Seminar: “Integrated forest and water management of mountain watersheds: Experiences and perspectives”

Landslides and Their Control in Mountain Watersheds of Japan – Processes and Countermeasures –

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Japan as Landslide Paradise!

- Typical Landscape with densely distributed landslides -

Densely Distributed Landslides on Hilly Terrains in Kubiki
Landslides in Tertiary Areas
Fig. 1 Geology and Landslide Distribution near Mt. Jogayama
Landslides in Volcanic Mountain Area

Souzan Landslide in Hakone / Landslides in Hydrothermal Alteration zones
Contents of the Report:

- Geology and Geomorphology of Japanese Archipelago
- Climate of Japan
- Characteristics of Landslides in Japan
- Distribution of Landslides and Geotectonic Structures
- Investigation Measures
- Mitigation Measures
- Representative Landslides and Mitigation Measures
- Perspectives
Trenches and island arcs around the Japanese Archipelago

- Kurile Arc
- Izu-Mariana Arc
- Southwest Honshu Arc
- Mid Niigata
- Sendai
- Tokyo
- Ryukyu Arc
Major Geologic Zones

- Quaternary Regional Pyroclastic Flow Zone
- Quaternary Volcano Zone
- Tertiary Rock Mantle Zone
- Cretaceous-Tertiary Volcanic Rock Zone
- Plutonic Rock Zone
- Pre-Tertiary Accretionary Zone

(Highest landslide occurrence)
Monthly Mean Precipitation and Temperature

Courses of Disastrous Typhoons
<table>
<thead>
<tr>
<th></th>
<th>Landslides</th>
<th>Rapid Slope Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geology</strong></td>
<td>often influenced by geology and geologic structure</td>
<td>little or no influenced by geology and geologic structure</td>
</tr>
<tr>
<td><strong>Soils</strong></td>
<td>moves along slip surface(s) that consists of highly plastic clay</td>
<td>usually involves topsoil, residual soil and (highly)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>weathered bedrock</td>
</tr>
<tr>
<td><strong>Topography</strong></td>
<td>occur on gentle to moderate slopes of 5 to 30° the upper slopes often</td>
<td>usually occurs on slopes steeper than 30°</td>
</tr>
<tr>
<td></td>
<td>have flat-plateau like topography</td>
<td></td>
</tr>
<tr>
<td><strong>Nature of</strong></td>
<td>continuous, recurrence (repetitive occurrence) duration of a single</td>
<td>occur suddenly short duration</td>
</tr>
<tr>
<td><strong>movement</strong></td>
<td>episode is generally long</td>
<td></td>
</tr>
<tr>
<td><strong>Rate of</strong></td>
<td>generally slow to very slow</td>
<td>very to extremely rapid</td>
</tr>
<tr>
<td><strong>movement</strong></td>
<td>0.01 to 10mm/day (most common)</td>
<td>10 m/sec or faster</td>
</tr>
<tr>
<td><strong>Nature of</strong></td>
<td>little disturbance within a sliding block</td>
<td>incoherent move as highly disturbed mass</td>
</tr>
<tr>
<td><strong>moving mass</strong></td>
<td>often move while retaining the original shape and characteristics</td>
<td></td>
</tr>
<tr>
<td>(blocks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Causes, triggering</strong></td>
<td>generally influenced by excess groundwater, elevated groundwater table</td>
<td>generally influenced by rainfall intensity</td>
</tr>
<tr>
<td><strong>mechanism</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>surface area is often large ranges between 1 to 100 ha</td>
<td>surface area is generally small with an average volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td>of about 440m³</td>
</tr>
<tr>
<td><strong>Warning signs</strong></td>
<td>often develop cracks, depressions, upheavals, groundwater fluctuation,</td>
<td>hardly any warning signs</td>
</tr>
<tr>
<td></td>
<td>etc. prior to sliding</td>
<td>almost always fail suddenly</td>
</tr>
<tr>
<td><strong>Typical original</strong></td>
<td>10 to 25°</td>
<td>35 to 60°</td>
</tr>
<tr>
<td><strong>gradient</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2-1 Summary of Designated Landslide Threatened Area

