ADVANCED SNOW AND ICE CONTROL MEASURES FOR HOKKAIDO'S EXPRESSWAYS

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ABSTRACT

The accumulation of snow during winter is a cause of road closure and obstruction of traffic on the expressways in Hokkaido. It is necessary to minimize road closures as much as possible in order to improve the service to customers and to ensure toll revenue. Therefore it is important to improve snow and ice control and to carry out efficient countermeasures against snow and ice.

This report describes an example of the use of a road image distribution system as a measure for improving snow and ice control. Using this system the road administrator can determine in real time the accumulation of snow on the road surface extensively in the patrol for snow and ice control, and use it for decisions regarding multi-vehicle snow removal or snow transport and disposal operations. Also, the results of using a snowfall amount web system for accurately determining the timing of snow removal operations are reported.

KEYWORDS

EXPRESSWAY / SNOW AND ICE CONTROL / WEB DISTRIBUTION

1. INTRODUCTION

The population of Hokkaido is about 5.63 million. The political and economic center of Hokkaido is Sapporo City, which has a population of about 1.82 million. The climatic characteristic[1)] of Hokkaido in winter is that winter arrives earlier and the period of snowfall is longer than the rest of the country. The total amount of snow varies greatly depending on the area, but in Sapporo it is 630cm, and the maximum depth of accumulated snow is about 100cm. It is very rare worldwide for cities with a population exceeding 1.5 million to be located in areas with such high snowfall. Also, the area of Hokkaido is large, and the cities are dispersed over a wide area forming a widely dispersed society, so the expressways that connect the main cities are indispensable socially and economically for the people of Hokkaido.

The expressways of Hokkaido[2)] opened to the public in December 1971, and 38 years later, as of December 2009, are a total length of 607km, carrying about 160,000 vehicles per day. The accumulation of snow during winter is a cause of road closure and obstruction of traffic, and road closures in one winter occur 10 times for about 70 hours on average over the past 5 years. The volume of traffic on the expressways crossing Sapporo City is a maximum of about 50,000 vehicles per day, so to improve the service to customers and to ensure toll revenue, it is necessary to minimize road closures as much as possible.

To date decisions regarding snow and ice operations are taken based on the experience of snow and ice patrol personnel during snow and ice patrols. In the future it will be important to determine the local conditions in real time, and make efficient and effective decisions using quantitative data regarding the accumulated snow, etc. Therefore it is necessary to improve snow and ice control.

This report describes the methods of and effect of introducing a “road image distribution system” to enable local images to be viewed in real time, and a “snowfall amount web system” to enable the amount of snowfall to be determined in a local area at 10 minute intervals as measures for advanced snow and ice control. Also as a future development, an operating plan taking into consideration cooperation between the trio of bus operators, climate consultants, and the road administrators, and pattern laser measurement that is capable of measuring the accumulation of snow on snow and ice road surfaces are described.

2. MEASURES TO IMPROVE SNOW AND ICE CONTROL

The expressways in Hokkaido are managed by East Nippon Expressway Company Limited (hereafter referred to as NEXCO East), Hokkaido branch. The main snow and ice measures are broadly classified into collection and forecasting of weather information, snow and ice patrols, snow and ice operations, traffic controls, providing information, and implementing snow defence measures.

In order to efficiently implement snow and ice operation, it is necessary to make comprehensive decisions based on information obtained from the latest weather data from weather observation equipment, the traffic situation and road images from CCTV and web cameras, and various weather forecasts announced by weather consultants, etc.

In order to improve the snow and ice operations, comprehensive snow and ice control that integrates both hard measures such as improvement of disaster prevention facilities and operating machinery, and soft measures comprehensively determined from information obtained from various types of weather data, etc., are important.

In the past, measures based on hard aspects have been positively carried out. On the other hand, the sharing of information obtained in real time using intelligent transport systems (hereafter referred to as ITS) and disaster prevention information including improved accuracy of weather forecasting as measures based on soft aspects are judged to be useful for efficiently implementing snow and ice operations.

