Secondary Hazards Associated with Coseismic Landslide

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Abstract

Landslide hazards induced by earthquakes are classified into a primary hazard and a secondary hazard from temporal and spatial viewpoints of damages. Working Group 3 (WG-3) of the Earthquake-induced Landslides Research Projects comprehensively investigated the secondary hazards associated with coseismic landslide. First of all, we provided a definition of them as the landslide hazard occurred with a delay in time and over a wider area, which triggered by post-seismic rainfall, snowmelt and transportation of debris. Then we collected past cases of the secondary landslide disasters, classified them by time scale and disaster type. This paper reports on some major secondary landslide disasters according to our classification as follows: (1) Formation and break of

Activities in WG 3 of JLS-ELRP.

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K. Ugai et al. (eds.), *Earthquake-Induced Landslides*,
DOI: 10.1007/978-3-642-32238-9_8, © Springer-Verlag Berlin Heidelberg 2013

landslide dams, (2) Post-seismic landslides, (3) Long-term degradation of mountainous forest watershed, (4) Isolated districts due to traffic disruption and functional decline of countermeasure works.

Keywords
Secondary coseismic landslide · Landslide dam · Post-seismic landslide · Long-term degradation · Isolation

1 Introduction

In Japan, major earthquakes have induced various types of landslides. Most of coseismic landslides are occur during seismic ground shaking, but some of them are actually induced with a delay in time and over a wider area; these are called secondary coseismic landslides. The Working Group 3 (WG-3) of the Earthquake-induced Landslides Research Projects, organized in the Japan Landslide Society, comprehensively investigated the hazards of secondary coseismic landslides. In this paper, we define secondary hazards associated with coseismic landslide and classify them by time scale and disaster type, then explain some cases of them.

2 Definition and Classification of Secondary Hazards Associated with Coseismic Landslide

WG-3 discussed issues concerning various aspects of secondary hazards associated with coseismic landslide. Firstly, we defined the hazards as follows: "Landslide hazards that were induced by post-seismic factors such as rainfall, snowmelt and aftershock with a delay in time and over a wider area". Here, direct hazards caused by the coseismic landslide are not taken into the definition. According to the definition, the secondary hazards are shown diagrammatically in Fig. 8.1 by phenomenological aspect, and in Fig. 8.2 in respect of social impact.

Next, we classified the secondary hazards into four groups based on time scale and disaster type as follows: (1) Formation and break of landslide dams, (2) Post-seismic landslides, (3) Long-term degradation of mountainous forest watershed and (4) Isolation of districts due to traffic disruption and functional decline of countermeasure works. (1) to (3) are direct hazards and (4) is an indirect hazard. Social unrest, economic concerns and psychological anxiety of victims are not considered since they are also affected by other disasters such as fire and tsunami.

3 Cases of Secondary Disasters Associated with Coseismic Landslide

3.1 Formation and Break of Landslide Dams

Coseismic landslides sometimes deposit debris in a river and obstruct its flow (called a "landslide dam"). Earthquake has almost the same number of triggers for landslide dam as rainfall (Fig. 8.3). A landslide dam may submerge houses and farms by the accumulation of water above the dam. Furthermore, breakage of the landslide dam often cause flooding, debris flow, and considerable damage in the downstream basin. Therefore, landslide dam is a serious mass movement that should be investigated with priority compared with other coseismic hazards.

In the Nikko Earthquake (AD 1683), a landslide occurred on the slope of Mt. Katsurou, and its debris formed a landslide dam in the Oga River in the upper basin of the Kinu River. Ikari village, which is located upstream of the dam, was submerged after 90 days, and the main road along the river was also submerged. In 1704, the

