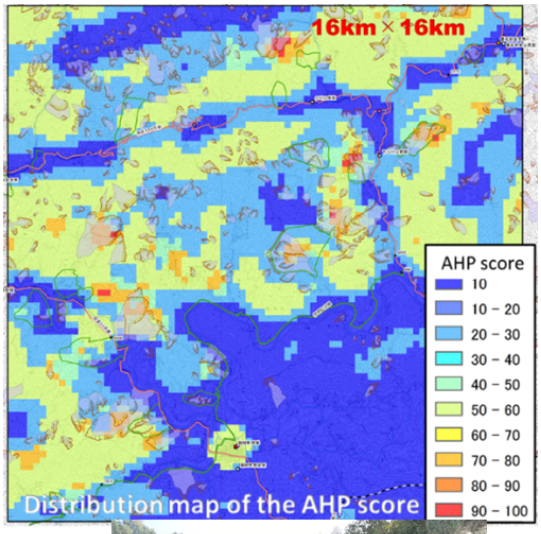
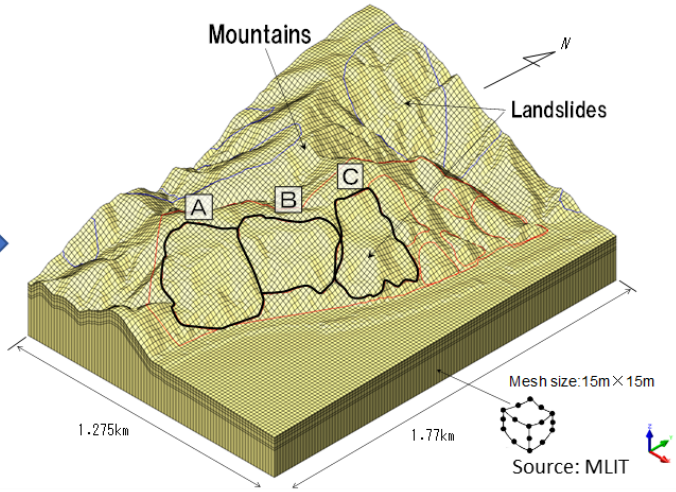
NIPPON KOEI

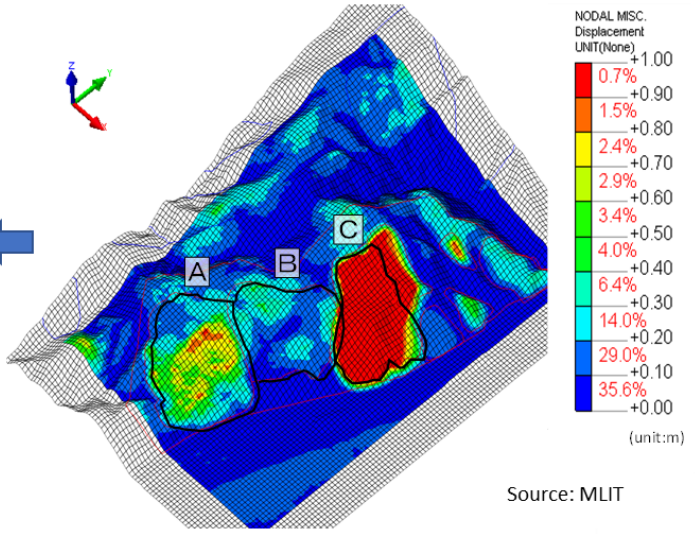
Prediction technology for slope behavior during earthquakes using numerical analysis

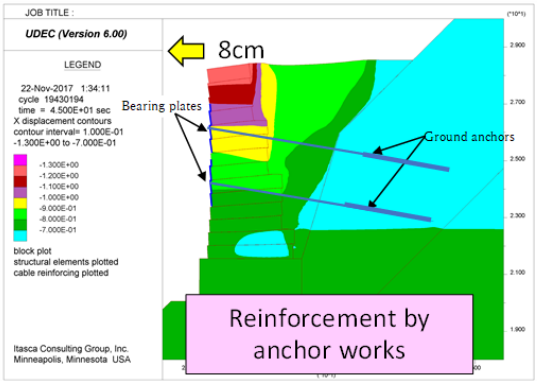
Determination of the effectiveness of countermeasure construction considering earthquakes











Note: The color does not indicate safety, but the relative displacement during an earthquake.

