Earthquake-Induced Landslides: An Overview 119

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Abstract

Strong earthquake has been a significant triggering factor of landslides in hilly and mountainous areas. Damages caused by earthquake-induced landslides are sometimes larger than damages related to the shaking of the earthquake itself. During the last decades, a number of reports have been published to show serious damages caused by landslides after a series of disastrous earthquake events in mountainous regions. A lot of researches on landslides induced by earthquakes have been intensively carried out by various institutions. In 2012, the Japan Landslide Society published a book "Earthquake-induced landslides" in Japanese and further organized an International Symposium on Earthquake-induced Landslides in Kiryu City in Japan. Nowadays earthquake is still unavoidable and unpredictable. The study of earthquake-induced landslides has a major importance for better understanding of the causal mechanisms and the relationship among the landslide type, size, occurrence location and geomorphology. This paper presents an overview of current issues and recent advances concerning earthquake-induced landslides. It includes (i) movement types, characteristics and processes; (ii) causal mechanisms; (iii) physical and numerical modeling; (iv) secondary disasters; (v) risk assessment and management. It is urgently needed to develop practical methods for risk evaluation and hazard zoning on the basis of recent knowledge with appropriate mitigation strategy in order to avoid catastrophic damages by earthquake-induced landslides.

Keywords

Earthquake-induced landslide • Overview • Causal mechanism • Risk evaluation • Hazard zoning

119.1 Introduction

Nowadays, it is well-established understanding that strong earthquakes often cause very large numbers of landslides in hilly and mountainous areas. A huge number of landslides were caused by the Chi-Chi earthquake in Taiwan (1999), by the Mid-Niigata Prefecture earthquake in Japan (2004), by the Kashmir earthquake in Pakistan (2005), by the Wenchuan earthquake in China (2008), by the Iwate-Miyagi Inland earthquake in Japan (2008) and by the Tohoku earthquake in Japan (2011). In assessing those catastrophic cases of earthquake-induced landslides, it is necessary to pay due attention to extremely high threats to vulnerable settlements in hazardous areas. Actually, some remarkable research results focusing on general characteristics of earthquake-induced landslides are available during the last two decades. For example, Keefer introduced a historical review of various investigation results on earthquake-induced landslides (2002). However, scientific and technical attentions to earthquake-induced landslides are still apparently increasing. In the First World Landslide Forum, which was held in Tokyo in 2008, a thematic session on

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"Landslides and Multi-Hazards" was organized and "Earthquake-induced Landslides" was the main topics of the session. Also in the Second World Landslide Forum, which was held in Rome in 2011, a thematic session focused directly on "Earthquake-induced landslide" was organized. The Japan Landslide Society has set up a special task force and has carried out comprehensive researches on "Earthquake-induced Landslides" since 2009. Essential results and findings of the research activities are described in the final report "Earthquake-induced Landslides" published in 2012 (in Japanese). Furthermore, the Japan Landslide Society has organized an International Symposium on "Earthquake-induced Landslides", which was held in Kiryu, Japan, in 2012. The state of the arts knowledge in the field of "Earthquake-induced Landslides" should be found in the proceedings of this international symposium.

119.2 Research Project on Earthquake-Induced Landslides

On the basis of the technical experiences through a series of remarkable disasters by the earthquake-induced landslides, a task force was officially established in 2009 by the Japan Landslide Society in order to carry out the special research project entitled "Development of a methodology for risk assessment of the earthquake-induced landslides". Altogether 8 Working Groups, which were carrying out concrete investigations and analyses on individual research items, were organized to satisfy the all objectives of the task force. To clarify the mechanism of the earthquake-induced landslides, a Working Group has been carried out detailed field investigations especially on landslide induced by the Iwate-Miyagi inland Earthquake in 2008. Characteristics of representative landslides, such as types, dimensions, distributions and run-out distances have been investigated. Relationships between occurrence of landslides and seismological, geological and geotechnical conditions have been analyzed. Parallel to the case studies on recent earthquake-induced landslides in Japan, the task force has been engaged in detailed field investigations first on landslides induced by the Kashmir earthquake in 2005 jointly with Geological Survey of Pakistan and later on landslides induced by the Wenchuan earthquake in 2008 jointly with Chengdu University of Technology. The individual research items of the each Working Group are the followings: WG1; Mechanism of the earthquake-induced landslides, WG2; Methodology for risk assessment and risk management, WG3; Secondary disasters, WG4; Countermeasures and design procedures, Wg5; Warning and evacuation, WG6; Historical analyses of the past events, WG7; Review of the overseas events, WG8; Review of the recent events in Japan. Whole investigation results by the individual Working Groups should be combined and finally appropriate technical guidelines for risk assessment of the earthquake-induced landslides should be formulated based on the comprehensive analyses of all collected data (Fig. 119.1).

