地震による雪崩発生リスク評価技術に関する研究

A Study on Technologies for Assessment of Earthquake-Induced Avalanche Likelihood

積雪期に大規模な地震が発生した場合、雪崩などの複合災害に伴う道路閉鎖などによって、災害状況の把握や復旧作業、警戒避難に遅れが生じることが危惧されます。しかし、地震による雪崩の発生機構について不明な点が多く、積雪期に地震が発生した場合の防災計画や雪崩対策の判断を行う上で、地震時の雪崩発生リスクを評価する技術が必要となっています。

このため寒地土木研究所では、地震による雪崩発生リスク評価技術に関する研究に取り組んでいます。

In the event of a large-scale earthquake during the snowcover period, it is feared that assessment of the situation, recovery work, and precautionary evacuation would be delayed by road closures because of complex factors in these disasters, including avalanches triggered by the earthquake. Technologies for assessing the likelihood of avalanche occurrence at the time of earthquake are necessary for decision-making in disaster prevention planning and for the development of avalanche countermeasures; however, the occurrence mechanisms of earthquake-induced avalanches have not been fully clarified.
To respond to the needs of society, the Civil Engineering Research Institute for Cold Region has been pursuing research on assessing the likelihood of earthquake-induced avalanches.

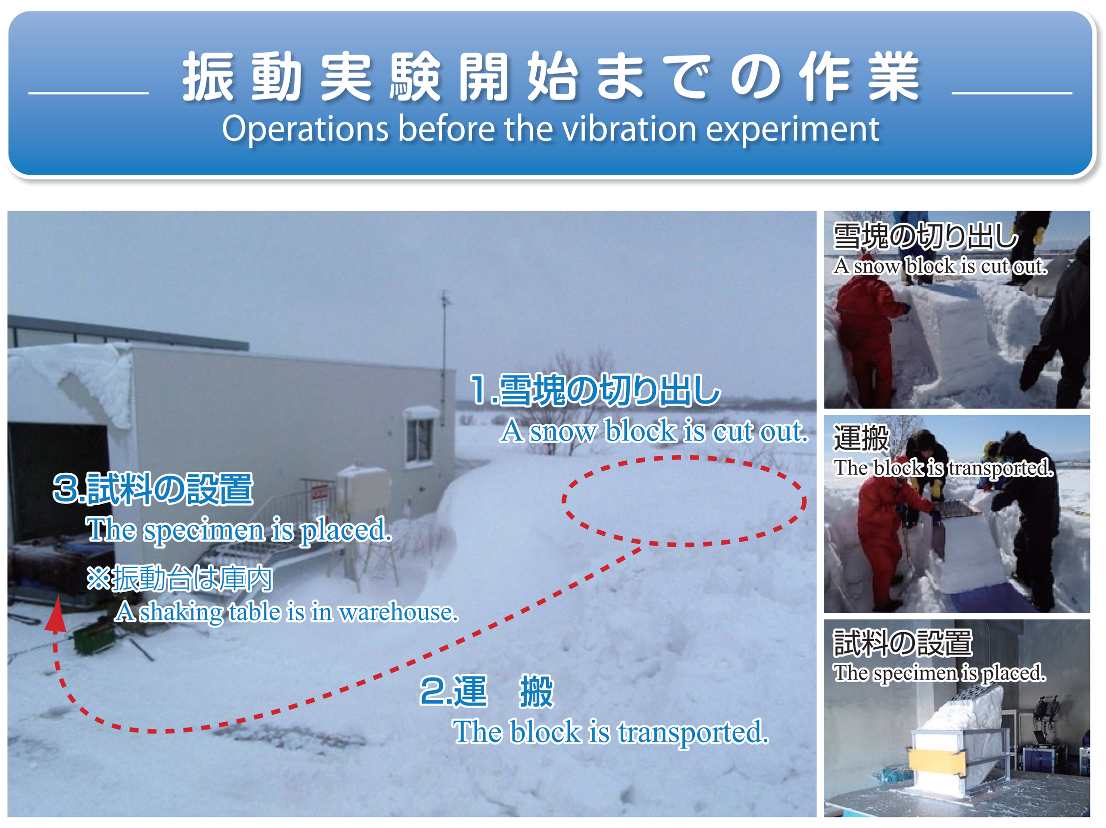
▲地震による雪崩の発生事例
Site of an earthquake-induced avalanche