Hazard

Earthquake Land Slide

Solution Purpose

Prevention & Mitigation Response Recovery

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Solution Theme

Research & Investigation Risk Assessment Infrastructure Technology Building Technology

Technology Subject

Technical Research & Development Hazard Identification Hazard Simulation Impact & Damage Simulation Road Facility for Disaster Prevention Emergency Base & Back-up Facility

Advantages

In order to reduce slope disasters during an earthquake, it is necessary to extract dangerous slopes in advance and take both soft and hard measures. This technology first extracts relatively dangerous areas in a wide area by Analytic Hierarchical Process（AHP） analysis. Next, it is a technology to predict the slope behavior at the time of an earthquake at a place judged to be dangerous by three-dimensional numerical analysis. Furthermore, it is possible to evaluate the effect of hard measures on individual slopes against earthquakes.

Solution Illustrated

Background

In addition to direct human damage caused by landslides slope disasters during an earthquake cause enormous damage such as the formation of natural dams due to landslides, flooding due to the subsequent collapse of natural dams, and long-term road closures. Both software and hardware measures are required to reduce damage, but it is necessary to take measures efficiently with a limited budget.

Exposition of the Solution

AHP is a method to support decision-making by providing evaluation indices which are computed by simulating the experts' evaluation processes. AHP software has been developed to obtain the areal hazard distribution of earthquake-induced landslides. We have calibrated and applied the software to extract hazardous slopes by layering and quantifying the judgment process of experts based on topography, geology, and seismic motion factors related to earthquake-induced landslides.
For example, when explaining topographical factors, landslides tend to occur during an earthquake in places where the vertical profile of the slope is convex and the relative height of the mountains is large (Fig.2). Therefore, factors such as topography, geology, and earthquake motion are ranked, and the points for each factor are added to calculate the risk evaluation score.　Then, the hazard map shown in the distribution map based on the evaluation points is created.

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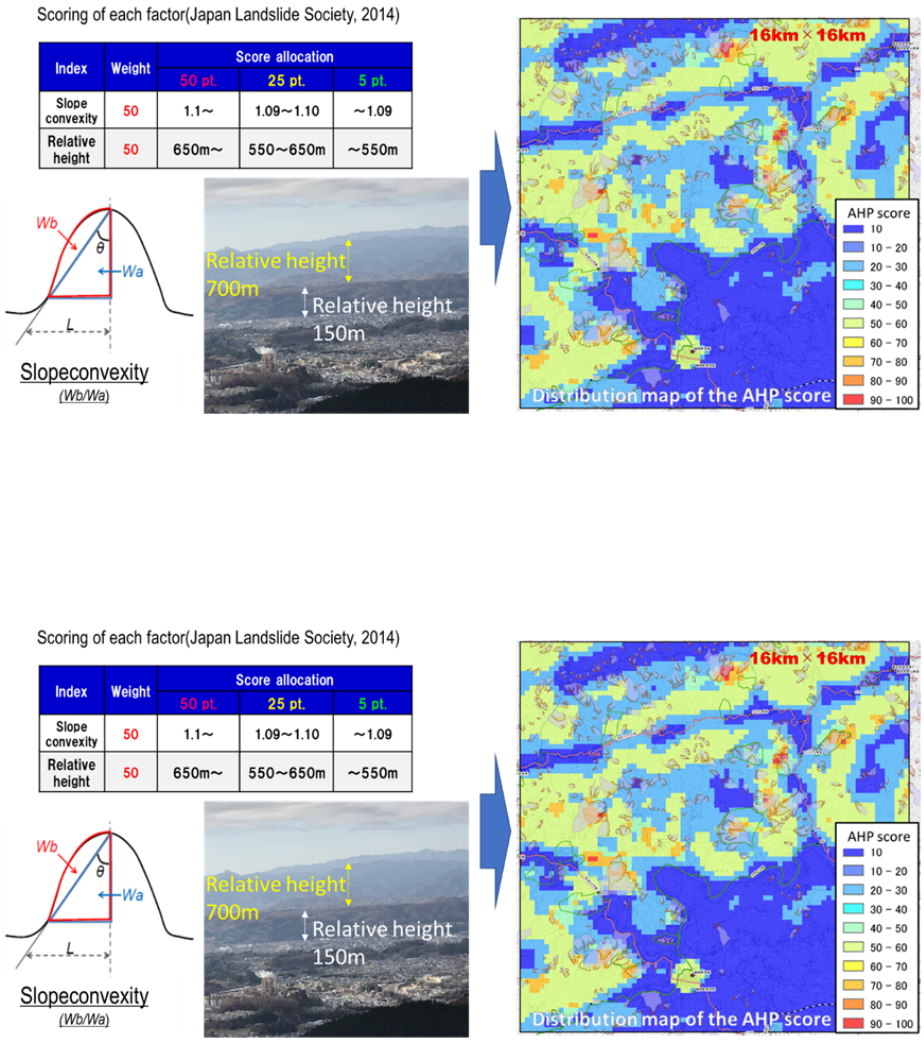

