The Expressway Control with the utilization of the Intelligent Avalanche Information System (IAS)

Gestion de l'autoroute qui utilise« Système de gestion de l'information d'avalanche avancée

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ABSTRACT

The National Research Institute for Earth Science and Disaster Prevention (The Independent Administrative Institution) is developing the "Avalanche Monitoring & Prediction System" with the "Avalanche Real-time Hazard Map," which predicts and displays the runout zone of avalanche with the combination of the "Avalanche Risk Prediction Model," which calculates the predicted weak layers of snow and the risk of avalanche for a wide area, and the "The Avalanche Dynamic Analysis Model."

After the suspension of traffic because of the risk of avalanche, which occurred in the Gassan IC on the YAMAGATA Expressway on February 27, 2011, The Tohoku Regional Head Office, The East Nippon Expressway Company Limited created the "Intelligent Avalanche Information System" in cooperation with the National Research Institute for Earth Science and Disaster Prevention (Independent Administrative Institution) and avalanche experts. The Tohoku Regional Head Office conducts observations of avalanches on the inclined plane by the expressway by applying the analysis results of the "Avalanche Monitoring & Prediction System" for their avalanche patrol and this is very

effective in expressway management during winter.

Résumé

L'Institut national de recherche pour la Science la Technologie et la prévention des catastrophes travaille sur le développement du « Système de la vigilance et prévision d'avalanche » par « Modèle de la prévision de risque d'avalanche » qui calcule globalement le risque de la couche faible et d'avalanche quand il neige, et aussi « Carte du risque avalanche en temps réel » (RTHM en anglais) qui prévoit et affiche la zone d'arrivée de l'avalanche, combiné avec « Modèle d'analyse du mouvement d'avalanche ».

A l'occasion de la suspension du trafic en raison du risque d'avalanche le 27 Février 2011, survenu à l'autoroute Yamagata et l'échangeur autoroutier de Gassan, la succursale de Tohoku de Nippon Oriental Autoroutière S.A. travaille en coopération avec l'Institut national de recherche pour la Science la Technologie et la prévention des catastrophes et les experts d'avalanches, construisent le « Système de gestion de l'information d'avalanche avancée », qui effectue la surveillance d'avalanche de la pente à côté de l'autoroute en utilisant le résultat de l'analyse de la « surveillance des avalanches et le système de prédiction" a la patrouille d'avalanche et il est très efficace dans la gestion de la autoroute pendant l'hiver.

1. THE EXPRESSWAY NETWORK IN JAPAN AND THE WEATHER IN WINTER

1.1 The Location of the Tohoku Region / The geographical features and the expressway network

Most Japan is located in a temperate zone. Japan has four large islands; Hokkaido, Honshu, Shikoku, and Kyushu. The Tohoku Region is located on the north end of the Honshu Island, which is the largest one of the four. It is situated at lat. 41-36 degrees N. There is the OHU Mountain-chain (Elevation: 1000m – 2000m) running from north to south as a mountain ridge in the middle of the region. The east side of the Tohoku Region faces the Pacific Ocean, and the west side faces to the Japan Sea.

Japan has National Expressway Development Plans for 14,000km. 10,232km out of the 14,000km has already been opened. The NEXCO East manages the highway network for 3,600km in the Northern East of Japan. The Tohoku Region has an Expressway Network Plan totalling 2,204km in length. As of March 2009, 1400km of the expressway has been already opened. The expressway network connects many cities, which are dotted from the coastal areas to the basins, such as Sendai, the largest city (population 1 million), 7 mid-sized cities with population averaging 300,000 people, and 12 cities population averages of about 100,000 – 200,000 people.

The NEXCO East operates a section for 1,266km, which has comparatively heavy traffic, as a toll way. There are 15 management offices along the expressway and they conduct maintenance work and toll collection work.