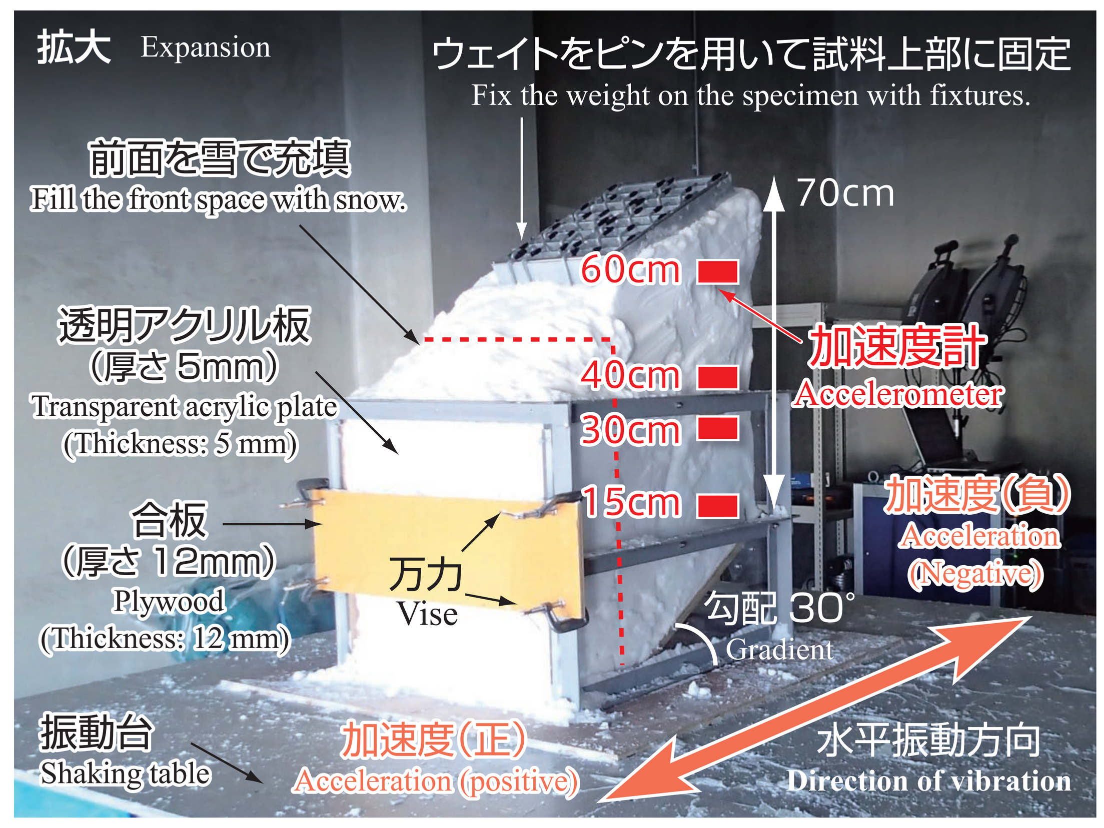
振動実験に基づく斜面積雪の地震応答

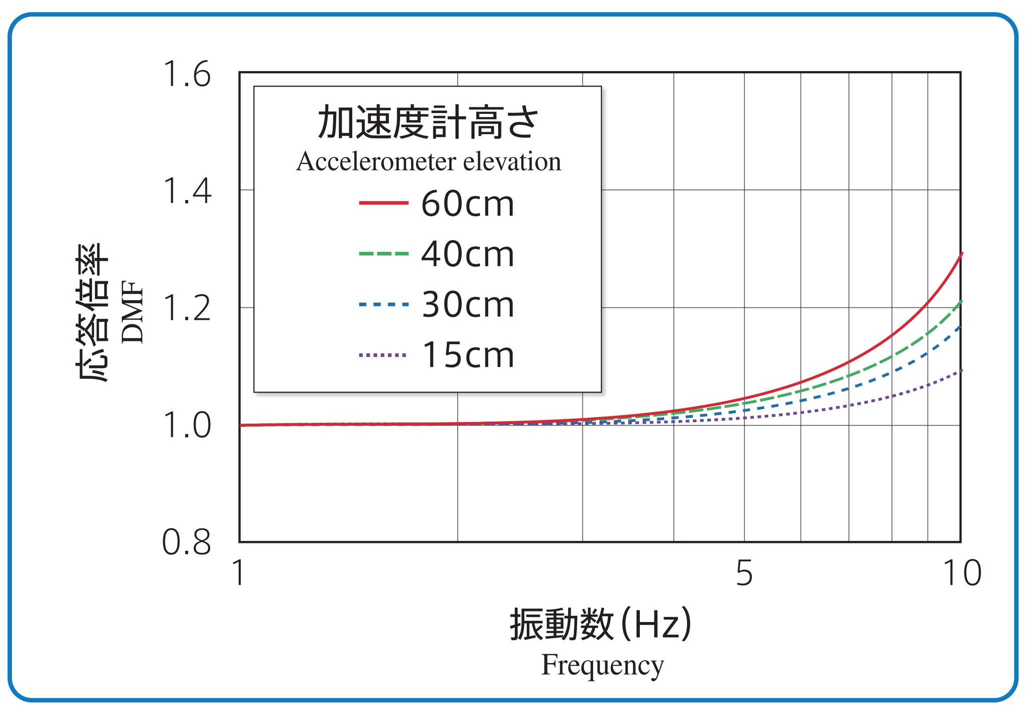
Seismic responses of snowpack on a slope in a vibration experiment

地震動に対する斜面積雪の応答を把握するために、振動実験を行いました。試料を水平方向かつ周波数1～10Hzに変化させながら加振しました。その結果、斜面積雪の応答倍率は、周期が短いほど、また積雪底面からの高さが大きいほど大きくなること、ざらめ雪の方がしまり雪よりも大きく、湿雪の方が乾雪より大きいことがわかりました。

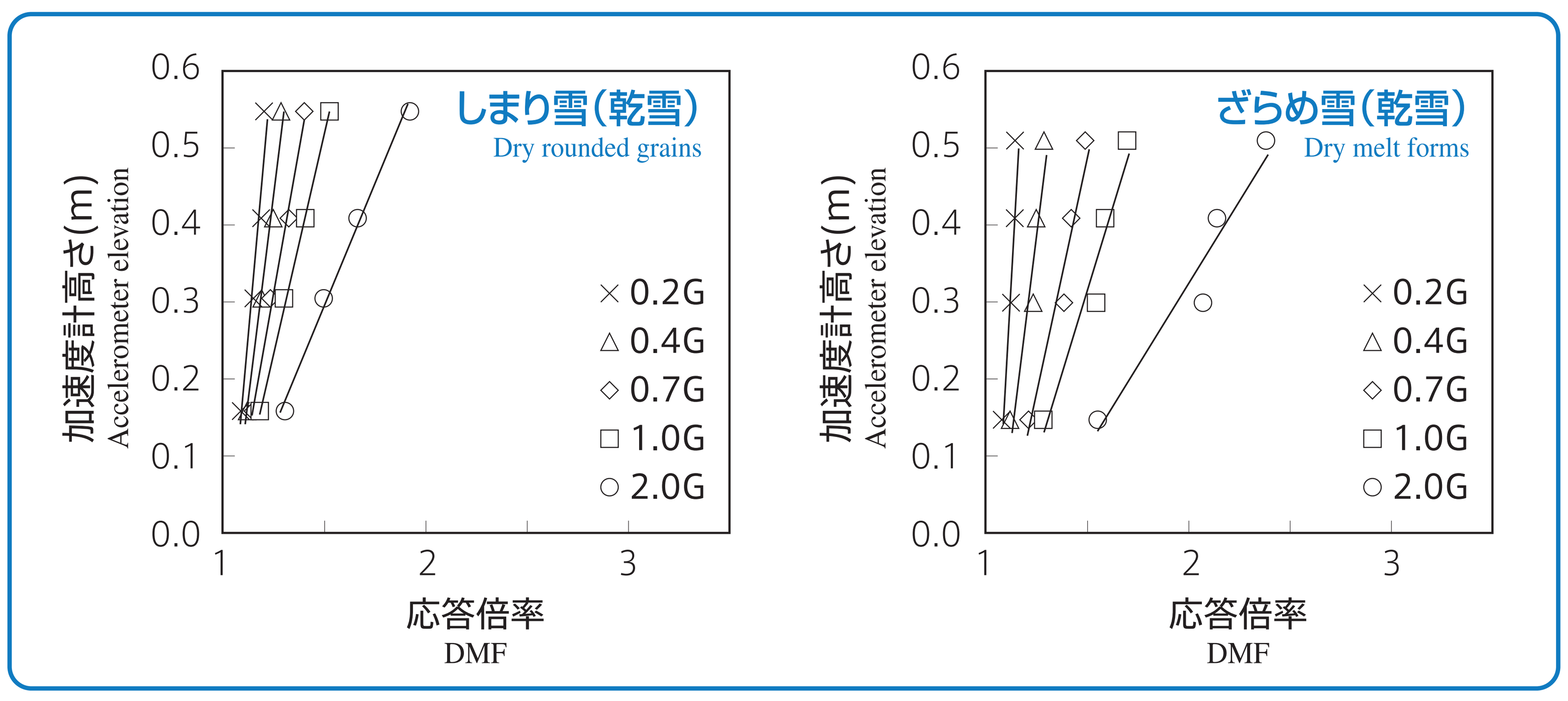
A vibration experiment was conducted to understand the seismic response of the snowpack on a slope. The experiment was conducted by accelerating the specimen in the horizontal direction and varying the frequency in the range of 1 to 10 Hz. The experiment clarified the following: the shorter was the frequency and the higher was the location in the snowpack from the bottom, the greater was the DMF; the DMF was greater for melt forms than for rounded grains; and the DMF was greater for wet snow than for dry snow.







