Characteristics of viscous debris flow in a drainage channel with an energy dissipation structure

CHEN Jian-gang1 http://orcid.org/0000-0001-6001-5413; e-mail: chenjg@imde.ac.cn
CHEN Xiao-qing1,2 http://orcid.org/0000-0002-0177-0811; e-mail: xqchen@imde.ac.cn
CHEN Hua-yong1 http://orcid.org/0000-0003-4033-3339; e-mail: hychen@imde.ac.cn
ZHAO Wan-yu1 http://orcid.org/0000-0003-4879-7541; e-mail: wyzhao@imde.ac.cn

1 CAS Key Laboratory of Mountain Hazards and Earth Surface Processes, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041, China
2 CAS Center for Excellence in Tibetan Plateau Earth Sciences

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Abstract: A new type of drainage channel with an energy dissipation structure has been proposed based on previous engineering experiences and practical requirements for hazard mitigation in earthquake-affected areas. Experimental studies were performed to determine the characteristics of viscous debris flow in a drainage channel of this type with a slope of 15%. The velocity and depth of the viscous debris flow were measured, processed, and subsequently used to characterize the viscous debris flow in the drainage channel. Observations of this experiment showed that the surface of the viscous debris flow in a smooth drainage channel was smoother than that of a similar debris flow passing through the energy dissipation section in a channel of the new type studied here. However, the flow patterns in the two types of channels were similar at other points. These experimental results show that the depth of the viscous debris flow downstream of the energy dissipation structure increased gradually with the length of the energy dissipation structure. In addition, in the smooth channel, the viscous debris-flow velocity downstream of the energy dissipation structure decreased gradually with the length of the energy dissipation structure. Furthermore, the viscous debris-flow depth and velocity were slightly affected by variations in the width of the energy dissipation structure when the channel slope was 15%. Finally, the energy dissipation ratio increased gradually as the length and width of the energy dissipation structure increased; the maximum energy dissipation ratio observed was 62.9% (where $B = 0.6$ m and $L/w = 6.0$).

Keywords: Debris flow; Drainage channel; Energy dissipation structure; Geological disaster

Introduction

Debris flows can travel several kilometers as a series of surges. These flows are common mass movements in mountainous areas, particularly in steep mountainous areas (Iverson 1997; Hungr et al. 2001; VanDine and Bovis 2002; Godt and Coe 2007; Cui et al. 2013). After the Wenchuan earthquake, approximately $2.6 \times 10^9$ m$^3$ of solid material was deposited in gullies. Later, rapid erosion of this material formed large-scale debris flows (Shieh et al. 2009; Parker et al. 2011). After the Wenchuan earthquake, a period of debris-flow
disasters persisted for 5–10 years (Cui et al. 2011; Tang et al. 2009; Wu et al. 2011), with a particularly large number of debris flows triggered in the 5 years following the earthquake. These debris flows were similar to those in the area affected by the Chi-Chi earthquake (Taiwan), where numerous landslides, collapses, and debris flows occurred for up to 10 years after the earthquake (Chen et al. 2006; Chiou et al. 2007; Liu et al. 2008; Wu et al. 2011; Hu et al. 2012; Tang et al. 2012; Zhang et al. 2013). Moreover, the scales of the natural debris flows were considerably amplified by cascading landside dam failures (Cui et al. 2013; Zhou et al. 2013).

After the Wenchuan earthquake, the new debris-flow gullies were characterized by large longitudinal slopes, rich sources of material with drainage areas of less than 5 km², and a high frequency of outbreaks. However, the characteristics of the debris-flow density and discharge were variable (Cui et al. 2010). Debris flow mitigation measures can be classified as structural measures, such as check dams, drainage systems, flexible barriers, and debris-flow basins, or as nonstructural measures, such as warning and evacuation systems, appropriate land use, and the improvement of buildings (Armanini and Larcher 2001; Hassani et al. 2009; Takahisa 2008; Canelli et al. 2012; Ikeya 1989; Liu et al. 2013; Navratil et al. 2013; Okano et al. 2012). Mitigation measures for debris flows were implemented in the new debris-flow gullies. Debris flows are a serious threat to local residents, traffic routes, and hydropower projects. In fact, debris-flow drainage channels were constructed for highway crossings to ensure the safety of highways during the rainy season. Because of their simple structure, drainage channels can be easily constructed by local materials in any areas where debris flows form and accumulate. Drainage channels are often constructed downstream of the drainage area. Figure 1 shows the engineered drainage channels connected to check dams in China. Previously, the Dongchuan-type drainage channel and V-type drainage channel designs were used extensively in debris flow prevention and mitigation projects (Li 1997).

Dongchuan-type and V-type drainage channels were proposed by Li (1997) and Wang (1996), respectively (as shown in Figure 2), based on engineering practices recommended for debris-flow gullies. In addition, extensive studies have been performed, such as those by Li (1997), Wang (1996), You and Liu (2008), and You et al. (2011). The Dongchuan-type drainage channel can reduce the velocity of debris flows, alleviate gully erosion, and control gully bed morphology. Thus, these drainage channels can be applied to debris-flow gullies with a slope (i) larger than 5%. In contrast, the V-type drainage channel is characterized by an increased debris-flow velocity, improved discharge capacity, and reduced siltation. Therefore, this type of drainage channel may be suitable for use in debris-flow gullies with channel slopes less than 5%. Erosion affects the two types of drainage channels during the discharge of a large-scale debris flow. In terms of anti-abrasion properties, the Dongchuan-type drainage channel is slightly...