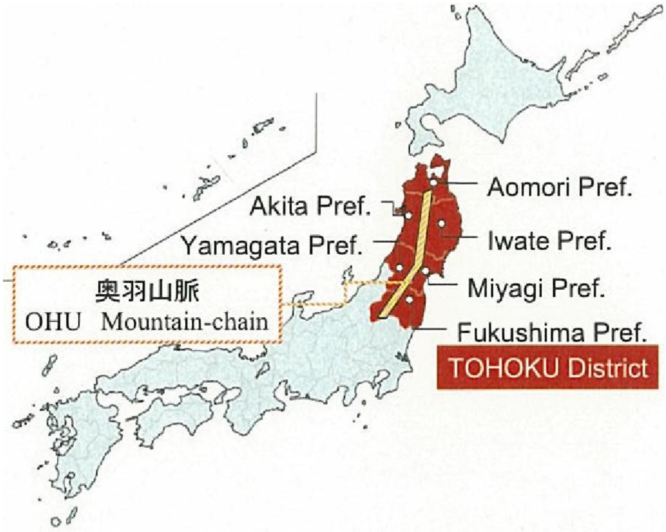


Figure 1-The location of the Tohoku Region

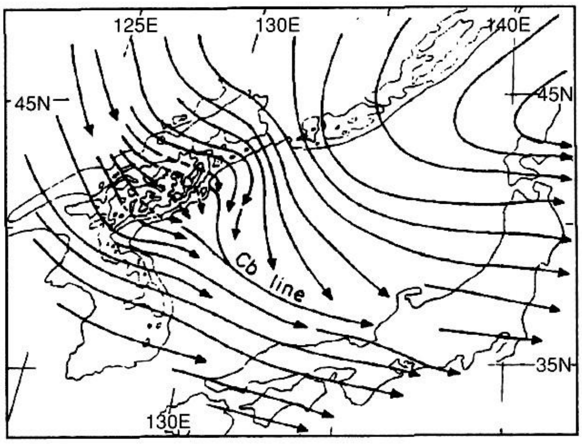
Figure 2- The Expressway Network

1.2 The Expressway in winter in Japan/the Tohoku Region

Japan is part of the temperate zone monsoon. The Tohoku Region is in the cool temperate zone, which has four distinct seasons with heavy rainfall. The region is covered with a cold air mass for a long term. The winter is from November to March, and January to February is the coldest period.

During winter, it can be measured with an atmospheric pressure chart pattern typical of winter, which means there are Siberian and Chinese continental anticyclones on the west side of Japan and there is a low pressure area in the Pacific Ocean on the east side of Japan. In this pressure pattern, the cold air, which comes from the Siberia and Chinese continent, absorbs a lot of vapor when it goes through the warm area over the Japan Sea, and hits the OHU mountain-chain to bring a lot of snow in the OHU mountain area and the west foot of the mountains.

Since the YAMAGATA Expressway and the KAN-ETSU Expressway run in the North-East part of Honshu, which has especially heavy snowfall, the annual snowfall reaches 6m to 12m and the expressways always have the risk of avalanche and snowslide. Therefore, the NEXCO East positioned various avalanche prevention facilities to control the occurrence of an avalanche. They also conduct a daily road patrol to check indications of avalanche or snowslide, and make pockets for deposited avalanche snow or remove snow as necessary.



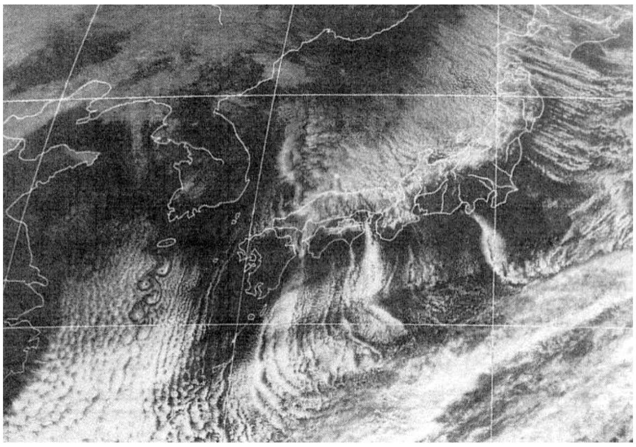


Figure 3- A Schema of the typical winter airflow

Figure4- A picture from the weather satellite/ the winter cirrus clouds

The 2 figures above are reprinted from "Weather in Japan, vol.1," (Masatoshi YOSHINO, Ninomiya Shoten)

2. SUSPENSION OF TRAFFIC FOR AVALANCHES ON THE EXPRESSWAY AND OTHER PROBLEMS

In the winter in 2010 – 2011, it snowed almost every day after the Christmas cold snap at the end of December. In February, warm air quickly became stationary over this area and the temperature rose rapidly. It reached 12 degrees Celsius on February 24, which was 3 days prior to the occurrence of the avalanche. In addition to this, since a certain amount of rain, which is about 25mm/hour, had fallen for 2 days over the 2.5m depth of fallen snow, the fallen snow had become very unstable being melted by the infiltration of rainwater and all the layers had become weak layers subject to melting.