Scoring of each factor(Japan Landslide Society, 2014)
Index
Weight
Score allocation
50 pt.
25 pt.
5 pt.
Slope convexity
50
1.1~
1.09~1.10
~1.09
Relative height
50
650m~
550~650m
~550m
Wb
θ
Wa
L
Slopeconvexity
(Wb/Wa)
Relative height
700m
Relative height
150m
16km × 16km
AHP score
10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
Distribution map of the AHP score

Fig.2 AHP scoring of topographical factors

In the past, hazard mapping required the advanced know-how and time of experienced specialists, but this technology has made it possible to extract dangerous slopes objectively and in a short time.

Next, we will evaluate the slope behavior during an earthquake in detail using numerical analysis for the areas evaluated by AHP as having a relatively high risk of slope disasters. Using the geological classification based on the geological and soil survey and the physical characteristics of the ground including landslides, we calculated which slope would become unstable in the event of an assumed seismic motion for an area of approximately 2 km2 (Fig.3) .

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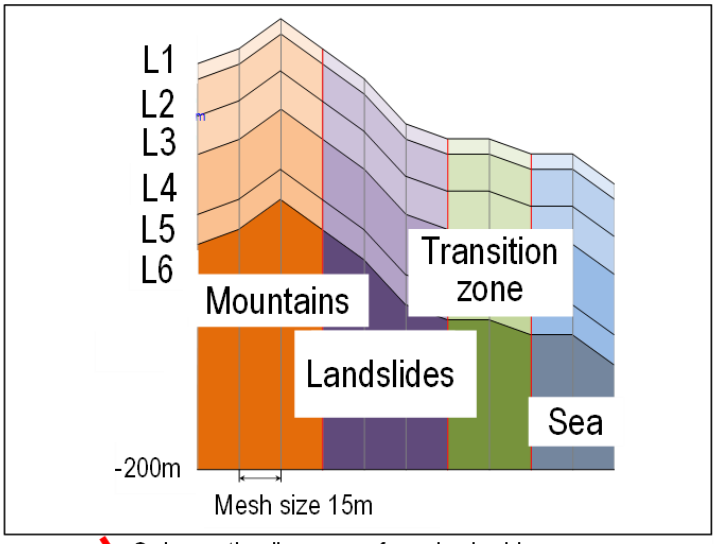
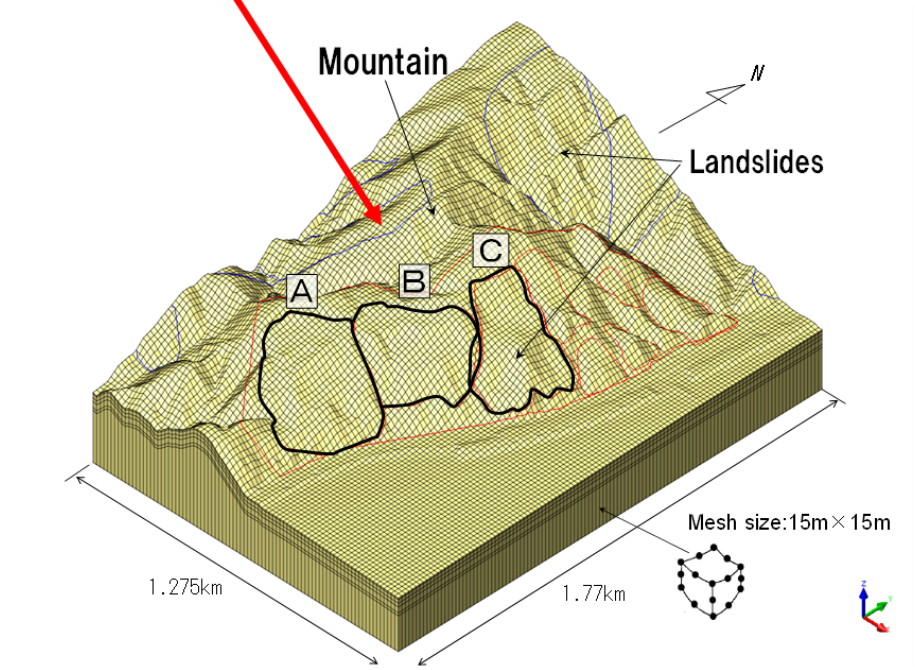


Schematic diagram of geological layers



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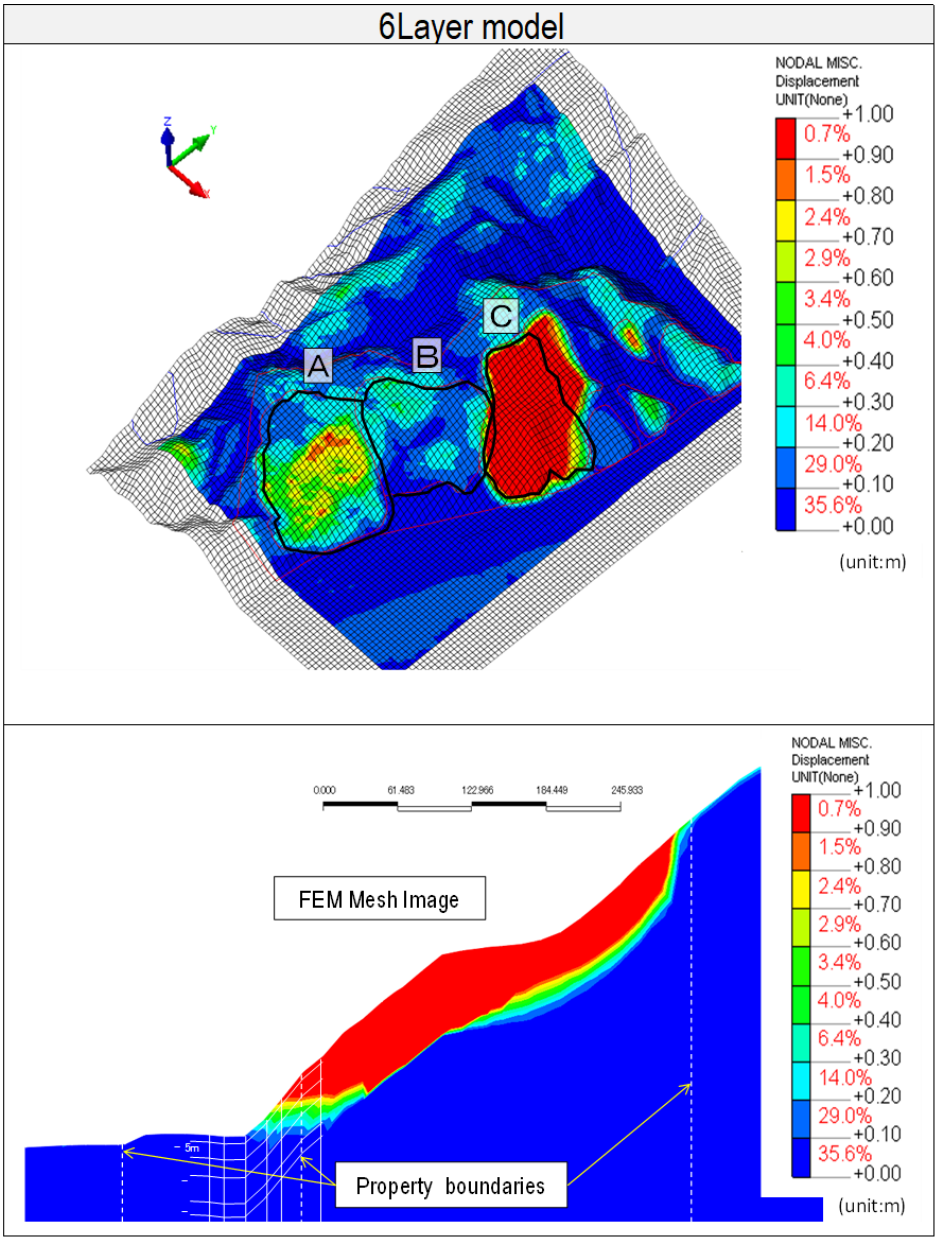

