Chapter 5

The Science of Landslides and Slope Hazards

Field of expertise: Geotechnical Engineering

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Summary

The Great East Japan Earthquake caused a number of ground disasters. In coastal areas, tsunami damage and liquefaction attracted attention, and in inland areas, landslides and damage to hilly residential areas occurred. Such ground and slope hazards occur not only in earthquakes but also in heavy rainfall disasters, and it is important to improve laws and technologies to know the risks and predict them in advance.

Keywords: geotechnical disaster, residential land development, numerical analysis

Introduction

The Great East Japan Earthquake caused a number of ground and slope disasters. Deformation of the ground or slope has a significant impact on the surrounding buildings and infrastructure, and directly leads to human suffering. Although it is impossible to prevent these disasters completely, it is possible to mitigate and control the damage through both structural and non-structural measures based on prior risk assessment, and it is important to conduct research to achieve this efficiently.

1: Problems Revealed by the Great East Japan Earthquake

What happened?

In the Great East Japan Earthquake, seismic motions propagated over a wide area, causing many ground and slope disasters. The details of these damages are summarized in the report of the joint survey team of several academic societies (Geotechnical Edition) (Japanese Geotechnical Society, 2014). Particularly in the coastal areas of the Tohoku region, tsunamis overcame or destroyed seawalls and river levees, causing the buildings and infrastructures that were protected by them to be swept away, resulting in a large number of human casualties. In addition, these coastal areas were pulled into the Pacific Ocean, causing land subsidence. This land subsidence caused problems such as a decrease in the height of levees, and the seawater from the tsunami not receding, which hindered reconstruction and led to secondary damage such as salt damage. Large-scale liquefaction occurred along the coast of Tokyo Bay and around the Tone River basin in the Kanto region, and the damage to reclaimed land was particularly severe. There are photos and videos that still exist today showing liquefaction in the coastal areas of the Tohoku region, but the traces of this liquefaction were washed away by the tsunami, and there are many aspects about this region's liquefaction that are still unclear.

The direct damage to buildings and infrastructure caused by the tsunami and liquefaction were the focus of attention in the coastal areas, but a lot of damage also occurred in the inland areas. Slope disasters occurred over a wide area, and damage to residential areas in hilly areas (Moriguchi, 2011; Sato, et al., 2015) was also significant.

As described above, different types of ground and slope disasters occurred in the coastal and inland areas, but since the damage in the coastal areas has been covered in many other chapters, I will focus on the damage to the inland areas.

The damage

According to a survey by the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), 141 slope disasters, including mudslides, landslides, and steep slope landslides (cliff collapses), have been confirmed to have occurred with a total of 13 fatalities (http://www.sabo.or.jp/saigai/110311touhoku-earthquake.htm (In Japanese)). However, this does not include small-scale collapses, and since traces of such collapses have been washed away and cannot be confirmed in coastal areas, we can assume that more damage would have been recorded if these types of collapses were included.

As for developed residential areas, damage occurred mostly in hilly areas built during Japan's period of rapid economic growth from the 1950s to the 1970s. In order to create flat land, land was carved out from the hills that used to exist there, and filled land is mixed in to create a hilly residential area. Sato et al. analyzed the developed residential areas in Sendai City, Miyagi Prefecture, that were damaged by the 2011 Great East Japan Earthquake, and reported that the incidence of ground deformation and damage to wooden buildings was more than twice as high at embankments and cut-and-fill boundaries (the boundary between embankments and cut-and-fill land) than at cut-and-fill areas. It is also reported that there is a correlation between the age of land development and the damage rate, which is strongly related to the changes in laws and design standards for residential areas.

2: Paradigms Destroyed by the Earthquake

In the aftermath of the Great East Japan Earthquake, the importance of prior information and forecasting of disaster risks has increased. These were not necessarily newly recognized in the wake of the earthquake, but the earthquake raised the shared awareness of their importance and accelerated related research.

In terms of prior information, tsunami hazard maps were of course closely watched, but this also marked a turning point in the recognition of the importance of landslide-related disasters. In addition, before the earthquake, there was little information disseminated on the details of the land in developed residential areas, and residents did not understand the necessity of knowing this information. Since the earthquake, there has been an increase in realizing the importance of knowing this information in advance.

In order to forecast disasters, it has become necessary to include and target complex phenomena and the scale of large areas. For example, in the case of landslide disasters, there is an increasing need for risk assessment at the practical level, not only to evaluate whether or not a slope is stable against external forces, but also to determine how far the sediment will reach in the event of a collapse and how much impact force it will have when the debris hits a building. We not only need to calculate the stability of a single slope, but also evaluate wide areas that include many slopes.

3: A New Approach

First of all, in the maintenance of prior information, I'd like to introduce the map of residential land development history in Sendai City. After the earthquake, the city of Sendai published a map of the distribution of cut-and-fill soil and the date of residential land construction (http://www.city.sendai.jp/kaihatsuchose-chose/kurashi/anzen/saigaitaisaku/kanren/joho/index.html (in Japanese)). This map was developed in response to the many cases of damage to developed areas in Sendai City. Anyone can access this information through the Internet and can easily find out where their house is located on the boundary of fill or cut-and-fill, and when the land was built. Figure 5-1 is a cut-and-fill map of a part of Sendai City, where orange represents the fill area and blue represents the cut area. Collapses of these residential areas can occur not only due to earthquakes but also due to heavy rain. In fact, a large-scale collapse occurred in Shogun, Izumi Ward, Sendai City, when Typhoon No. 19 hit eastern Japan in 2019. This map shows that the collapse was caused by an embankment constructed in the 1960s, a form of embankment in which soil is attached to a slope.