Finally, a large-scale all-layer avalanche, which was from 135 m high on a naturally inclined plane from the road surface, occurred on the Gassan road of Route 112 (Tsukiyamazawa, Nishikawa-cho, Nishimurayama-gun, Yamagata prefecture), which the Gassan IC of the YAMAGATA Expressway joins.

A crack was found in the inclined plate of the Gassan IC, which is located near the inclined plate concerned, and there was a risk of avalanche depending on the snowfall and weather conditions. Therefore, from outset of the day, there was no other choice than suspending the traffic not only on Route 112 but also on the YAMAGATA Expressway. It was April 26, when the suspension was lifted after the confirmation of safety. This means the ramp way had been closed for 59 days in a row.

After the avalanche occurred in the inclined plate on Route 112, a snow profile observation was conducted. According to the results of the observation, the depth of snow was 1.9m.

Though the top 10cm from the surface was new snow, the lower was all granular snow (in the form of weak layer). Therefore, temporary avalanche guard measures were taken by placing large-sized sandbags in the ramp part of the Gassan IC against avalanche.

The NEXCO East conducted a daily fixed point observation of the status of the change of the snow on the inclined plate in the Gassan IC of the YAMAGATA Expressway. In addition to this, they set up extensometers on the spots, in which there is the possibility of an avalanche, and continuous real-time measurements of the amount of the moving snow below the crack quantitatively. They set up an automatic e-mail distribution system to alert authorities of the disorder when the amount of the moving snow increased.

Though occurrence and expansion of the cracks and small avalanches which stopped in the middle of the inclined plate were discovered, no avalanche occurred which influenced conditions on the Gassan IC. But some problems were found.

One of those problems is that it was impossible to keep observing the status of the inclined plate when the weather was bad. In this way, the frequency of the observation was very limited and quick measures could not be taken when the avalanche occurred. Also, the snow profile observation on the inclined plate, which has a high risk of avalanche, was very constrained.

Figure 5- Fixed point observation (on Feb.22, 2012)

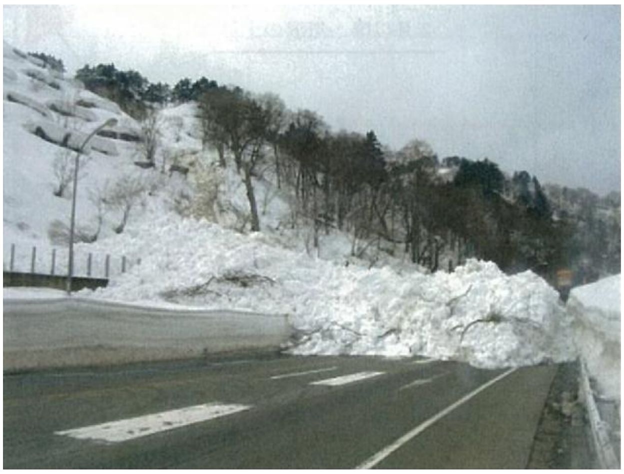


Figure 6- The avalanche on Route 112 which Gassan IC joins

3. THE DEVELOPMENT, UTILIZATION, AND EVALUATION OF THE AVALANCHE MONITORING & PREDICTION STSTEM

3.1 Development of the Avalanche Monitoring & Prediction system

National Research Institute for Earth Science and Disaster Prevention, Snow and Ice Research Center (NIED・SIRC) have been conducting laboratory experiments and field observations for a long time to analyze the mechanism of the generation of avalanche and blowing snow. Based on the records, the Research Center clarifies the relationship between the occurrence of disaster and the weather conditions, such as snowfall, the status of the snow, and temperature, etc. They also develop the" Snow Disaster Forecasting System" (SFDS), such as avalanche and visibility impact because of blowing snow.