Fig.3 Bird's-eye view and cross-sectional view of residual displacement distribution by numerical analysis　Source:MLIT

As shown in the figure, the displacement of the ground differs depending on the flat location and depth, so a range with a large swing width and a relatively high risk is extracted.

We conducted a two-dimensional seismic response analysis on the anchor work constructed as a reinforcement measure for the Gabion retaining wall damaged by the 2015 Gorkha earthquake in Nepal and verified the effect of the anchor on the earthquake (Fig.4).

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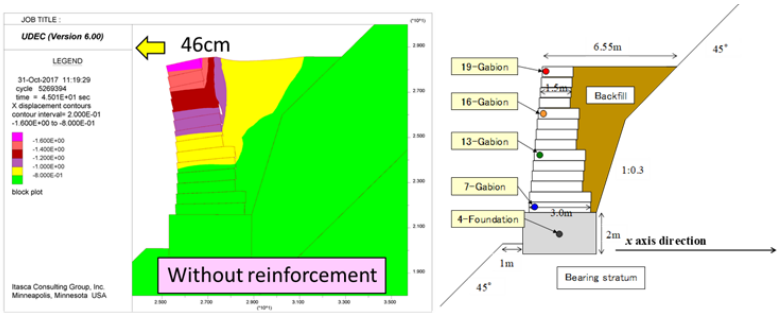
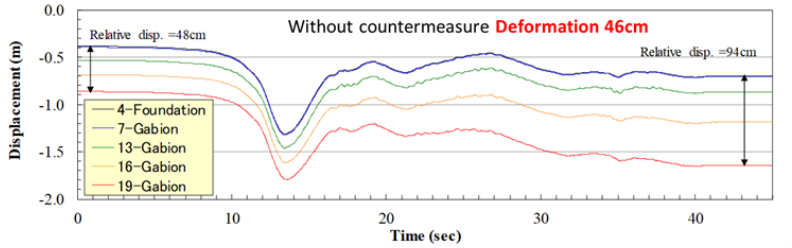
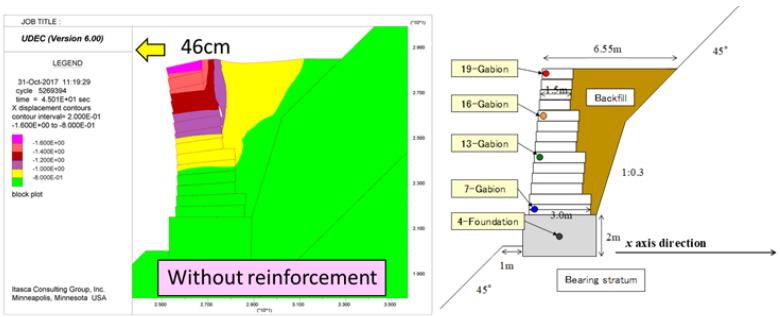