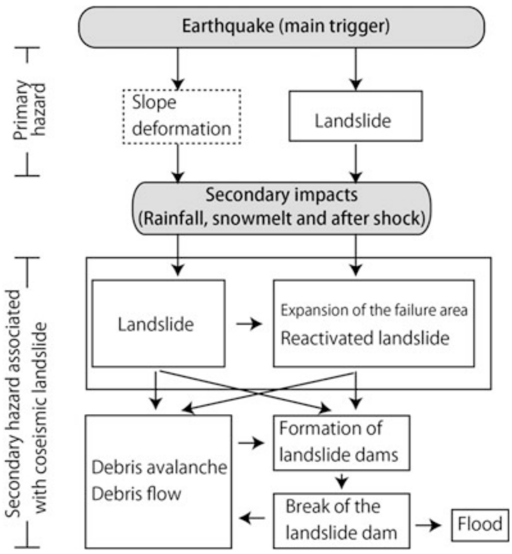

Fig. 8.1 Overview of the secondary hazards associated with coseismic landslide

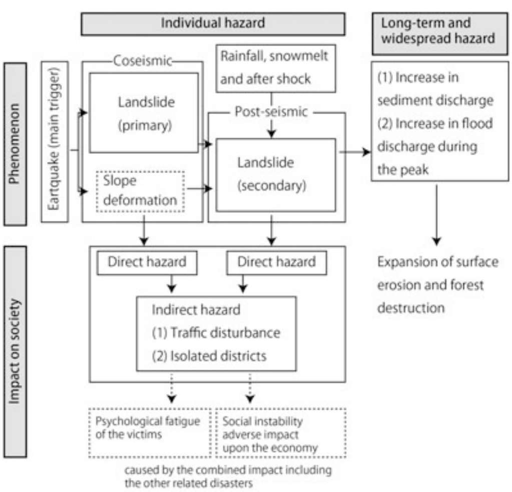

Fig. 8.2 Social impacts by the secondary hazards associated with coseismic landslide

landslide dam broke by heavy rain and the resulting floodwater reached the town of Utsunomiya (Sato 1983).

In the Zenkouji Earthquake (1847), more than 60,000 landslides were induced and 51 landslide dams were formed in the Matsushiro domain. One of the largest landslides at Mt. Iwakura dammed the Sai River, and a dammed lake of up to 70 m depth and 23 km length formed. This

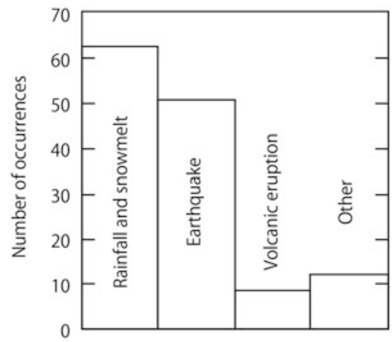

Fig. 8.3 Trigger for landslide dam formation (Schuster 1986)

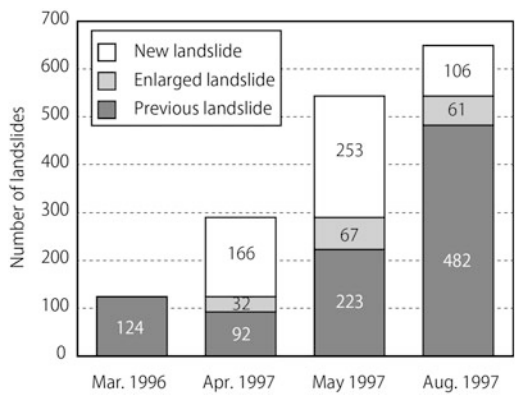

Fig. 8.4 Temporal variation in number of landslides after the earthquake in the northern part of Kagoshima Prefecture (1997) (Matsumoto et al. 1998)

lake broke after 19 days, causing flood damage in the lower reaches (Akahane 1998).

In the Mid Niigata Prefecture Earthquake (2004), 55 landslide dams were formed along the Imo River. The largest dam at Higashi-Takezawa village was 30 m high and submerged upper villages and roads (Photo 8.1). As an emergency measure, the water was drained by pumps and a temporary channel, then the dam was stabilized by check dams and channel works (Ministry of Land, Infrastructure and Transport Yuzawa Office 2005).

In the Iwate-Miyagi Nairiku Earthquake (2008), some landslide dams submerged a hot spring hotel and some houses along the river (Photo 8.2). Many landslide dams were also formed by the Wenchuan Earthquake (2008): the largest dam created a lake more than 6 km long

Photo 8.1 Submerged village and road by landslide dam caused by the Mid Niigata Prefecture Earthquake in 2004 (Higashi-Takezawa village, Niigata Pref., Japan) (Sakurai and Goto 2005)

Photo 8.2 Submerged houses by landslide dam caused by the Iwate-Miyagi Nairiku Earthquake in 2008 (Yunokura village, Miyagi Pref., Japan) (taken by Okamoto T.)

Photo 8.3 Landslide dam caused by the Wenchuan Earthquake (2008) in China (taken by Sakurai M.)

Photo 8.4 Debris flow disaster at Oyama village, Kanagawa Pref., Japan caused by heavy rain two weeks after the Kanto Earthquake (1923) (Editional committee of Isehara municipal census 1963)

along the river (Photo 8.3) (Chigira et al. 2010). Although channel works have been constructed, long-term sediment discharge is still a concern.

