Clarification on the Internal Structure of Landslide Dam by Microtremor array survey method

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Landslide dam

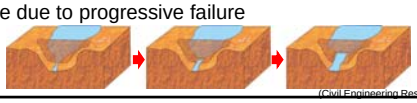
It is formed by backing up river current due to landslide.

Failure factor

①Failure due to overflow erosion

②Failure due to sliding failure

③Failure due to progressive failure



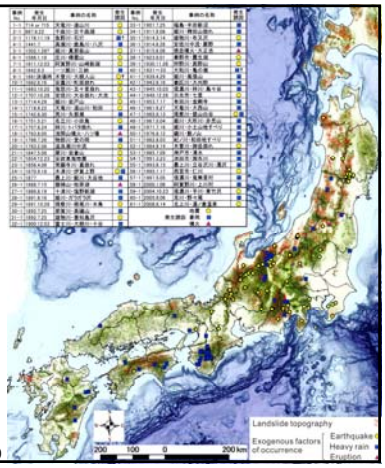
(Civil Engineering Research Institute, 2008)

Natural dams in the world

(Mizuya et al, 2011)

Formation sites of landslide dam in Japan

Formation of landslide dam centers site is related to **topographic** and **geological conditions**, **natural phenomena** (**earthquake**, **heavy rain**, **eruption**).



(Mizuya et al, 2011)

Past study outcome

From the aspect of topography and geology, hydrology, study of landslide dam made progress. Therefore, precision of failure and countermeasure techniques were developed.

Matter of present situation

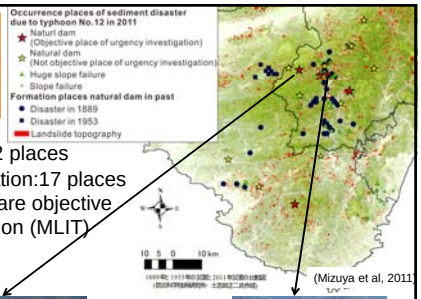
Not understand about the internal structure of landslide dam.

Less-advanced about study of progressive failure that is depended on the internal structure of landslide dam.

Study purpose

Clarify the internal structure of landslide dam using geophysical exploration.

Occurrence distribution of Sediment disaster in Kii peninsular



(Mizuya et al, 2011)

Huge slope failure:32 places
Landslide dam formation:17 places
Five places of those are objective of urgency investigation (MLIT)

Akatani landslide

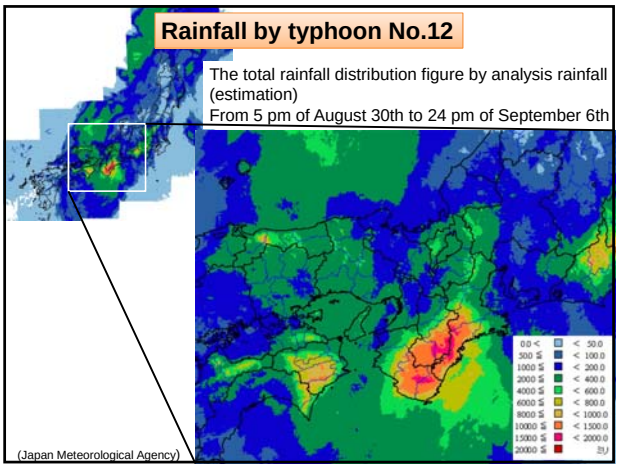
Photographing by Aero Asahi

Kuridaira landslide

Photographing by Aero Asahi

Rainfall by typhoon No.12

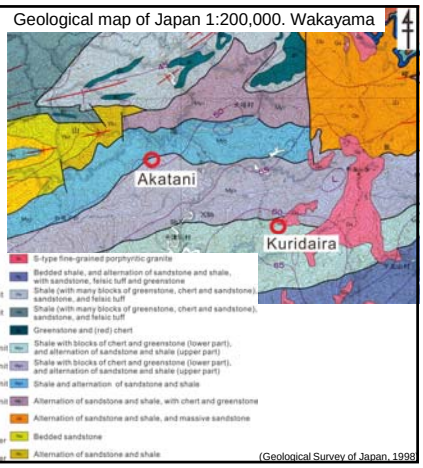
The total rainfall distribution figure by analysis rainfall (estimation)
From 5 pm of August 30th to 24 pm of September 6th