▲応答倍率と振動数の関係(例)
DMF vs. frequency (example)



▲斜面積雪の高さと応答倍率との関係(10Hz)
Relationship between the height of snowpack on the slope and the DMF (10Hz)

地震による雪崩発生評価技術の提案

Suggested Technologies for Assessment of Earthquake-Induced Avalanche Likelihood

振動実験の結果を用いて、積雪の安定度に基づく地震による雪崩発生危険度を推定する手法を提案しました。

Based on the vibration experiment results, we proposed a method for estimating the likelihood of earthquake-induced avalanches by using the stability of snow cover.

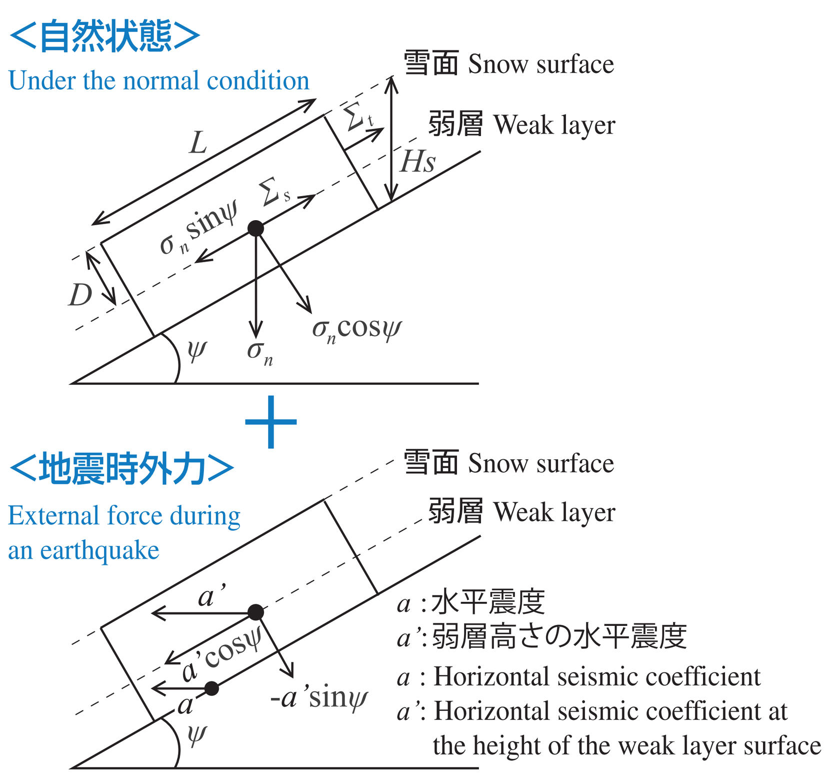
■地震動を考慮した斜面積雪の安定度SI_E'