3. ROAD IMAGE DISTRIBUTION SYSTEM

The expressways passing through Sapporo City are important roads connecting Sapporo City, the most populous city in Hokkaido, with the other main cities. The traffic volume is highest, the cumulative amount of snowfall is high, and in addition the 21.9km from Sapporo South IC to Sapporo West IC is an elevated viaduct, so it is particularly necessary on this route to pay attention to snow removal and disposal operations.

Therefore during the winter of 2008 a trial operation of a road image distribution system using ITS was carried out on this section, to provide valuable material for making decisions regarding efficient snow and ice operations.

3.1 Method

The snow and ice patrol[3)] is dispatched every 3 to 4 hours in normal times and as-needed in times of emergency, to determine the weather conditions and road and traffic conditions, which are constantly changing, and to collect and transmit information necessary for efficiently and smoothly carrying out snow and ice controls and snow and ice operations.

The snow and ice patrol image distribution system consists of web cameras, GPS, communication modules, and control PC provided in the snow and ice vehicles, that takes video and still images at each imaging interval, and transmits the still images with kilopost data (hereafter referred to as KP) to the web. By accessing a specific URL and using special software, it is possible to download images of the road.

(1) Outline of the road image distribution system (Fig. 1)

1) The imaging interval is set (100m, 200m, 500m)
2) The longitude and latitude information from the GPS is converted into KP data for the expressway in real time.
3) Still images are extracted from the video images taken by the web camera at set intervals, and picture processing.
4) The KP data is added to the still images as a telop
5) The still images with KP data are uploaded in real time via the communication module
6) The road images are downloaded using dedicated software (to automatically access a specific URL)

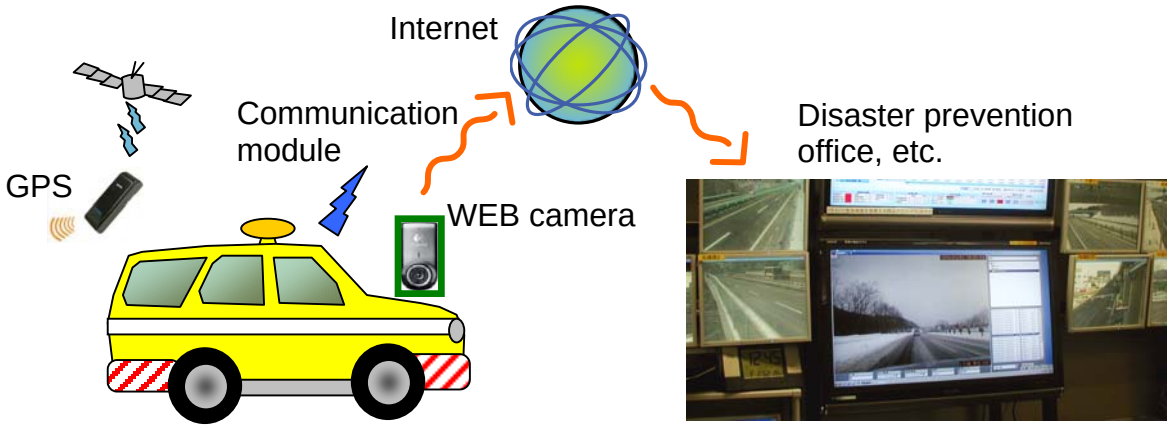


Fig. 1-Outline of the road image distribution system

(2) Dedicated viewing software (Fig. 2)

- Checks for newly arrived information every minute, and displays the road images in real time
- Scrolls and displays the road images at high speed
- By clicking the point on a road diagram to be viewed, road images at that area can be searched and displayed

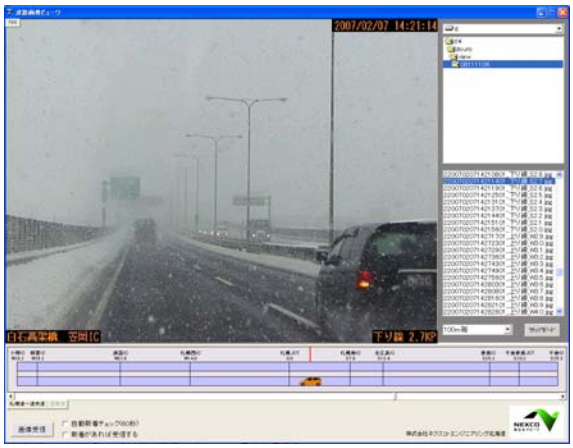


Fig. 2-Dedicated viewing software

3.2 The effect of introduction

Using the road image distribution system, it is possible to determine in real time the local road surface conditions extensively and the condition of accumulation of snow. Also, by sharing information among the patrol staff and the road administrator, it is possible to order efficient snow and ice operations. Further, by discussing the data after the snow and ice operations, it is possible to improve the efficiency of subsequent snow and ice operations.