(Japan Meteorological Agency)

Geological map of around study area

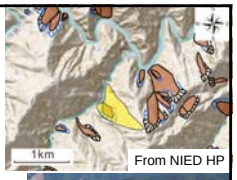
Geological map of Japan 1:200,000. Wakayama



(Geological Survey of Japan, 1998)

Akatani landslide

Failure scale
Slope length: Approx 1,030m
Width: Approx 420m
Relative elevation: Approx 610m

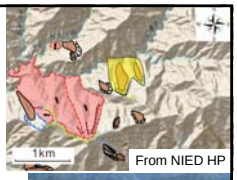


From NIED HP

Landslide dam
Height: 85m
Flood volume of full capacity: 5500,000m³
Sediment volume: 9000,000m³

Kuridaira landslide

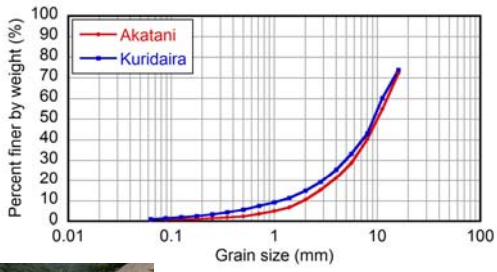
Failure scale
Slope length: Approx 850m
Width: Approx 600m
Relative elevation: Approx 460m



From NIED HP

Landslide dam
Height: 100m
Flood volume of full capacity: 7500,000m³
Sediment volume: 13900,000m³

Grain size distribution of materials from dam body



	D_{10}	D_{30}	D_{60}	U_c	U_c'
Akatani	1.87	6.27	13.47	7.20	1.56
Kuridaira	1.11	5.29	14.15	12.70	1.78

Conducted geophysical exploration on investigation area

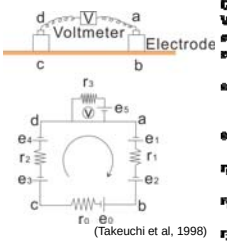
Self-potential method
It can figure out subsurface characteristic by measuring electrical potential that occur as natural phenomenon.

Feature: Easy to use and inexpensive price, not affected by season.

Microtremor array survey (Chain array survey)
It can estimate subsurface structure of ground by extracting surface wave from micromotion of ground surface.

Feature: Easy to measure, not damaged ground

Self-potential method



(Takeuchi et al, 1998)

Measuring system
V: Voltmeter a-b, d-c : Electrode
Circuit model
V: Ground potential
e_0: Ground potential
e_1, e_2: Each electrode potential difference
e_3, e_4: Each contact potential difference with ground of electrode
e_5: Internal potential difference of voltmeter
r_0: Resistance of electrode contact
r_1, r_2: Each internal resistance of electrode
r_3: Impedance of voltmeter

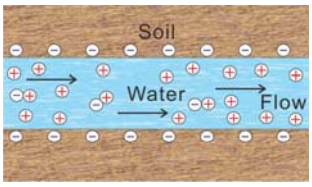
V = ① Internal potential difference of voltmeter(e_5)
+ ②Potential difference between a pair of electrodes ($-e_1 + e_4$)
+ ③Each contact potential difference with ground of electrode
$\{(a-b) = -e_3,\ (c-d) = +e_3\}$
+ ④Potential difference of ground between two electrodes ($b - c = e_0$)