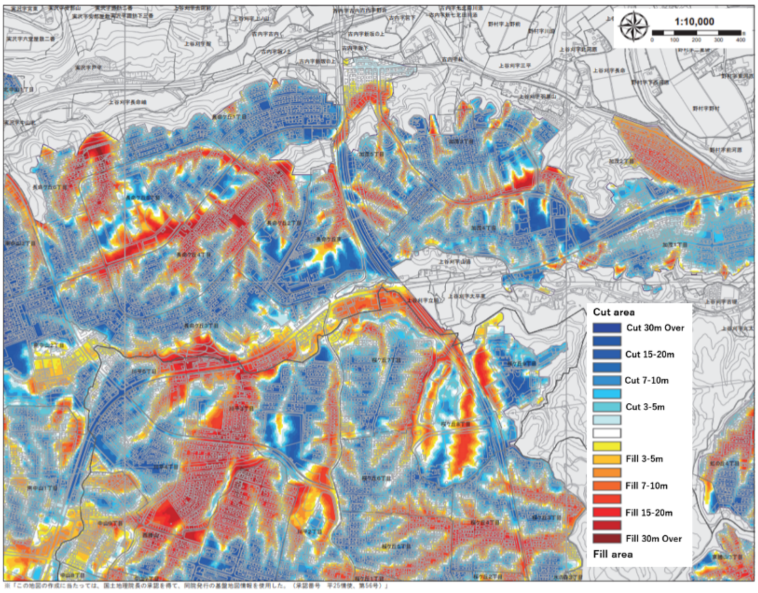

Figure 5-1. An example of the Sendai City residential land development history map

Next, as a new approach to forecasting, I'd like to introduce a simulation method for landslide risk assessment in a wide area. This simulation method, based on mechanics, was developed at Tohoku University and was refined by our research group to enable the evaluation of a wide area. Figure 5-2 shows the map of the simulation results as well as the actual slope disaster distribution of the 2018 Hokkaido Eastern Iburi Earthquake. The actual collapse distribution map is published on the web by the Geographical Survey Institute of Japan, and the simulation results show the thickness of the collapse as a contour diagram. The simulation results are generally consistent with the distribution of slope disaster occurrence. The simulation results are generally consistent with the distribution of slope hazards. Although the simulation is still in the verification stage, it has high potential for future slope disaster prevention because it can take into account the effects of rainfall as well as earthquakes.

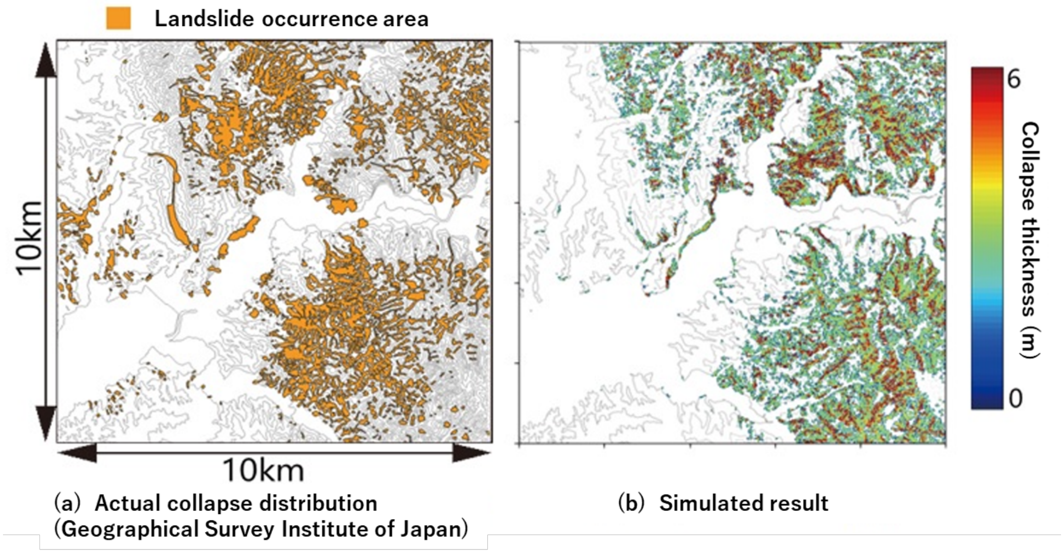

Figure 5-2. Hokkaido Eastern Iburi Earthquake landslide area

4. Achievements and the Future

As mentioned above, new attempts have been made to know and assess the risk of ground and landslide disasters in advance. However, this information and technology has not yet been used effectively in practical disaster management. In particular, there is a lack of information on the internal structure of the ground and the properties of geomaterials as input conditions for simulation. This needs to be improved, including through better preparation of information.

Conclusion - From the author

In addition to the information development and forecasting technologies for ground disasters and landslides described above, various other information and technologies have been developed and are evolving everyday. However, in order to protect human lives from ground disasters and landslides, it is essential for individuals to become more aware of disaster prevention as well. It is my sincere hope that a world in which people can coexist with disasters will be created through the accurate understanding of disaster risks in advance and the development of individual disaster prevention capabilities.

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