(1) Multi-vehicle snow removal

In the elevated part (21.9km) of the expressway crossing Sapporo City, in addition of normal snow removal operations using 3 snow removal vehicles and 2 traffic sign vehicles (5 to 30km/h), multi-vehicle snow removal operations are carried out using teams of 7 snow removal vehicles and 2 traffic sign vehicles in order to speed up the snow removal operations and relieve traffic congestion. Depending on the type of snow, snow removal operations are carried out in parallel on the main road as well as the entrance and exit ramps, so it is possible to remove snow at 2 or 3 times the speed (30 to 40km/h) of normal snow removal operations.

For multi-vehicle snow removal, the timing of the start of operations is important. During rush hours and other time periods with heavy traffic, it is not possible to start operations immediately. The road administrator is pressed to make an early decision. Also, in the case of partial snow removal, normal snow removal is advantageous, so it is necessary to know the snow accumulation on the road surface extensively to carry out multi-vehicle snow removal. Using the road image distribution system, the road administrator can grasp the road surface snow accumulation extensively in real time during the snow and ice patrol, so it is possible to make rapid decisions. Fig. 3 shows an example of the decision to carry out multi-vehicle snow removal operations.

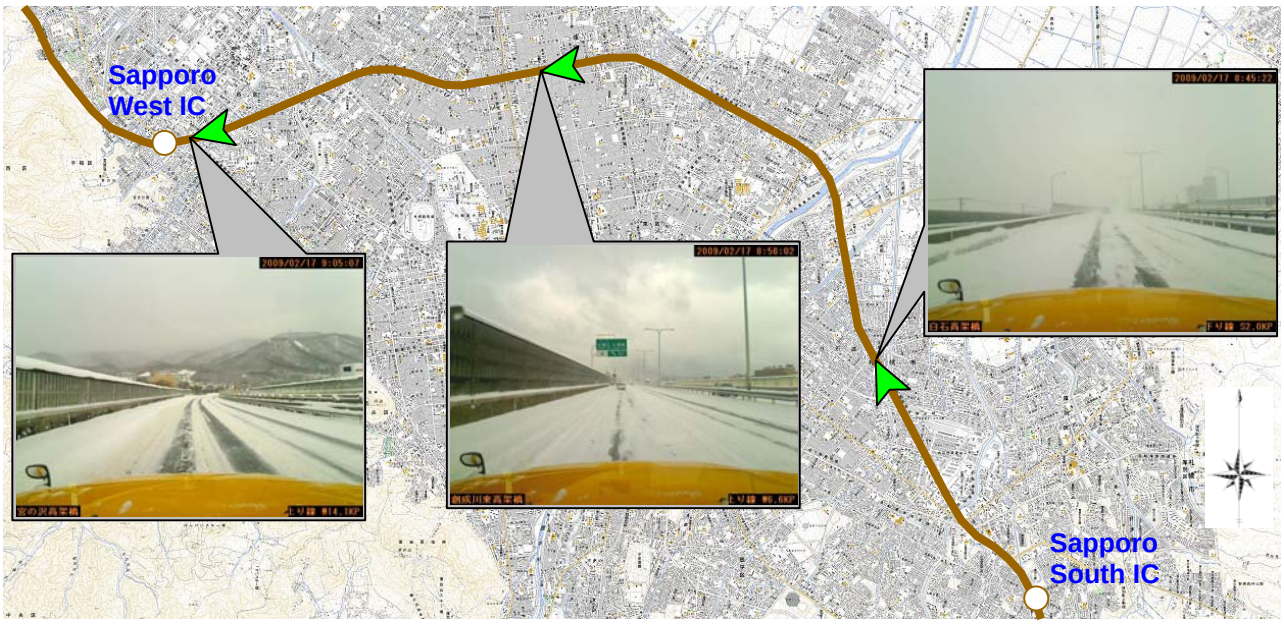


Fig. 3-Example of photos used for deciding to carry out multi-vehicle snow removal (17th February 2009)

