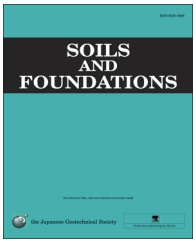
Soils and Foundations 2015;55(5):1305–1317

The Japanese Geotechnical Society

Soils and Foundations

www.sciencedirect.com
journal homepage: www.elsevier.com/locate/sandf



Investigation of landslide calamity due to torrential rainfall in Shobara City, Japan

Takashi Tsuchida[a,*], A.M.R.G. Athapaththu[a], Takashi Hanaoka[b], Masaki Kawaguchi[c]

[a]*Department of Civil and Environmental Engineering, Institute of Engineering, Hiroshima University, 1-4-1, Kagamiyama, Higashi-Hiroshima 739-8527, Japan*
[b]*Hiroshima Prefectural Hiroshima Technical High School, Japan*
[c]*Tottori City Government, Japan*

Received 18 July 2014; received in revised form 29 January 2015; accepted 7 May 2015
Available online 4 October 2015

Abstract

On 16th July 2010, a series of slope failures occurred in the city of Shobara, Japan due to a torrential rainfall. The slope failures were found to have occurred at about 200 locations in a narrow area of 16 km^2. Most of the failures in this catastrophic disaster were due to the collapse of the middle portion of a mountainous slope. The primary purpose of this study was to present the landslide event that took place in Shobara City and to explore the mechanism of the multiple planar slope failures in the region. A series of field tests was carried out using a recently developed lightweight dynamic cone penetrometer in the middle portion of the selected planar slopes. The results revealed that the slopes were composed of two soil layers, weathered Rhyolite and Kuroboku. The failures took place at the boundary of these two soil layers. Laboratory tests were conducted to find the relevant parameters for the stability analysis, and laboratory scale model tests were performed to understand the mechanism of the slope failures in this region. The results of the model tests revealed that the Kuroboku layer led to a rise in the water table in the middle portion of the slope, while preventing the downward flow of groundwater. As a result, the failures are found to have initiated and occurred in the middle portion of the mountainous slope. The factor of safety, evaluated based on a slope stability analysis, was found to be close to 1, when the groundwater level rose to the ground surface and the apparent cohesion of the weathered Rhyolite soil over the Kuroboku layer decreased to 1.3 kPa.
© 2015 The Japanese Geotechnical Society. Production and hosting by Elsevier B.V. All rights reserved.

Keywords: Slope failure; Rainfall; Site investigation; Model test; Slope stability

1. Introduction

In recent years, unexpected and extreme rainfall events have caused landslide disasters all over Japan due to abrupt changes in weather conditions. Some of these rainfall events occurred within a few hours, and certain areas received more rainfall than is usually experienced over an entire month ((Ex. Aso, Kumamoto Prefecture in July 2012 (Miyabuchi, 2012); Kii Peninsula in September 2011 (Yamada et al., 2012), Hofu in Yamaguchi Prefecture in July 2009 (Fukuoka et al., 2009)). These events have become more frequent in the past few years and have not only claimed human lives and caused considerable property loss, but have also severely affected the day-to-day activities and the development of the area. On 16th July 2010, a series of slope failures occurred in Shobara City, Hiroshima Prefecture, Japan due to abrupt and heavy rainfall. This torrential rainfall led to simultaneous slope failures at more than 200 locations within a narrow 4 km × 4 km area. The area where the slope failures occurred is shown in Fig. 1.

*Corresponding author.
E-mail address: tkstsuchida@mse.biglobe.ne.jp (T. Tsuchida).
Peer review under responsibility of The Japanese Geotechnical Society.

http://dx.doi.org/10.1016/j.sandf.2015.09.028
0038-0806/© 2015 The Japanese Geotechnical Society. Production and hosting by Elsevier B.V. All rights reserved.