3.2 Post-Seismic Landslides

At an unstable slope due to strong ground shaking, post-seismic landslides are sometimes induced by the subsequent rainfall, snowmelt and aftershock. In this section, we describe cases of post-seismic landslides including debris flows.

In the Kanto Earthquake on September 1 (1923), many landslides occurred in the Tanzawa mountainous district, and large amounts of debris were deposited on unstable slopes. Between September 12 and 15, heavy rains (200–300 mm in 4 days) during a typhoon induced many landslides including some serious debris flows. At Oyama village, one person was killed and 140 houses were destroyed by a large debris flow (Photo 8.4), and other villages were also damaged by other debris flows. Some post-seismic landslides also occurred in the Hakone volcanic mountainous area near Tanzawa (Nakamura et al. 2000). There was heavy rainfall throughout the Tanzawa district from north to south, including part of the Hakone area. These debris flows occur in the areas with strong ground shaking by the Kanto Earthquake.

In the Hyogo-ken Nanbu Earthquake (1995), many landslides were induced around the fault of Mt. Rokko. Four months later, a newly-induced landslide and expansion of collapsed areas were found by interpreting aerial photographs. Furthermore, landslides after the earthquake were caused by less rainfall than before the earthquake (Tomita et al. 1996).

After the Mid Niigata Prefecture Earthquake (2004), a secondary failure was found at the Higashi-Takezawa landslide area during the subsequent snowmelt season. In addition, many small landslides were also found on the slopes by airborne laser survey along the Imo River after the snow-cover season.

3.3 Long-Term Degradation of Mountainous Forest Watershed

When many landslides or a large landslide are caused by an earthquake, a large amount of debris is rapidly supplied to mountainous slopes. The landslides destroy the forest soil and forest floor plants which prevent surface erosion of the slope, and so the damaged mountainous area remains degraded for a long time.

In March 1997, earthquakes with magnitude 6.5 occurred in the northern part of Kagoshima Prefecture, and many landslides were induced where granitic rocks are distributed near the epicenter. In this area, new landslides and the expansion of landslides increased due to the magnitude 6.3 aftershock in May 1997 and subsequent rainfall during the rainy season. The number of landslide gradually increased from 124 before the earthquake to 649 after the earthquake (Fig. 8.4) (Matsumoto et al. 1998).

After the Kanto Earthquake (1923), the ratio of landslide area was estimated to be 21.4 % in the Nakagawa river basin and 25.3 % in the Kurokura river basin (Kanagawa Prefecture 1930). However 22 % of the degraded area was restored, the degraded area remained for a long time after the North-Izu Earthquake (1930) and heavy seasonal rains in 1937 and 1938 (Ozawa 1998). In recent years, the basins were finally stabilized by continuous countermeasure works (Ishigaki et al. 2007).

Photo 8.5 Landslide close to the Omigawa railway Station caused by the Niigata-ken Chuetsu-oki Earthquake (2007) (Niigata Pref., Japan) (taken by Sakurai M.)

In the Western Nagano Prefecture Earthquake (1984), 36 million m^3 of collapsed soil traveled down the slope of Mt. Ontake as debris flow, and degraded forested area covering 6 million m^2. Even though countermeasure works such as check dams and revegetation were carried out, a debris flow occurred in 1987 (Nagano Regional Forest Office 1991).

3.4 Isolation of Districts due to Traffic Disruption and Functional Decline of Countermeasure Works

Roads and railways are sometimes disrupted by coseismic landslides, thus they often isolate some districts. In addition, loss of infrastructure such as electrical power and communication means makes isolation more serious. Particularly, traffic may be easily disrupted and cause the isolation of mountainous and island villages where the traffic system is sparse.

In the swarm earthquakes of the northern Izu Island chain (2000), Wakagou village on Niijima Island was isolated when a coseismic landslide blocked a road (Furukawa 2001), showing how easily a depopulated district may become isolated.

In the Mid Niigata Prefecture Earthquake (2004), 41 roads were damaged and 17 routes were closed by coseismic landslides, and 61 villages were isolated (Hokuriku Regional Development Bureau 2005). Furthermore, coseismic landslides destroyed many fences for snow avalanche control and reduced their effect during winter (Sakurai and Goto 2005).

In the Niigata-ken Chuetsu-oki Earthquake (2007), a landslide of 20 m width, 40 m height and 5 m depth occurred, blocking the railway track close to Omigawa Station (Photo 8.5) (JSEG Research Mission of the Niigataken Chuetsu-oki Earthquake Disaster 2007). As a result, a section of the railroad was closed for 2 months.

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