(2) During road closure

The main reasons for road closure due to snow are the accumulation of snow on the road surface and spillage of the snowbank on the roadside onto the road lanes. Greater efficiency is needed for rapidly completing the snow removal and disposal operations. In recent years the number of road closures due to localized snowfalls has been increasing. By determining the accumulation of snow on the road surfaces during the snow and ice patrols, and the localized scale of snowbank on the road side, it is possible to carry out centralized snow removal and disposal operations.

(3) Snow transport and disposal

In the elevated viaduct section there is no space for piling up snow, and it is not possible to leave the snow by the side, so the snow temporarily piled up on the hard shoulders of the road must be transported and disposed of in a planned manner. In order to efficiently carry out snow transport and disposal operations, it is important to decide priority areas, and the road image distribution system supports this decision-making. Table 1 shows examples of photos used in making decisions regarding snow transport and disposal.

Table 1-Example of snow transport and disposal decision-making

Scale	Small scale accumulation of snow on the hard shoulder	Medium scale accumulation of snow on the hard shoulder	Large scale accumulation of snow on the hard shoulder
Decision	Not necessary to transport and dispose of snow	Necessary to transport and dispose of snow within 4-6 days	It is judged necessary to urgently transport and dispose of the snow
Date	5th February 2009	7th February 2009	10th February 2009
Road photos			

(4) Checking after carrying out the snow and ice operations
For efficient snow removal and disposal operations, it is necessary to carry out checking afterwards, to decide on any subsequent actions. A snow and ice patrol is carried out after the snow removal and disposal operations, and by using the road image distribution system, it is possible for the patrol staff and the road administrator to confer regarding any subsequent actions, and make decisions efficiently.

3.3 Future developments

(1) Outline of the system (Fig. 4)
As a result of the trial operation of the road image distribution system on the Sapporo Expressway in winter 2008, good results were obtained. In the winter of 2009 operation will be extended to the 130km stretch between Sapporo and Asahikawa, the second most populous city in Hokkaido, where traffic is frequently disrupted by poor visibility due to blizzards. Here cooperation with scheduled buses and weather consultants is planned as a new trial.

The scheduled buses as public transport system operate at 30 minute intervals, so road closures are a major obstacle to transport. Also, in recent years localized worsening of the weather, which is difficult to predict, has tended to increase.

The snow and ice patrol vehicle with the road administrator operates every 3 to 4 hours, so it is difficult to grasp poor visibility which can occur in a short period of time. Therefore, a trio operation is planned in which the image distribution system will be installed on the expressway buses that travel at 30 minute intervals, a weather consultant company will provide weather information, and the road administrator will make rapid decisions. The buses will be private expressway buses, and the weather consultant will be a company that provides weather forecasts commissioned by the Hokkaido branch of NEXCO East.