$e_1 = e_4,\ e_2 = e_3,\ r_1 = r_2,\ e_5 = 0$

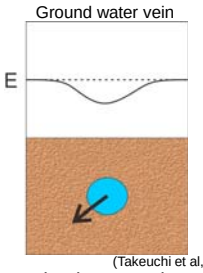
Potential difference : $V = e_0$

Occurrence of streaming potential by ground water flow

Model of electric double layer



Ground water vein

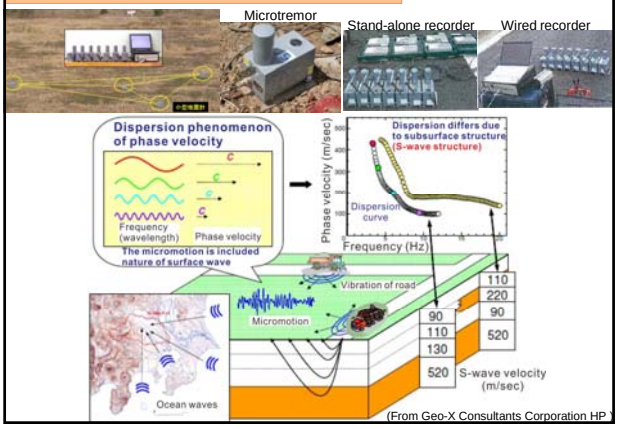


(Takeuchi et al, 1998)

Potential difference occur by negative electric charge of soil and positive electric charge of water in interfacial surface between soil and water.

Area having negative electric charge is obtained due to ground water takes out positive electric charge from surrounding soil.

Microtremor array survey method



(From Geo-X Consultants Corporation HP)

Theoretical concept of spatial auto correlation method

i) **Correlativity between center point and circle point**

$$\gamma_{xy}(f,0;r) = \frac{\mathrm{Re}\left[S_{xy}(f,\theta;r)\right]}{\sqrt{S_x(f)\cdot S_y(f,\theta;r)}}$$

$\gamma_{xy}(f,\theta;r)$: complex coherence function real part
$S_x(f)$: Power spectrum of observation waveform in center
$S_y(f,\theta;r)$: Power spectrum of observation waveform in circle point
$S_{xy}(f,\theta;r)$: Cross power spectrum of observation waveform between two points

ii) **Correlativity of all circumferences orientation average**

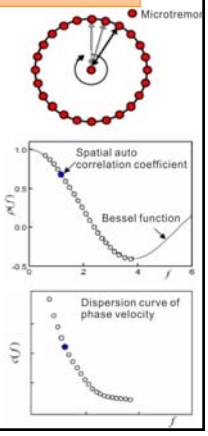
$$\rho(f) = \frac{1}{2\pi}\int_0^{2\pi} \gamma_{xy}(f,\theta;r)\,d\theta = J_0(2\pi f r/c(f))$$

<Bessel function of the first kind zero-order >

$\rho(f)$: Spatial auto correlation coefficient
r: Radius
f: Frequency
$c(f)$: Phase velocity

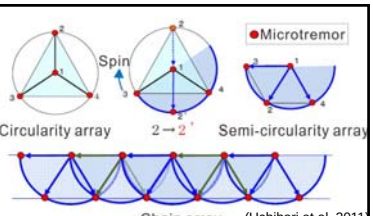
iii) **Compute of phase velocity from inverse function of Bessel function**

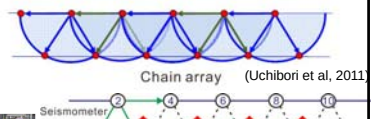
$$c(f) = 2\pi f r / J_0^{-1}(\rho(f))$$



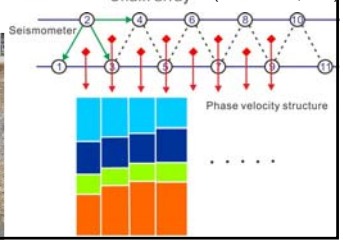
Chain array survey

Microtremor placement on SPAC method can set up linear arrangement by making replacement to semi-circularity, get **the phase velocity section** from dispersion curve.

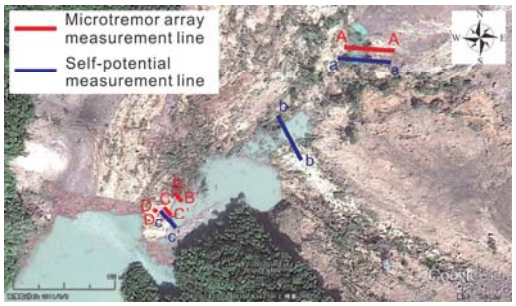




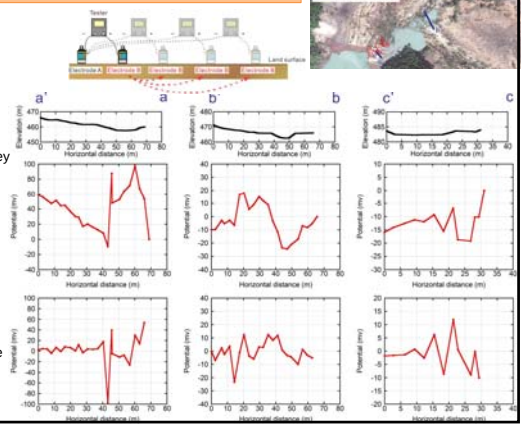
(Uchibori et al, 2011)