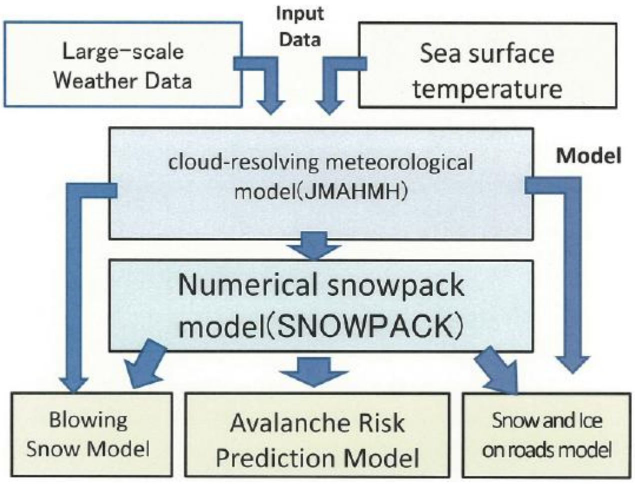


Figure7-Snow disaster forecasting system (SFDS)

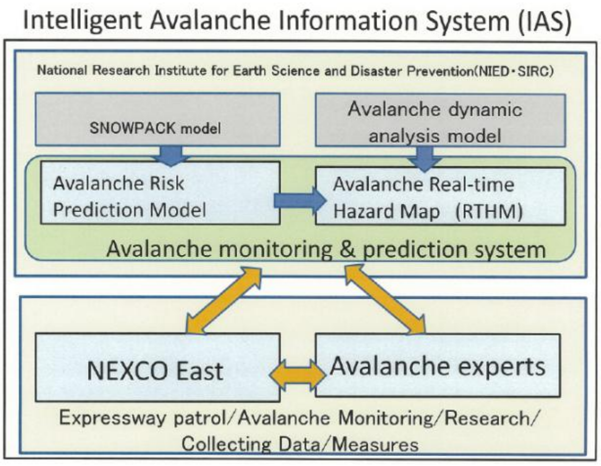


Figure8- Intelligent Avalanche Information System(IAS)

Some numerical models in the vertical uniaxial direction to evaluate the fallen snow status have been developed since the late 1980's mainly by the Swiss Federal Institute for snow and avalanche Research. These numerical models can predict the fallen snow status, such as density, the grain diameter, the snow temperature, etc.

The NIRD・SIRC introduced a numerical snowpack model (SNOWPACK model) (Lehning and Fierz,2008; Lehning et al.,2002), which can express the detailed structure of snow and can predict the status of snow. At the same time, the NIED・SIRC has been researching the status of the Japanese wet type of snow by adding many improvements to the SNOWPACK model to be able to check the formation of a weak layer, the motion of the water from the melted snow, and the water drain at the bottom of the fallen snow, which can be one of the reasons of the avalanche.

Based on these research results, the NIED・SIRC has developed the "Avalanche Monitoring & Prediction System" by using the snow status which is predicted by the SNOWPACK model, adding the "Avalanche Risk Prediction Model," which evaluates or predicts the risk of occurrence of avalanche in inclined plates, and the "Avalanche Real-Time Hazard Map (RTHM)."

That is to say, to predict the risk of the occurrence of an avalanche, you have to combine the weather data (snowfall, temperature, wind direction, wind speed) by every 1.5km square, which were calculated by the “Cloud-Resolving Meteorological Model”(JMANHM)l, with the inclination of the slope and the direction data, which relate to the calculation of the solar radiation, then input these data into the SNOWPACK model to analyze the structure of the fallen snow.

In this way, they developed the “Avalanche Risk Prediction Model,” which can predict accurately the deterioration of the snow, such as shear strength by the change in weather conditions, and then calculate the expected weak layer in the snow and the risk of avalanche for a wide-range.

The risk of the occurrence of an avalanche can be expressed by “The natural snow stability index (SI),” which can be calculated by dividing the shear strength by the shear stress which will occur. It can be said the risk of avalanche is high when the SI is 2 and smaller. By applying the “Avalanche Risk Prediction Model,” the stability of snow (=the risk of avalanche) can be assumed by time and area, without digging the snow.

NIED･SIRC has confirmed the utility of the system by applying it practically in cooperation with the road managers. The prediction results of avalanche risk by the system will be distributed to the road managers through the internet. The multiple spots on the slope for the evaluation will be marked as a map in the picture which will be distributed. If a road manager selects one spot out of the marked ones, the snow condition (the snow grain type, drainage, the accumulated positive temperature) will be displayed.

The Avalanche Risk Prediction Model will predict the change of the structure of the accumulated snow and the snow stability on the targeted slope. And it will display the chronic change of the structure of accumulated snow and the snow stability by color coding on two different charts, which have time for the horizontal axis and the depth of snow for the vertical axis.