119.3 International Symposium on Earthquake-Induced Landslides

In order to exchange ideas and information on the mechanism of the earthquake-induced landslides and methods for the mitigation of the disaster brought by them, the International Symposium on Earthquake-induced Landslides was held in Kiryu, Japan, in 2012. During the symposium, the scientific reports on the recent results carried out in the framework of the special research project on "Earthquake-induced Landslides" have been also presented and they have provided wide range of essential information on the related topics. Main topics of interest in the International Symposium are the following: (1) Investigation of recent and historical earthquake-induced landslides and their impacts, (2) Characteristics, processes and mechanisms of earthquake-induced landslides, (3) Physical and numerical modeling of earthquake-induced landslides, (4) Instrumentation and monitoring technologies for earthquake-induced landslides, (5) Risk assessment and management of earthquake-induced landslides, (6) Stabilization and disaster mitigation of earthquake-induced landslides, (7) Landslide dams formed by the earthquake-induced landslides and their risk assessment and management, (8) Monitoring, prediction and early warning systems for post-earthquake landslides and debris flows, (9) Other relevant topics concerning earthquake-induced landslides.

Altogether 109 contributions are included in the proceedings of the symposium. Among them, 23 papers deal with case study, 22 papers deal with mechanism, 15 papers deal with simulation, 15 papers deal with hazard mapping and risk management, 7 papers deal with monitoring and countermeasures and 11 papers deal with landslide dam and post-earthquake phenomena.

Concerning movement types, characteristics and processes, Higaki and Abe (2013) reported on the relationship between common movement types of earthquake-induced landslides and geological formations. Various authors mentioned concerning causal mechanism. For example, Wang (2013) reported that high pore-water pressure could be generated after failure with increase of shear displacement, resulting in great loss in the shear strength. Various simulation methods were proposed to explain large displacement and long travel distance of sliding soil mass of earthquake-induced landslides. A lot of efforts were made also for risk assessment and hazard zoning with various approaches using data on past landslides induced by earthquakes. However, most of such approaches show still insufficient accuracy for

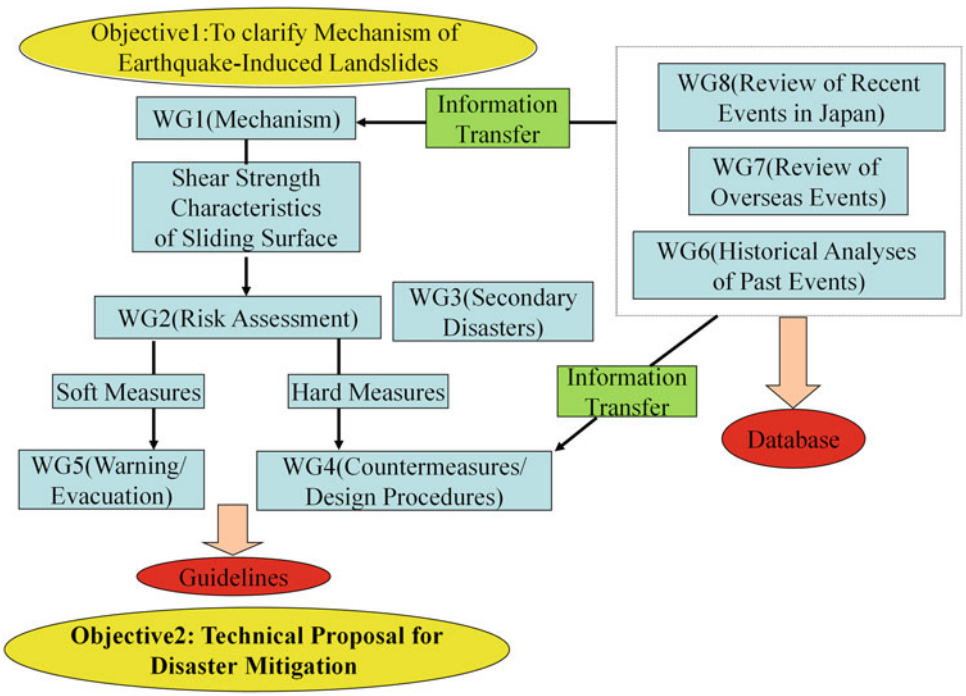

Fig. 119.1 Relationship among the individual working groups of the task force in the special research project of the Japan landslide society

practical disaster mitigation purpose. Okamoto (2013) reported on secondary hazards associated with earthquake-induced landslides including their social impact.

119.4 Necessity of Future Researches

Although certain advances have been already made as a result of intensive recent research activities on earthquake-induced landslides, several open problems are still remaining to be solved. Further researches are needed to evaluate various issues. For example, the relationship between the location of the epicenter or the source fault and that of the earthquake-induced landslides should be explained more clearly. Physical and mechanical characteristics of unconsolidated volcanic sediments should be clarified, because flow type landslides with long travel distance in such geological layer occur also in far distant areas from the epicenter. Concerning practical disaster mitigation, appropriate risk assessment methods and hazard zoning methods should be developed with sufficient accuracy to promote reasonable land-use to avoid damages by the earthquake-induced landslides. Concerning the efficiency of technical prevention measures, it is already found that most of existing prevention measures showed certain effective functions also to the earthquake-induced landslides. However, it is still remaining question how to design sufficiently resistant technical prevention measures.

It is expected that intensive discussions will be carried out in this session especially on still remaining open problems.

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