Occurrence mechanism of rockslide at the time of the Chuetsu earthquake in 2004
- A dynamic response analysis by using a simple cyclic loading model -

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The point of this presentation

Recent trend in seismic response analysis

Problems:
Not easily applicable for reviewing the occurrence mechanism of the landslide in mountainous area during an earthquake.

Solutions:
Application of UW model capable of dealing with dynamic deformation characteristics and shear strength together.

Case study analysis: The Hitotsu-minesawa Landslide
The Hitotsu-minesawa Landslide was induced by the Niigata Chuetsu Earthquake which occurred in Japan 2004.

Results:
1. A large increase of horizontal acceleration is in action at the ridge area.
2. A large shear stress is in action at the valley area.
Map of the landslide damaged area (from the Chuetsu earthquake, 2004)

Profile of the earthquake

Date:
   at 17:56 on 23rd October 2004

Location:
   E.L. 138° 52’ 00” ± 24”
   N.L. 37° 17’ 30” ± 18”

Depth of focus: 13km
Magnitude: 6.8
Maximum acceleration:
   over 1000 gal

Quoted from [Landslide Distribution Map (Yagi et al., Japan Landslide society, 2004)]
The Hitotsu-minesawa Landslide: Profile 1

A large-scale rockslide with Tertiary formation as its slide surface.

Overall view of Hitotsu-minesawa (Photo by Haraguchi, 2004)
The Hitotsu-minesawa Landslide: Profile 2

Severe fractures at the front-end of the slide

A summary by the photograph (Photo by Haraguchi, 2004)
The Hitotsu-minesawa Landslide: Profile 3

Many cracks occurred in the stream by the ridges.

- Cracks pointing towards the NS direction
- Size of the cracks: approx. 5cm wide
- Condition: fresh, with no intrusion of tree roots nor discoloration

The fractures at the front end of the landslide body
Many cracks occurred in the stream

Suggestion: Strong inertial force being at work on the slope-end.
The geological structure of the Hitotsu-minesawa landslide

Moving zone:
- mainly of silty sandstone

Slip surface:
- black mudstone

Strike and dip of the layer:
- approx. N15° E, 0~5° W
3D dynamic response FEM applied to the mountainous area

Response analysis method
applied to the Hitotsu-minesawa landslide:
A simple cyclic loading model (Ugai & Wakai model)

<Characteristics>
1. Shear strength is based on the Mohr-Coulomb standard
2. Capacity to take G-γ, h-γ relationship into consideration
3. Employment of the substructure calculation algorithm for time and memory saving purpose (ability to analyze wide area using a generally available PC)
4. Both wide area geology and physical properties per geological attribution can be taken into consideration
3D Analysis Model

- Ground Layer:
  - Kawaguchi L.
  - Shiraiwa L.
  - Wanazu L.
  - Sand silty L.

- Analysis range: 1075 × 1075 m
- Number of nodal points: 9680
- Number of elements: 7396
- Element size: 25 × 25 m

- Depth in m:
  - 0 to 5: subsurface weathered L.
  - 5 to 30: fresh part
  - 30 to 80: fresh part
  - 80 to bottom: fresh part

- Input seismic waveform (for 3D model basement)

- Graphs:
  - Input seismic waveform in EW direction
  - Input seismic waveform in NS direction
3D Dynamic Response Analysis Results
(maximum horizontal acceleration)

Markedly amplified acceleration at topographically sharp area

Hitotsu-minesawa landslide
3D Dynamic Response Analysis Results (maximum shear stress)

Tendency of shear stress increase at the stream area

fractures

cracks

Hitotsu-minesawa landslide
Discussion on the Occurrence mechanism of landslides

1. A large increase of horizontal acceleration at the ridge area
2. Development of inertial force induced by amplified acceleration.
3. A large shear stress at the valley area
4. A highly developed inertial force induces the slip surface formation.

<Additional causing factors>
The ridge protrusion and the slope of the layer point to the same direction.
The both sides of the ridge are open.
Similar case

Togawa landslide:
A rockslide of primary landslide with the Senpoku earthquake

Geology:
Sandstone and mudstone from the Oligocene-Neogene

Senpoku earthquake:
15th March 1914
Magnitude: 7.1
(direct hit earthquake)

Quoted from [Seismic intensity and geomorphological/geological feature of landslides due to earthquakes in the area of Tertiary strata in Japan. (S.Abe et al. Journal of the Japan Landslide Society, Vol.43, No.3, pp.27-34, 2006)]
Conclusion

Occurrence mechanism of rockslide at the time of earthquake:
A highly developed inertial force generating plasticised boundary that promoted the formation of slip slid surface.

▪ Above findings are supported by the evidence found at the subject area.

▪ Some questions on rockslide occurrence mechanism have been answered.

▪ A step nearer to accurately predicting the behavior of slopes at the time of a large-scale earthquake.