Each chart shows the evaluation of the snow condition and the predicted value which was calculated by the Snow Disaster Forecasting System (SDFS).

Also, NIED･SIRC developed the “avalanche real-time hazard map (RTHM),” which can show the estimated damaged area, such as the runout zone of avalanche, with the variables of the depth of snow, the namely reduction coefficient of bottom friction, the internal friction angle / cohesion / density of the accumulated snow, which can be calculated by the combination of the “Avalanche Risk Prediction Model” and the “Avalanche Dynamic Model (Avalanche Dynamic Analysis Model).”

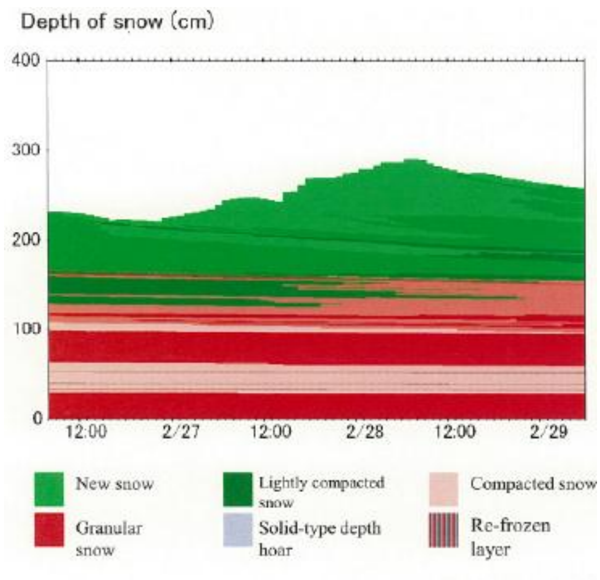


Figure9-The structure of accumulated snow by the prediction system

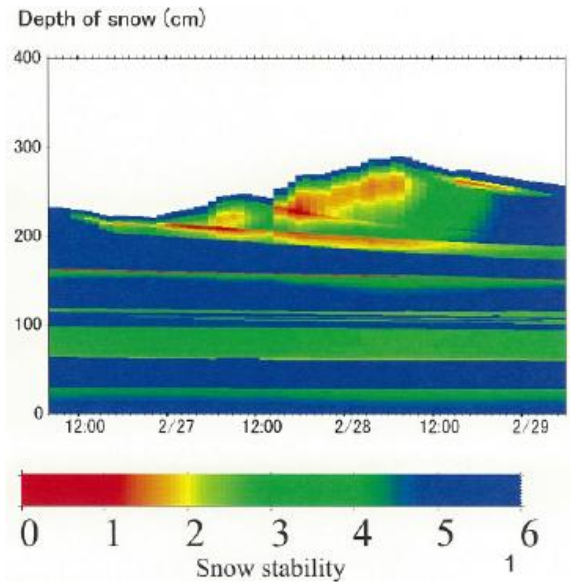


Figure10- The snow stability by the prediction system

3.2 The Utilization and evaluation of the “Avalanche Monitoring & Prediction system”

After the long closed for the risk of avalanche at Gassan IC, NEXCO East makes good use of the prediction information of the occurrence of avalanches for the management of the YAMAGATA Expressway, in cooperation with NIED・SIRC.

We conducted a simulation of the changing status of the quality of the internal accumulated snow with the SNOWPACK by adding the data from the other observation facilities in the neighborhood (temperature, the depth of snow, wind direction, wind speed, etc.) and being retroactive before the occurrence of avalanche.

In addition to this, we conducted research on a section of the accumulated snow on the next day of avalanche. The results of the simulation matched the results of the accumulated snow section research, because almost all the layers had turned into “granular snow” and had become very weak snow layers. In this way, we verified the as to how the stable snow without a lower layer became a weak layer right before the occurrence of avalanche because of the temperature rise and the rain in February.