<table>
<thead>
<tr>
<th></th>
<th>Ministry of Land, Infrastructure and Transport</th>
<th>Ministry of Agriculture, Forestry and Fisheries</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of area</td>
<td>3,329</td>
<td>1,868</td>
<td>5,197</td>
</tr>
<tr>
<td>Total area (ha)</td>
<td>114,023</td>
<td>107,061</td>
<td>221,084</td>
</tr>
</tbody>
</table>

Table 2-2 Summary of landslide mitigation expenditures in fiscal year 2000

<table>
<thead>
<tr>
<th></th>
<th>Ministry of Land, Infrastructure and Transport</th>
<th>Ministry of Agriculture, Forestry and Fisheries</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Subsidy</td>
<td>37,505</td>
<td>14,068</td>
<td>51,573</td>
</tr>
<tr>
<td>Direct spending</td>
<td>8,421</td>
<td>5,892</td>
<td>14,313</td>
</tr>
<tr>
<td>Total</td>
<td>45,926</td>
<td>19,960</td>
<td>65,886</td>
</tr>
</tbody>
</table>

Unit: 1 Million Yen

ca. 7000
ca. 320,000 ha

Altogether 100 Billion Yen
Northern Fossa Magna

Median Tectonic Line

Landslide Prone Areas and Geotectonic Structures
Syncline

Anticline

Neogene Formation
- Black Mudstone
- Alternation of Sandston and Mudstone

• Extremely low shear strength

Distribution of Landslide Areas in Matsunoyama-District in Niigata
Fractured Zone along the Median Tectonic Line

- Metamorphic Rock Formation
Flow Chart for Landslide Investigation and Analysis
Fig. 4-15  Automated monitoring system using IT Technology
Fukuzono’s Method:

Increment of the logarithm of Acceleration is proportional to Logarithm of Velocity of Surface Displacement
Fig. 33 Landslide investigation procedures
Various Types of Landslide Mitigation Measures

- Landslide Control Measures
  - Surface Drainage Control
  - Groundwater Control
    - Shallow Groundwater Control
      (Interceptor Under Drains, Horizontal Gravity Drains, Interceptor Trench Drains)
    - Deep Groundwater Control
      (Horizontal Gravity Drains, Drainage Wells, Drainage Tunnels)
  - Earth Removal
  - Buttress Fill
  - River Structures

- Landslide Restraint Measures
  - Piles
  - Large Diameter Cast-in-Place Shafts
  - Anchors
  - Retaining Walls
Sarukuyoji Landslide in Niigata Prefecture

Length: 1,700 m  Neogene Formation
Width: 400 m   -Weathered Black Mudstone
Depth: 4-15 m  Area: 44.3 ha
Jizukiyama Landslide

Length: 700 m
Width: 500 m
Depth: 60m
Area: 25 ha

Upper Tertiary, Late Miocene
Rhyolitic Tuff
Overview of Odokoro Landslide

Length: 1000 m
Width: 400 – 800 m
Depth: deeper than 100 m
Area: 60 ha

Crystalline Schist, Mesozoic and Paleozoic Sedimentary Rocks
Sepentine Melange Zone
Plan of Akasaki Landslide

Overview of Akasaki Landslide

Colluvial Soil
Green Tuff
Sandstone

Length: 1100 m
Width: 500 m
Area: 30 ha

Distribution of Drainage Wells and Tunnels

Cross Section of Akasaki Landslide and Distribution of Drainage Wells and Tunnels

Control Measures
A tremendous number of landslides were induced by the Mid-Niigata Prefecture Earthquake

- Important target: Earthquake-Induced Landslides -

*Imo River Basin immediately after the 2004 Mid-Niigata Earthquake*

(Ministry of Land Infrastructure and Transport)
Distribution of slope failures and landslides caused by the Mid-Niigata Prefecture Earthquake

- Black : Slope failures
- Gray : Main scarp of landslides
- Oblique line : Displaced soil mass

(Interpreted by Prof. Yagi)

Overview of Imogawa River

Area of Watershed: 38km²

Maximum Elevation : 680m

Minimum Elevation : 75m

Length of channel: 16km

River Bed Inclination : 1/70
The largest landslide induced by the strong Vibration of the Mid Niigata Earthquake 2004, Japan
(500m x 500m x 100m)
Main scarp of the Higashitakezwa landslide (photographed on 27th October)
Emergency drainage from reservoir by Higashitakezawa landslide
Reservoir formed by the Higashitakezawa landslide dam

