THE DEVELOPMENT OF SNOW AND ICE CONTROL MACHINERY

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1. Abstract

The Japan Highway Public Corporation (JH) has been carrying out its operation of intercity expressways and the total length is about 6,900 kilometers now. The winter climate of Japan is characterized by much snowfall, owing to the complexity of its geographical features and the seasonal wind. Therefore, JH is now trying to expand the functions of snow and ice control machinery to accomplish more efficient, speedier and safer expressway operation. Presently, one of the most crucial issues is the development of various efficient machines and equipments.

In this paper, some representative trial examples of the development are introduced. Firstly, an automatic information collection system on road surface conditions is introduced. Such information is fundamental for snow and ice control operation and this task can be carried out only by little number of experts who enable to judge surface conditions correctly. Therefore, the developed automatic system has been tested and reasonable results have been obtained so far.

The rest of the examples are a one-operator snow removal truck, a slush removal truck and a snow removal machine around emergency telephones. These could contribute to reduction of the required time of snow and ice control operation, and would lead to providing safe and comfortable conditions on expressways.

2. Introduction

The archipelago of Japan is stretched from north to south but narrow from east to west. There are ranges of high mountains, forming a sort of backbone in the central part of Japan. In winter, strong winds from the Asian Continent cross the Japan Sea, and strike the ranges. This results in large amounts of snowfall in the northern areas of the mountains.

Mountain- cold, snowy areas occupy approximately 60 percent of the land and contain several cities of more or around 1 million people. On the other hand, southern areas of the mountains facing the Pacific Ocean have larger amounts of sunlight, more stable weather and much less snowfall.

The Japan Highway Public Corporation (JH) manages over 6851 km of national expressways and 824 km of other ordinary toll-roads. Approximately 50 percent of the expressways and toll-roads pass through with cold, snowy areas. Moreover, about 2700 km of them pass though heavy snowfall areas with one meter or greater accumulated snow. Therefore, control of snow and ice is one of the most important operations of JH and JH is making various efforts to increase its efficiency.

In this paper, a few major trial types of equipment and machines developed to increase snow and ice control efficiency are introduced. The first is a mobile machine collecting information on the surface conditions of a road automatically. Such information is fundamental for every operation on the road. The rest are machines that effectively remove snow and prevents road from freezing after obtaining information on the road surface conditions.

3. Mobile system for examination of road surface conditions

3.1 Background and purpose

Knowing the latest surface conditions of a road is important under ever changing weather conditions. Until now, we have collected information on surface conditions through wireless communication by a limited number of expert patrolmen and/or monitoring CCTV images sent from units at limited points of suddenly changing weather. A staff member in charge of ice and snow control at a control office would give commands to remove snow and scatter antifreeze. Unfortunately, these commands have not always been efficient because they are based on limited information. In addition, it is difficult to employ enough skilled workers nowadays. Therefore, it is necessary to develop a machine that collects information on the surface conditions of a road and automatically sends it to the control office. We have developed and been testing such a system, which can be installed on a patrol vehicle, for monitoring the surface conditions of roads.

3.2 Overview of mobile system for monitoring road surface conditions

Fig.1 provides an outline of system configuration of the mobile system for monitoring the surface conditions of roads. The trial system consists of two major types of equipment: one installed in a patrol vehicle and the other placed in a control office. Various sensors used with the first type collect information on the surface conditions of roads. The information is sent through a communication unit to a data-monitoring unit in the operation office (data flow-1). Moreover, we have a future plan to send the data to the operation branch supervising some offices and a wide-area information data processed by the central weather information processing system would be passed such local operation offices (data flow-2).

3.2.1 Equipment installed in a patrol vehicle

A patrol vehicle with information-collecting equipment is shown in Fig.2. This vehicle is equipped with three *road-surface-condition sensors*, a *differential global-positioning system* (D-GPS), *road-temperature meter*, a *salt-concentration meter* and *data-processing unit*. Obtained data on road conditions and temperature is sent to an operation office at regular intervals. The main features of the equipment are as follows:

> Road-surface-condition sensor: For determination of whether the road surface is dry, wet, snowy, or frozen every meter of the distance by using infrared beam (with information edited every 10 meters) at a speed of between 5 km/h and 100 km/h
>
> D-GPS: Accuracy of detection = 1 meter or less
>
> Road-temperature meter: Infrared-energy thermoelectric conversion type with a measurement range between –18° C and +30° C
>
> Salt-concentration meter: Optical refracted rate observation with a measurement range between 0 and 15% of aqueous solution concentration of sodium chloride.
>
> Data-processing unit: Road-observation PC with a 200-MHz MMX Pentium, 2-GB HDD, RS232C communication port, and 15" TFT monitor under Windows NT4.0

The road-surface-condition sensor cooperates in conjunction with an application for detecting surface patterns using a space filter. Once sensor receives light, which is uni-directionally emitted and reflected by the road surface, and detects changes in luminance and unevenness in pattern and level. The application combines these bits of information to determine whether the road surface is dry, wet, snowy or frozen.