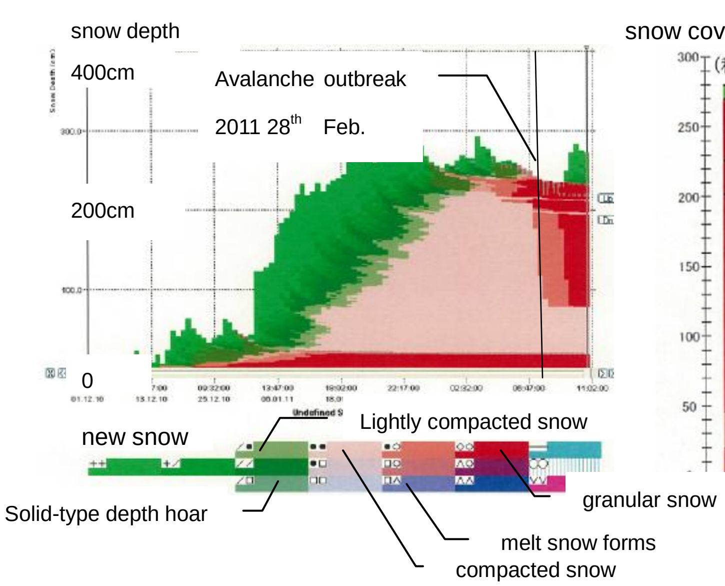
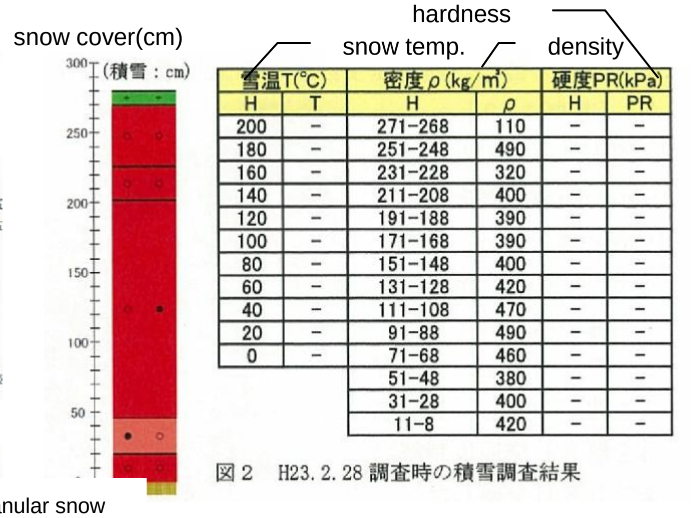


Figure11-A simulation for the status change inside the accumulate snow



雪温T(℃)		密度ρ(kg/m³)		硬度PR(kPa)	
H	T	H	ρ	H	PR
200	−	271−268	110	−	−
180	−	251−248	490	−	−
160	−	231−228	320	−	−
140	−	211−208	400	−	−
120	−	191−188	390	−	−
100	−	171−168	390	−	−
80	−	151−148	400	−	−
60	−	131−128	420	−	−
40	−	111−108	470	−	−
20	−	91−88	490	−	−
0	−	71−68	460	−	−
		51−48	380	−	−
		31−28	400	−	−
		11−8	420	−	−

図 2　H23. 2. 28 調査時の積雪調査結果

Figure12-The results of snow research (Feb.28, 2011)

4. COOPERATION WITH AVALANCHE EXPERTS

To take measures for snow damage such as avalanche and snowslide, it is important to take steps not only for the hardware side such as setting up an avalanche guard etc., but also the software side for example, improving the check-up on the slope to perceive the risk of avalanche or snowslide in advance, or taking care of the slope which faces to the road before the snow season comes, etc.

To judge the risk of avalanche accurately or to examine the countermeasures for avalanche, it is required to have a high specialty in this area which is well supported by numerous experiences. Therefore, NEXCO East is conducting the following activities in cooperation with avalanche experts, who have been patrolling to monitor avalanches along the road in regions with heavy snow for a long time.

a. We watch and research closely dangerous slopes, considering the avalanche risk information which is distributed by NIED･SIRC. The avalanche experts give NEXCO East some advice and instructions for risk judgment, warning, and measures, as necessary.

b. Since avalanches and snowslides have a tendency to occur repeatedly, we determined some avalanche caution spots. We created the “avalanche and snowslide hazard map,” and the “Avalanche Patrol Handbook” for the YAMAGATA Expressway, and applied them for the daily patrol and snow disposal.

c. The avalanche experts instruct us for the pre-cleaning snow works (a suitable treatment of the trees and other plants on the slope and the cut slope which could cause avalanche), and inspection works in the snow period and snowmelt period (direction for the inspection, shaping treatment for the disposal of snow and the snow on the slope, and how to make a snow guard to prevent the arrival of avalanched snow.)

d. The avalanche experts instructed the section research of the accumulated snow, emergency correspondence training for when avalanche happens, safety measures for working on the slope with snow.

e. The avalanche experts examine and instruct the countermeasures for the hardware side, such as the additional positioning of avalanche countermeasure constructions, etc.