Deformation with x-displacement contours

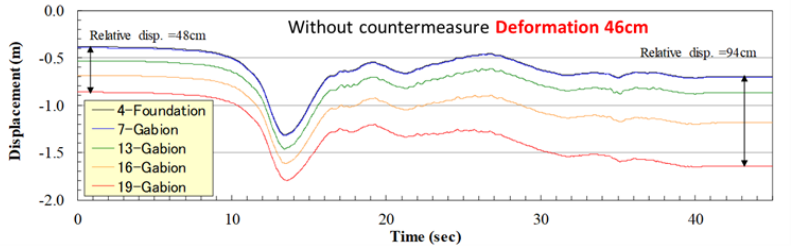


Displacement vs time

Appraisal of countermeasure design without Anchor works



Deformation with x-displacement contours



Displacement vs time

Appraisal of countermeasure design without Anchor works

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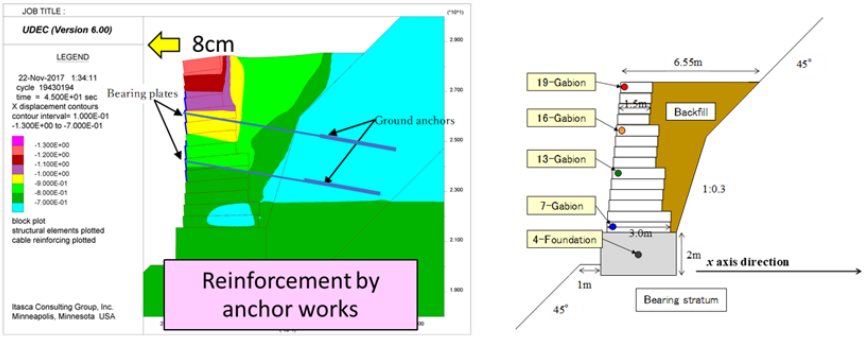
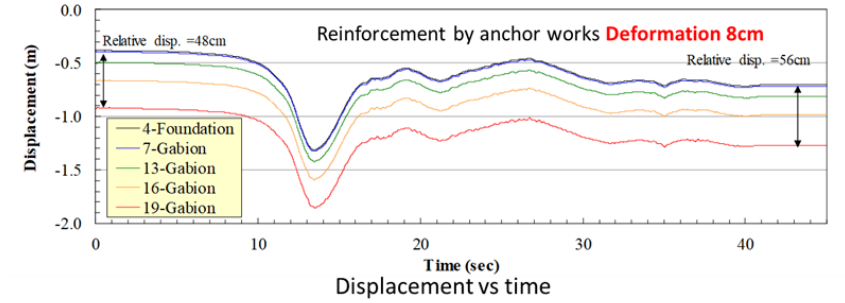


Deformation with x-displacement contours



Displacement vs time

Appraisal of countermeasure design with Anchor works

Fig.4 Reinforcement effect of anchor works predicted by two-dimensional seismic response analysis

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Achievements of Examples

・Risk assessment of road slopes destabilized by earthquakes
・Judgment of the effect of countermeasures such as anchor works and steel pile works etc. against collapses and landslides during an earthquake

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