Geophysical exploration loci on Akatani landslide



SP method result on Akatani landslide



Upper figure: Topography cross section figure of survey line

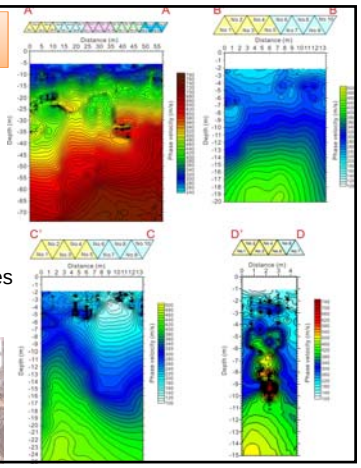
Middle figure: Potential cumulative curve figure

Lower figure: Potential gradient curve figure

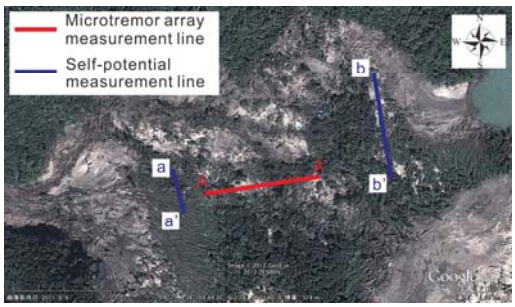
Chain array survey result on Akatani landslide

Placement spacing of microtremor
AA' survey line: 3m
BB' survey line: 3m
CC' survey line: 3m
DD' survey line: 1.5m

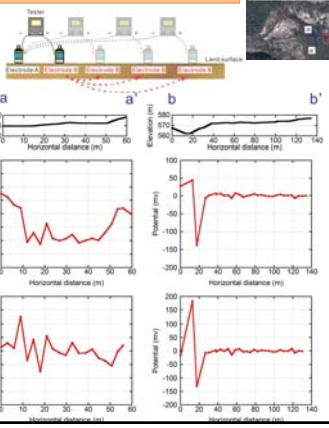
Observation time: 15 minutes



Geophysical exploration loci on Kuridaira landslide



SP method result on Kuridaira landslide



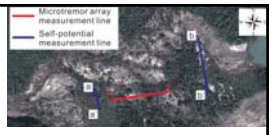
Upper figure: Topography cross section figure of survey line

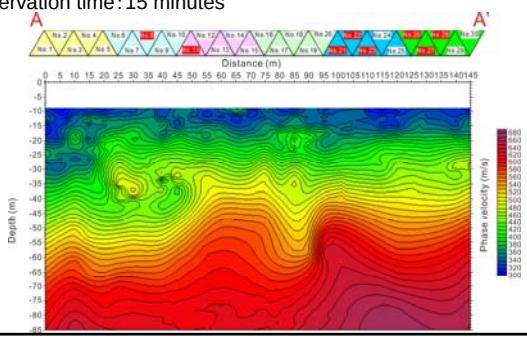
Middle figure: Potential cumulative curve figure

Lower figure: Potential gradient curve figure

Chain array survey result on Kuridaira landslide

Placement spacing of microtremor
AA'survey line: 10m
Observation time: 15 minutes





Conclusion

Conclusion of Akatani landslide dam

- **There are changing sites of streaming potential, then it can presume that those sites are ground water vein from lake.**
- **Surface layer of dam is soft layer and high void ratio. Layer thickness of dam internal is not showed uniformity, was deposited as disturbance state.**

Conclusion of Kuridaira landslide dam

- **Changing sites of streaming potential was measured near drainage during construction.**
- **Surface layer of dam is soft layer and high void ratio. Dip angle is gradual, dip direction trended downstream.**

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