Characteristics of Landslide Distribution and Dimension, Comparison of Landslides Induced by Reverse-fault Earthquake and Normal-fault Earthquake in Japan

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INTRODUCTION

After 2004, a series of strong earthquakes struck Japan, caused severe damage to the focal areas. In these cases of earthquakes, most of the victims due to landslides and debris flow induced by the earthquakes. The issue of earthquake-induced landslides has been a significant problem related to reduce victims from earthquake disaster. Different type earthquakes may induce different characterized landslides, especially related to their distribution and dimension. In this paper, to clarify the differences between landslides induced by reverse-fault and normal-fault earthquakes, two recent earthquakes were analyzed. One is the Iwate-Miyagi Inland earthquake (hereafter Iwate-Miyagi earthquake) 2008, which marked $M_{\text{JMA}}$7.2 and intensity of 6 upper [JMA, Japan Meteorological Agency scale]. And another is the Fukushima Hamadori (hereafter Fukushima earthquake) earthquake in 2011, occurred just one month after the huge 3.11 Tohoku earthquake, marked $M_{\text{JMA}}$7.0 and intensity of 6 lower in JMA scale.

STUDY AREA AND REGIONAL SETTINGS

Study areas are shown in Fig.1. The study area 1 is located in north eastern Japan, distances about 370 km north east from Tokyo. The study area 1, occupies about 1,042 km$^2$, is around the source fault and focal area of the Iwate-Miyagi earthquake. The Study area 2 is also located in north eastern Japan, distances about 170 km north east from Tokyo. The study area 2 occupies about 720 km$^2$, is around source fault and the focal area of the Fukushima earthquake.

Around the study area 1, the geology is mostly composed of volcanic rocks from Neogene to Quaternary, and the relief of mountainous area ranges from 300 to 1,600 m above sea level. In the study area 2, the geology is mainly composed of Neogene sedimentary rocks and metamorphic rocks (Cretaceous). The relief of study area 2 is relatively low compared to the study area 1, ranges about 100 m to several hundred meters. The Iwate-Miyagi earthquake occurred on northwest dipping reverse fault while the Fukushima earthquake occurred on northwest dipping normal fault.

Fig. 1 Location of the study areas
CHARACTERISTICS OF LANDSLIDES DISTRIBUTION AND DIMENSION

The landslides induced by these two earthquakes were extracted from aerial photographs and the satellite images of Google Earth. The landslide inventory data are shown in Table 1. For these landslides, the characteristics of distribution as well as the dimensions with the distance from source fault were analyzed.

According to the analysis, some characteristics of landslides induced by reverse-fault and normal fault earthquakes were revealed as below.

1) For both reverse-fault earthquake and normal-fault earthquake, most of the landslides occurred on hanging wall. The characteristics of landslide distribution coincide with the PGA distribution of earthquakes.
2) For both reverse-fault earthquake and normal fault earthquake, the maximum size of landslides occurred on hanging wall is larger than that on the footwall.
3) Compared to reverse-fault earthquake, normal-fault earthquake tends to induce fewer landslides.
4) Compared to reverse-fault earthquake, normal-fault earthquake tends to induce smaller landslides.

<table>
<thead>
<tr>
<th>Name of Earthquake</th>
<th>Area (km²)</th>
<th>Landslides</th>
<th>Total number</th>
<th>Hanging wall (number / %)</th>
<th>Foot wall (number / %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iwate-Miyagi</td>
<td>1042</td>
<td>810</td>
<td>741</td>
<td>91.5</td>
<td>69</td>
</tr>
<tr>
<td>Fukushima</td>
<td>720</td>
<td>17</td>
<td>13</td>
<td>80.0</td>
<td>4</td>
</tr>
</tbody>
</table>

Tab. 1 Distribution of landslides induced by two earthquakes

**Keywords:** earthquake-induced landslide, reverse fault, normal fault, peak ground acceleration