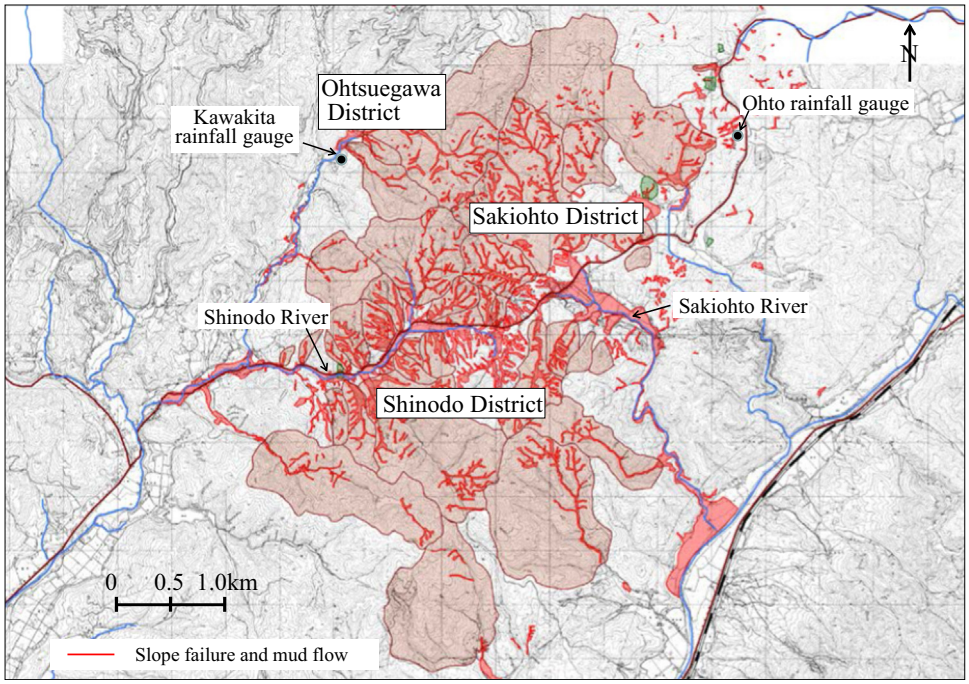


Fig. 1. Extent of area affected by heavy rainfall in city of Shobara, Japan.

This disastrous event led to the swallowing of trees, the spilling out of streams, and the flattening of villages in mountainous areas as well as the overflowing of roads and farmland. The mountainous areas on both sides of the roads experienced concentrated slope failures. Most of these failures were found to have occurred in the middle portion of the mountain and in slopes having gradients of more than 30°. A failed mass flowed over roads, decimated houses and farmlands in the region, claimed 1 life, and caused 1 major injury. According to the statistics published on the Hiroshima Prefectural Government web site, 12 houses were fully destroyed and 11 houses were partially damaged (Tsuchida et al., 2010; Hiroshima Prefecture, 2014). Moreover, it was reported that 502 farms and agricultural facilities, 65 forestry facilities, 51 rivers, 2 erosion-control barriers, and 21 roads were damaged due to this event (Tsuchida et al., 2010). Therefore, this disaster was considered to be one of the major events, in terms of the number of slope failures, property loss, and the pattern of failures, that has occurred in the region over the past few decades.

The overall purpose of this paper is to present the series of failures that occurred in the city of Shobara, in Hiroshima Prefecture, Japan and to examine the failure mechanism of the slope failures that occurred in the region. Emphasis is given to discovering the failure mechanism of the planar slopes in the area through aerial photographs, site surveys, and site investigations. In addition, a series of in-situ and laboratory tests was conducted to examine the engineering properties of soils and to use the data for stability analyses. Besides that, a series of laboratory model tests was conducted to observe the failure mechanism of the planar slopes for different rainfall intensities. Stability analyses were carried out based on the data collected from field and laboratory tests to gain a better understanding of the slope failures in the region. Based on the site investigations, site and laboratory tests, models tests, and stability analyses, the failure mechanism of the slope failures that occurred in Shobara City is presented in this paper.

1.1. Geology and topography of the affected area

The affected area is composed of weathered remnants of Rhyolite and Kuroboku soils. Rhyolite is an igneous volcanic rock and Kuroboku is a mixture of volcanic ash and organic matter. Kuroboku soil is black in colour and covers most of the area in the region. The thickness of Kuroboku soil in the affected area varies from a few centimeters to a few metres. Weathered Rhyolite is underlined by Kuroboku soil in most parts of the slopes in the area. Its thickness varies from location to location and is about 1.0–1.5 m at the lower part of the slope. Most of the land in the area is mountainous. The angle of the mountainous slopes varies from 17° to 46°.

1.2. Meteorological data in and around the affected area

Rainfall data were collected from the rainfall gauges in and around the affected area, as shown in Fig. 2. Table 1 presents the cumulative rainfall data before and during the slope failures and the maximum hourly rainfall at different gauging stations in the vicinity of the affected area. Fig. 3(a) shows the cumulative rainfall and hourly rainfall at Ohto gauging station from 1st to 17th July 2010 with reference to the data presented on the Hiroshima Prefectural Government web site (Tsuchida et al., 2010). Fig. 3(b) shows the cumulative and hourly rainfall on the day, 16th July 2010, that the series of slope failures occurred. The peak rainfall recorded at Ohto rain-gauge station was 91 mm/h from 3:40 to 4:40 pm on 16th July 2010. However,

Download English Version:

https://daneshyari.com/en/article/307108

Download Persian Version:

https://daneshyari.com/article/307108

Daneshyari.com