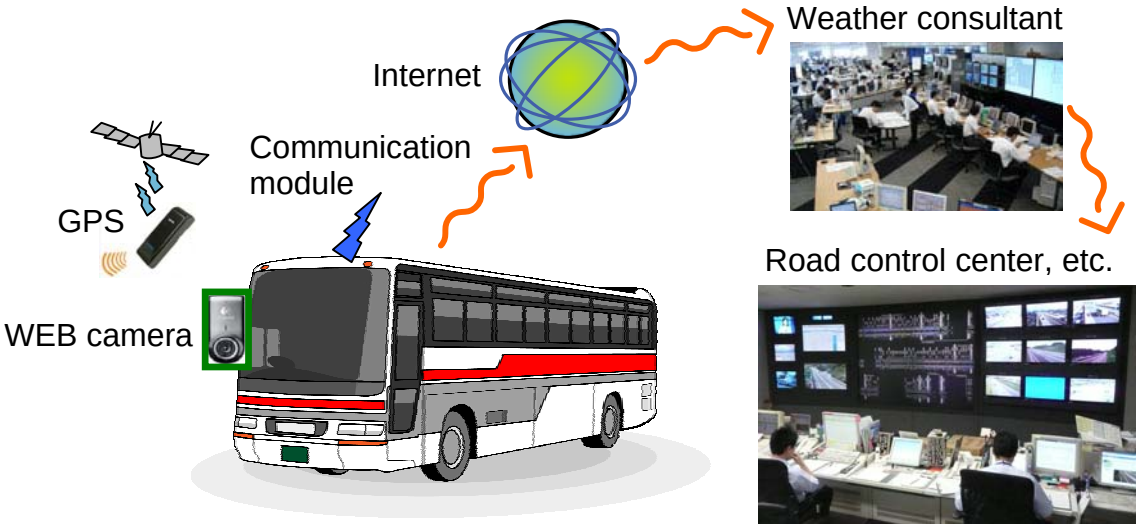


Fig. 4-System outline

(2) Contents image (Fig. 5)
By downloading still images with KP data, and displaying them on a map, it is possible to grasp the present position and visibility conditions in real time. Further, a method for inferring the visibility from road images is the method proposed by Hagiwara and others[4)], in which images are converted into spatial frequency, passed through band pass filters, the power spectrum values are calculated, and from these values the visibility level is

inferred in 4 levels. By applying this technology, it is possible to quantitatively indicate extensive visibility information.

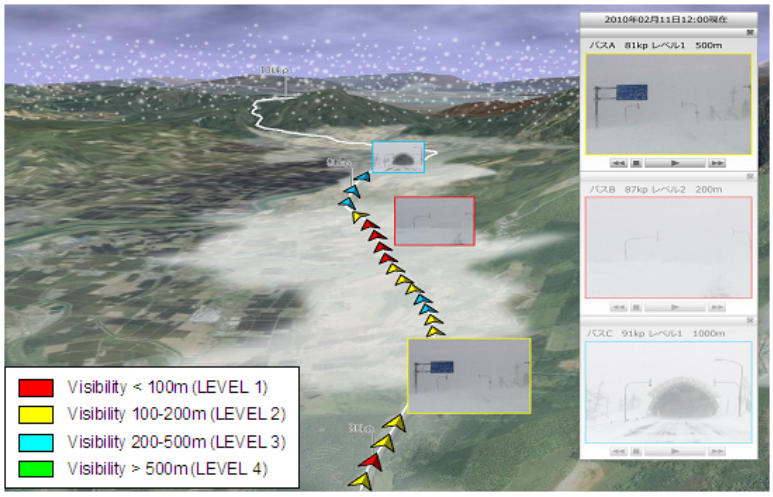


Fig. 5-Contents image

(3) Expected effect

- Road administrator (decision): Earlier cancellation of road closures, improved customer satisfaction, increased revenue
- Scheduled buses (image distribution): Maintenance of schedule, improved customer satisfaction, increased revenue
- Weather consultant (information provision): Improved accuracy of weather predictions, improved company value

4. SNOWFALL AMOUNT WEB SYSTEM

To date meteorological observation equipment such as snow depth meters and snowfall amount meters have been installed at interchanges, the measurement methods were visual, and the measurement intervals were about every 3 to 4 hours at the time of the snow and ice patrol. The snow depth and the snowfall amount are useful decision-making material for implementing snow and ice operations, but the measurement intervals were long, so the information was not effectively used.

In winter 2005 the Japan Meteorological Agency changed the method of measurement of snowfall amount from the “snow plate” measurements 3 times per day used until that time to measuring the snowfall amount from the depth of snow (the difference of the present snow depth value and that 1 hour previously (1 hour snow depth difference))[5].

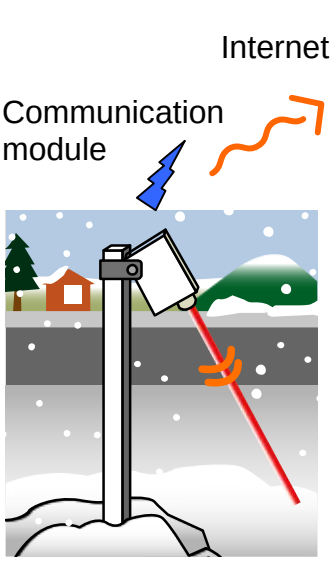
In order to determine the snow fall conditions in real time on the expressways of Hokkaido also, for efficient snow and ice operations, from 2007 the snowfall amount web system was installed at 36 locations that are representative of the weather, such as in the plaza at ICs, at the entrance to tunnels, and at locations where the snowfall phenomena change. In the future it is planned to install them also along the Kan-etsu Expressway, which has the important function of connecting the Tokyo area with the Japan Sea side.