Inundation of houses at Kogomo-District
Legends: Situation in March 2005

Blue color along river channels: Reservoir

Landslide dams are shown by circles and triangles:
- Circles show River Channel Blockages which are still existing.
- Orange circle: Countermeasures installed
- Blue circle: Overtopping
- Red circle: Without Overtopping
- Triangles show River Channel Blockages which are already solved.
- Green triangle: naturally washed away
- Violet triangle: artificially excavated

Distribution of Landslide Dams

(Hokuriku Regional Development Bureau)
Accomplishment of Stabilization works at Higashitakezawa

Two and half years after the Earthquake
Remarks for mitigation of future landslide hazards

Reconnaissance and evaluation of slope stability

1) Primary reconnaissance after the Earthquake
2) Secondary detailed reconnaissance after snowmelt

Landslides and reconstruction of main roads

1) Reconsideration of route plan of main roads
2) Stabilization of landslides

Control and management on landslide dams

1) Monitoring on displaced soil mass
2) Monitoring on snowmelt
3) Permanent countermeasures

Other remarks:

1) Evaluation of danger degree by sediment disasters after the Earthquake
2) Hazard mapping for prediction of landslides in relation to the next possible earthquake
Aratosawa Landslide
– the largest landslide caused by the 2008 Iwate-Miyagi Earthquake
- Important target: Earthquake-Induced Landslides -
Topographic displacement of Aratosawa landslide
(Japan Landslide Society)
Before earthquake

Old subsidence zone

Sliding surface

After earthquake

Compression zone

Subsidence zone

Tuff

Welded tuff

Pumice tuff

Sandstone/Siltstone

Longitudinal profile of Aratosawa landslide (Tohoku forestry bureau)
Flow type landslide
Location of epicenter area

Surface displacement and active faults (Geographical Survey, 2006)
Large scale surface landslides in Muzzafarabad
Hattian landslide – the largest landslide caused by the Northern Pakistan Earthquake
Landslide along main road
Interpretation of Landslide Topography using IKONOS Satellite Image and Risk Identification by Analytical Hierarchy Process

Factors for Risk Identification:
* Surface Gradient
* Geological Structure
* Location to the River Channel
* Clearness of Surface Deformation

Danger Degree of Landslide

(Example in Pakistan)
Objective 1: To clarify Mechanism of Earthquake-Induced Landslides

WG1 (Mechanism)
- Shear Strength Characteristics of Sliding Surface

WG2 (Risk Assessment)

WG3 (Secondary Disasters)

WG4 (Countermeasures/Design Procedures)

WG5 (Warning/Evacuation)

WG6 (Historical Analyses of Past Events)

WG7 (Review of Overseas Events)

WG8 (Review of Recent Events in Japan)

Information Transfer

Guidelines

Database

Objective 2: Technical Proposal for Disaster Mitigation
Risk Management for Mitigation of Landslide Disasters Caused by Earthquakes in Asian Orogenic Zone
(by the Mid-Niigata Prefecture Earthquake, by the Northern Pakistan Earthquake, etc.)

*Common tasks in Asian Orogenic Zone

*Severe Landslide Disasters Caused by the Mid-Niigata Prefecture Earthquake
  — Emergency Operations.
  — Response to Successive Disasters
  — Mitigation of Future Slope Disasters Caused by Earthquakes

*Technology and Information Transfer
(International Cooperation)
Croatia-Japan Joint Research: Risk Identification and Land-use Planning for Disaster Mitigation of Landslides and Floods in Croatia

Hideaki Marui
Project Leader: Niigata University

(Split at Adriatic Cost)
Landslides in mountainous areas along the Adriatic Cost
Apparent danger to the main roads
Interruptive factor against development in Croatia

Grohovo Landslide (southwest side)
faced to the Rjecina River near Rijeka City
Summary: Scheme of Research

- Survey of Triggers
- Urbanization Development
- Topography
- Observation of Triggers
- Runoff in Karst Areas
- Rainfall (Groundwater)

Landslides

- Landslide Risk Assessment
- Landslide Hazard Map
- Integrated Landslide-Flood Hazard Map
- Risk Identification and Land-Use Planning for Disaster Mitigation of landslides and floods in Croatia

Flash-Flood

- Flash-Flood Risk Assessment
- Flash-Flood Hazard Map

Floods

- Formulation of Land-Use Guidelines for Mitigation of Disasters
We are very grateful to you for your kind attention