western has become prominent. This kind of slope engineering problem was widely concerned and paid attention to in the late 1990s[¹]. Granular slope, also known as sand-sliding slope, is widely development in the alpine mountainous areas in western China. It refers to the high-steep rock slope that suffered the strong physical weathering formed a large number of sand and rock debris. They under the action of gravity moved in various ways and naturally accumulated at the foot of the slope which formed the conical slope[¹]. For example, up to now, there are 19 sand-sliding slopes along the national highway 217 Tian shan highway, which seriously threaten the traffic safety of the road under the slope[²¹]. On June 19, 2013, granular slope instability occurred at 923km + 600m of Duku highway in Xinjiang, causing more than 800 vehicles and 2600 people to be blocked. On June 6, 2016, road landfill and traffic interruption occurred for more than 10 days at 700m of k636 section of Duku high way in Xinjiang due to the instability of granular slope. In addition, on August 18, 2003, due to the earthquake, Zhongba sand-sliding group in Bomi County of Sichuan Tibet highway collapsed, causing nearly 2 km of road surface to be destroyed by rocks, resulting in more than 120 vehicles blocked in the road section of nearly 190 km. The frequent occurrence of accidents caused by granular slope and the fact that a large number of existing slopes with granular have not yet been effectively treated make this kind of engineering problems need to be solved. Based on this, on the basis of typical case analysis, this paper
systematically summarizes and analyzes the research results of granular slope from four aspects: prevention measures of granular slope.

2. DISTRIBUTION CHARACTERISTICS OF GRANULAR SLOPE

Granular slope is mainly distributed in Western China, such as Shaanxi, Gansu, Tibet, Xinjiang and other places, while the research on granular slope mainly focuses on Sichuan Tibet highway and Tian highway (Tab 1). According to Tab 1, there are a large number of granular slopes in the short highway section, and the gradient is mainly concentrated between 33° and 39° with complex composition of granular material, less vegetation coverage and alpine area. Once the vegetation is forced to be damaged, it is difficult to recover, and the activity intensity is frequent, resulting in frequent disasters. The climate is mainly semidry climate. Therefore, the engineering geological problems caused by granular slope are very complex and needs instantly further research to provide theoretical basis for the control of road traffic.

| Place | Number | Gradient | Composition | Veg-ch | Climate |
|-------|--------|----------|-------------|--------|---------|
| Zhongba Section of Sichuan Tibet highway Mouth of Midui Ditch.[1] | There are more than 30 sand-sliding slopes only in the 20 km section. | 34.6°~35.6° | It is mainly composed of gravelly clastic rocks with strong weathering of granite. | The vegetation is sparse with a few shrubs. | Semi dry climate |
| Zhongba section of Sichuan Tibet highway in Bomi County, Tibet. [3] | There are 18 in only 26 km. | 34°~39° | Acid biotite granite is dominant, Devonian metamorphic sand slate distributed on both sides. | The vegetation is generally good | Semi dry climate |
| National Highway G318, Yupu to Ranwu in Tibet. [4] | More | 33°~35° | They are mainly weathering products of granite and gneiss. | There is little vegetation growing. | Semi dry climate |
| China Pakistan highway (Oitak town - Bulunkou township).[5] | 35 | About 36 | Diabase | No show | No show |
| National Highway 217, the total length of Tianshan highway is about 537km.[5] | At present, there are 19 sand-sliding slopes along the line. | 4°~39° | They are mainly basalt, slate, granite and diorite. | Small amount of vegetation | Mountainous climate in arid area |
| Tianshan Highway (Dushanzi-Kuqa section)[5] | 189 | 34°~39° | No show | No show | No show |
| North of Hahiligen Daban at the northern foot of Tianshan Mountain[6]. | 73 | About38 | Slate, basalt, diorite and granite. | There is little vegetation growing. | Semi dry climate |

3. REINFORCEMENT AND PREVENTION MEASURES OF GRANULAR SLOPE

At present, there is no unique treatment method for the prevention and control technology of granular slope in China. What methods mainly used are the same as landslide and sand control. The main control measures are: vegetation sand fixation[7, 8, 9], anchor reinforcement[10, 11](Figure 1 shows the results of the anchoring test with different anchor spacings. It can be seen from the figure that as the anchor spacing increases, the particles in the anchoring range fall off and the anchoring effect becomes worse.), embankment wrapping[12, 13, 14] and so on.
Wang Zhaoyin (2009) and others carried out field tests with blowers and found that there was a certain relationship between the amount of particles blown down and the size of blown particles and the wind speed. Spraying dilute mud with moss spores powder can play a role in repairing. Bu Xianghang (2013) obtained the best sand control effect when the setting angle of shed chamber plate which used in sand retaining engineering of shed tunnel is about 1 degree than the natural repose angle of loose particles through field simulation physical experiment. The increase of particle cohesion after rainfall in sand retaining wall project is conducive to the stability of sand pile. Bu Ye Tangjin (2017) and others put forward the treatment method of undulating SNS seepage and water conservation active protection net + vegetation slope protection, so as to achieve effective prevention and control of sand sliding slope disaster.

At present, the main work of granular slope protection is sand consolidation engineering, which alleviates the occurrence of granular slope accidents to a certain extent, which is economic and environmental protection. However, it is mainly used in the case that the granular slope is relatively stable, that is, most of the existing research results regard it as a static slope, ignoring that the granular slope is a growing process, and less research on how to effectively protect the stability of dynamic slope, which results in the research results difficult to solve the problem of granular slope recurrence and instability, and can’t effectively promote the prevention and control process of granular slope.

4. EXISTING PROBLEMS AND PROSPECTS
Based on the stability of granular slope, this paper summarized the distribution characteristics, and further discussed the results obtained and the problems easily occurred in the future research and development of granular slope. The conclusions are as follows:

It summarized the reinforcement and prevention measures of granular slope, concluded the research results of sand fixation at present stage, analyzed the advantages and disadvantages of the results, and put forward the research direction in the next stage.

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