4.1 Method

The snowfall amount web system automatically distributes on the web the snow depth values measured at 10 minute intervals using a light wave phase difference measurement method. The system does not use a dedicated circuit, but connects directly to the web

from a transmission control device installed with a wireless device. Because of the web environment, it is a system in which the snowfall conditions can be viewed from anywhere by accessing the specific URL. Further, by providing the web server with a graph preparation function, it is possible to visually display the snowfall intensity. Fig. 6 shows an outline of the snowfall amount web system, and Fig. 7 shows a graphical display of the snowfall intensity (cm/10min).

Snowfall amount web system



Disaster prevention office, etc.

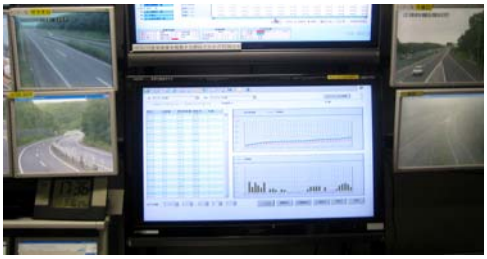


Fig. 6-Outline of snowfall amount web system

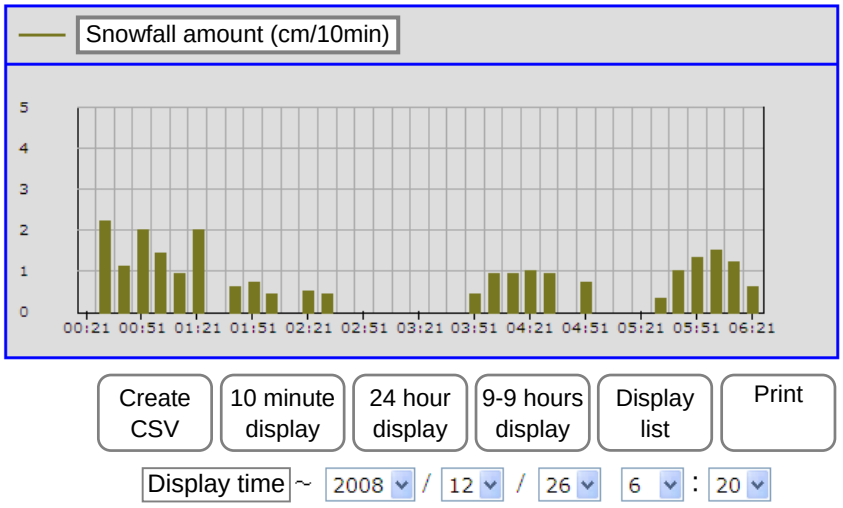


Fig. 7-Graphical display of snowfall intensity (cm/10min)

4.2 Effect of introduction

(1) Snow removal operations

Decisions on the timing to start snow removal operations are supported by being able to know in real time the snowfall intensity at a particular location. Removal of new snow (primary snow removal) is the most important snow removal operation, and the target that the accumulated snow depth will not exceed about 5cm is used for management purposes. The average rotation for each station for snow and ice operation is about 2 hours per time (about 30km). Therefore appropriate decisions regarding the starting time are required. As a result of the experience and quantitative data accumulated to date, it is possible to accurately determine the starting time. Efficient snow removal operations are contributing to shortening snow road closure times.

(2) Snow and ice control

To date the meteorological data from the weather forecasting equipment was connected to a dedicated circuit, and it could only be used by the road administrator in the disaster prevention office within the jurisdiction. By using the web system, it is possible to share the information with the road administrators at headquarters, and other traffic administrators, etc., so it is possible to take more efficient snow and ice measures.