Stability of the snowpack on the slope considering seismic motion SI_E'

(SI_E'<1.5で雪崩発生危険度が高くなる)
(The avalanche occurrence likelihood is high when SI_E'<1.5.)

$$SI_E' = \frac{CL + \sigma_n L(\cos\psi - a'\sin\psi)\tan\phi + \Sigma_t D}{\sigma_n L(\sin\psi + a'\cos\psi)}$$

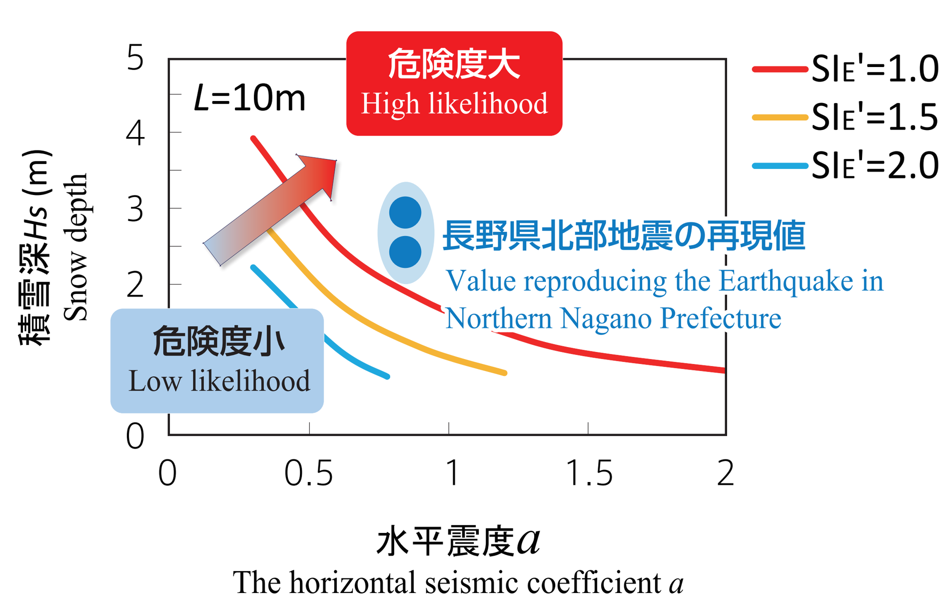
・弱層における積雪粒子の凝集力C	Cohesive force between snow particles in the weak layer: C
・斜面積雪の長さL	Length of snowpack on the slope: L
・単位面積あたりの弱層より上部の積雪荷重σn	Unit area snow load on the weak layer: σn
・斜面勾配ψ	Slope gradient: ψ
・弱層高さの水平震度a'(振動実験の結果)	Horizontal seismic coefficient at the height of the weak layer surface (result of the vibration experiment): a'
・弱層の内部摩擦係数$\tan\phi$	Internal friction coefficient of the weak layer: $\tan\varphi$
・斜面積雪上部に作用した雪粒子の結合による張力Σt(引張破壊強度)	Tensile force from binding between snow particles, which acts in the upper part of the snowpack on the slope: Σt (tensile fracture strength)



▲水平震度a:重力加速度g(gal)に対する地震動の水平加速度(gal)の比
The horizontal seismic coefficient a:
The ratio of horizontal acceleration of seismic motion (gal) to gravitational acceleration (gal)

■しまり雪(乾雪)での表層雪崩発生を想定した例

An example assuming a surface avalanche of dry rounded grains



▲積雪深Hsと地震動の水平震度aによる試算結果
The result of a trial calculation by using the snow depth Hs and the horizontal seismic coefficient a

<条件>
- ・斜面長L:10m
- ・地震周波数:10Hz
- ・斜面勾配Ψ:40°
- ・弱層より上部の積雪の厚さD: 0.6m
- ・弱層:こしもざらめ雪

Conditions
- Slope length L: 10 m
- Earthquake frequency: 10 Hz
- Slope gradient ψ: 40°
- Thickness of the snow layer above the weak layer D: 0.6 m
- Weak layer: faceted crystals