5. INTELLIGENT AVALANCHE INFORMATION SYSTEM (IAS)

NEXCO East has been receiving the distribution service of the avalanche risk information, which is distributed by NIED・SIRC since the winter in 2010 and 2011, in cooperation with NIED・SIRC. The avalanche risk information is shown with the actual value and predicted value of the layer structure and snow stability.

NIED・SIRC checks the current status and calculates the predicted value with the latest observed value every 4 hours, 6 times a day. And they distribute the results twice a day, at 6:00 a.m. and at 4:00 p.m. to NEXCO East.

NEXCO East makes good use of the avalanche risk information, which is distributed by NIED・SIRC, for the avalanche patrol. When they receive high risk avalanche information, the patrol staff pay the most attention to the slope all the while mindful of the risk of avalanche when they patrol.

However, since the "Avalanche Risk Prediction Model" still has some unstable elements, it is very difficult to predict all the avalanche phenomenon perfectly. Therefore, when the risk is higher, the avalanche experts conduct a close research and monitoring, then they give NEXCO East some advices and instructions for the assessment, warning, and taking counter measures, as necessary. If this the case, the tendency and the information such as "why it is dangerous," "when and how the snow status changes," or "if it is getting more dangerous, or improving," which the numerical snowpack model provides, will be well useful.

In this way, NEXCO East, NIED・SIRC, the avalanche experts, and the local data observatories were linked up and created the "Intelligent Avalanche Information System (IAS)," which interchanges and shares the information concerning avalanche. Since all the staff concerned can recognize, share, and predict the risk of avalanche equally, this produces a good result for planning and practicing the countermeasures, such as reinforcement patrols.

In addition to this, NIRD・SIRC is trying to make the accuracy of the stereotyped numerical snowpack models by examining the results of prediction calculation by the "Avalanche Risk

Prediction Model” with the application of the snow status data, which the avalanche experts collected through fieldwork, such as the depth of the accumulated snow, the density of the snow, the snow quality, etc.

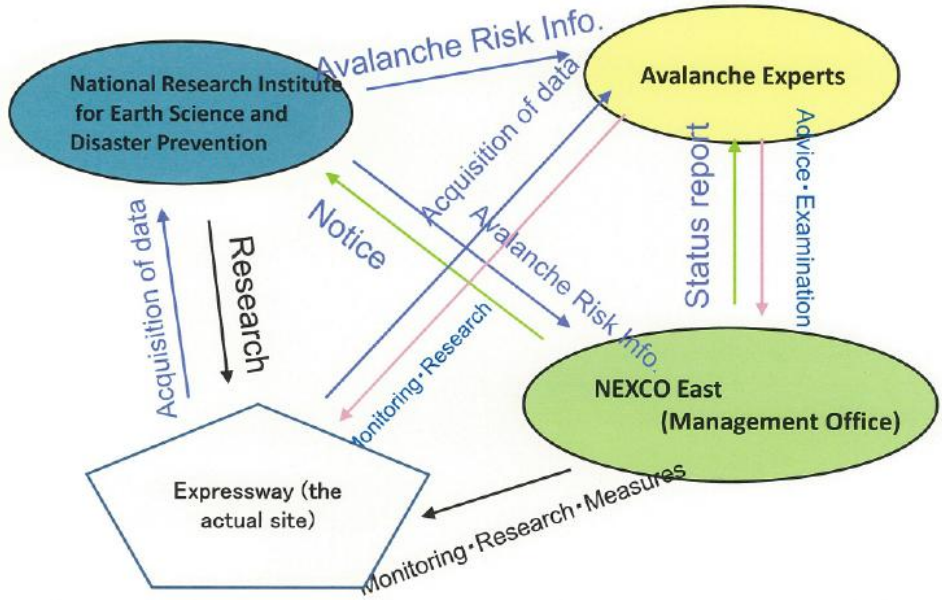


Figure 13- The concept of the Intelligent Avalanche Information System (IAS)

REFERENCE

1.Sento Nakai,Takeshi Sato,Isao Kamiishi and so on. (2012). A snow Disaster Forecasting sytem(SFDS) constructed from field observations and laboratory experiments. Cold Regions Science and Technology 70

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