4.3 Future development

The Kan-etsu Expressway is an important road for transport of freight, etc., between the Tokyo area and the Japan Sea side. The area between Minakami IC and Yuzawa IC is steeply sloping and passes through areas of heavy snow, and the amount of traffic from the Tokyo area without taking measures for snowy roads is large. Traffic accidents in winter account for 70% of all accidents throughout the year. In order to prevent these accidents the regulations require the use of chains when snow has accumulated on the road surface and the snow has been compacted to the extent that it is considered dangerous to travel on the road with summer tires. However, in order to prevent accidents due to breakage of the chains within the Kan-etsu Tunnel, it is necessary to remove the chains at the entrance to the Kan-etsu Tunnel. This series of operations requires effort, so it is necessary to maintain the road surface in as good a condition as possible. Therefore in addition to the normal snow removal that is carried out after seeing the snowfall conditions, snow is continuously removed without stopping, from the start of snowfall until the termination of snowfall, regardless of the amount of snow accumulated, or “constant snow removal[6)]”.

With constant snow removal, the work continues without rest, so the necessary personnel for the snow removal work, including relief personnel, must be secured. As a measure for efficient snow and ice operations, determining in detail the snow accumulation status on the expressway, and carrying out snow removal at intervals determined by the snowfall amount is being examined.

The measuring instrument for measuring the amount of snow on the road surface used to date is the light wave phase difference detection method, which was adopted for the snowfall amount web system. This provided information is limited to one point, so it is not suitable for measurement of the road surface. However in the snow condition measurement system[7)] by processing pattern laser images, line laser light is shone across the surface on which the snow has accumulated (the road surface) in the transverse direction. Images taken by a camera are processed by computer to obtain the average depth of snow on the road surface, and the system is also capable of measuring the furrows in road surfaces that are covered with snow and ice.

By using this system, it is possible to accurately determine the state of snow accumulation on expressways, so it is possible to consider changing from the constant snow removal system to snow removal at intervals in accordance with the amount of snow accumulation. Fig. 8 shows the principle of pattern laser measurement.

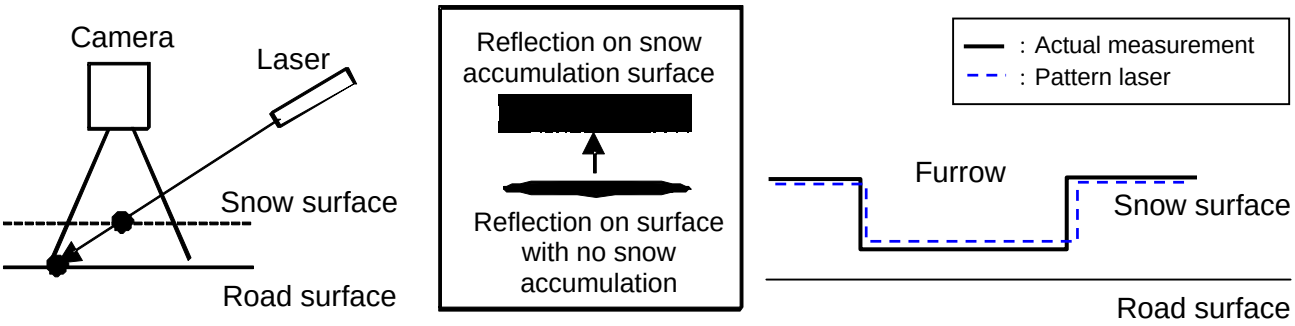


Fig. 8-Principle of pattern laser measurement

5. CONCLUSIONS

In the Hokkaido branch of NEXCO East, which is responsible for managing Hokkaido's expressways, great importance is placed on measures against snow damage, in accordance with the fundamental policy of "ensuring safe and comfortable travel during winter". In this report, we introduce soft technology measures using ITS as an initiative for improving snow and ice control. It is difficult to grasp the full situation from the verbal communications of patrol personnel. When a decision is difficult, an inefficient response on the safe side is taken. By obtaining local road images, patrol personnel and the road administrator can share information, and it is possible to take efficient snow and ice operation decisions. Also, the merit of being able to obtain real time quantitative data is large in terms of carrying out snow and ice operations.

We intend to continue our research into advanced snow and ice measures, introducing new hard technology measures while continuing to place importance on the soft technology measures.

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