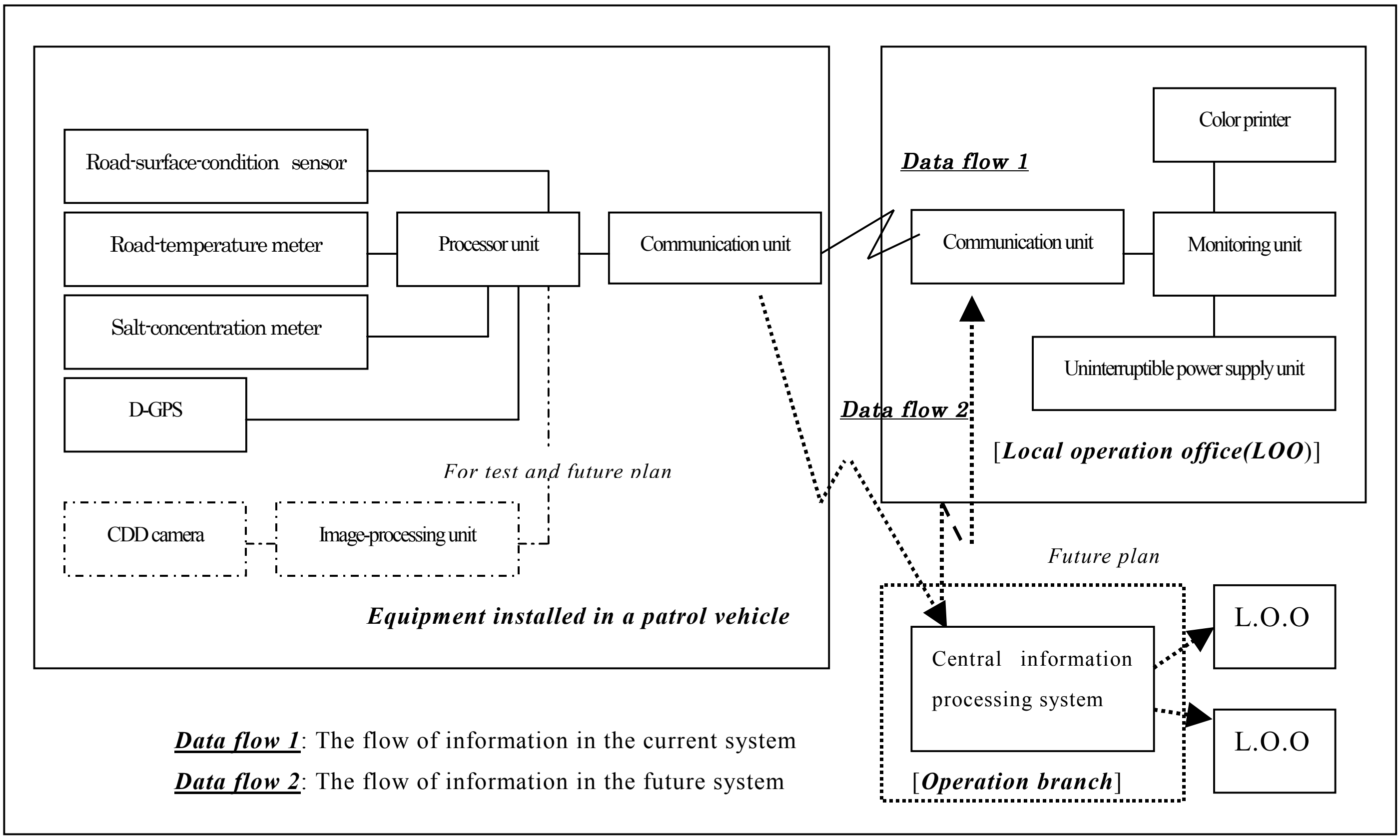

Fig.1 Overview of mobile system for monitoring the surface conditions of a road

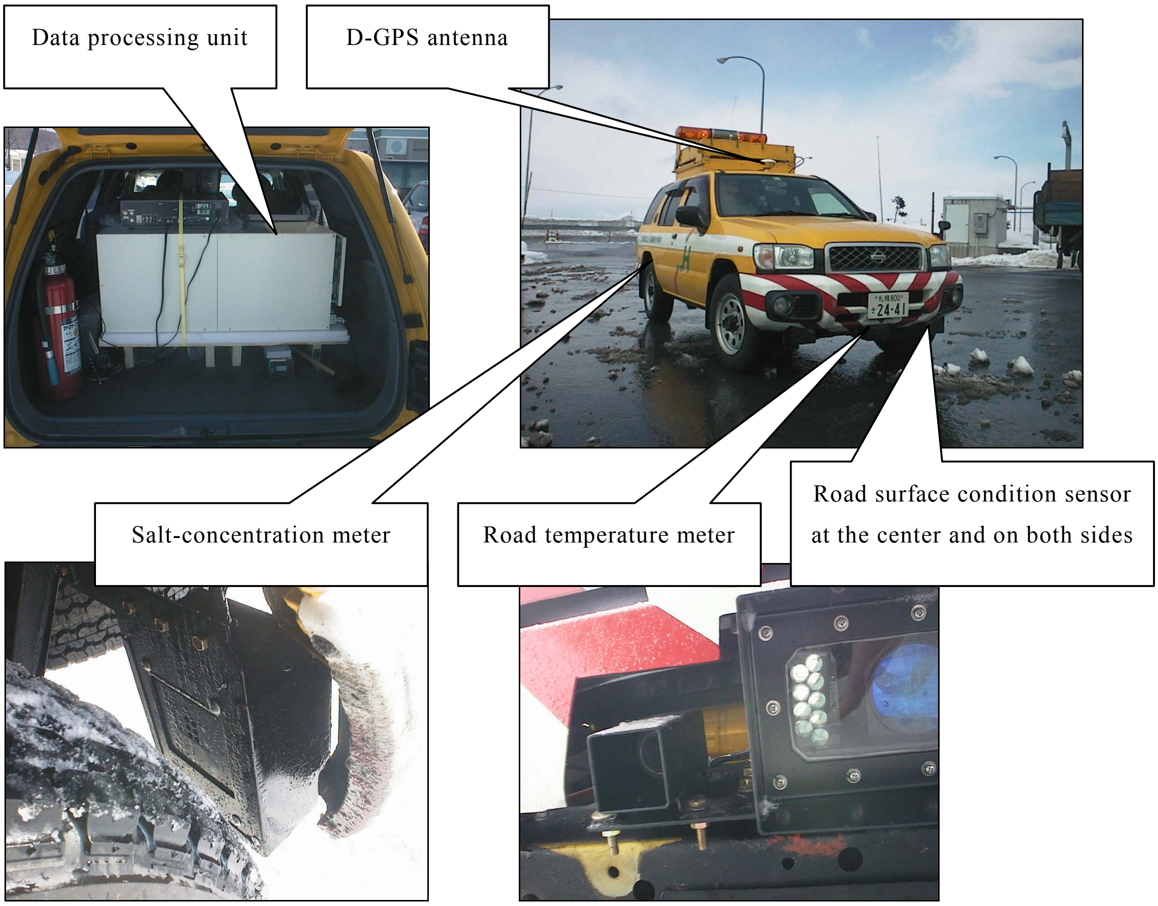

Fig.2 Patrol vehicle with equipment for collecting various information of road conditions

3. 2. 2 Equipment placed in operation office

The operation office has equipment consisting of a *data-monitoring unit, a color printer, an uninterruptible power supply* (UPS), and a modem. The monitoring unit comprises a PC with a 450-MHz CPU with Pentium III, 46.4-GB HDD under Windows NT4.0; a 21" monitor; and a color printer. The UPS has a continuous inverter power supply with a power output of 1 kVA/700 W for 5 minutes. The modem is a full-duplex, asynchronous type operating at 9600 bps.

The monitoring unit receives observation data from the communication unit of a patrol vehicle to display, in color, the location and time of each vehicle, with an ID and the determined condition (dry, wet, snowy, or frozen), every km (made on a basis of ten determinations every 100 meters). The unit displays the road temperature graph with measurement range between -15°C and +15°C. If necessary, at a location at which freezing is possible, such as on bridge, the unit displays similar data every 100 meters (made on a basis of ten determinations every 10 meters), as shown in Fig. 3.

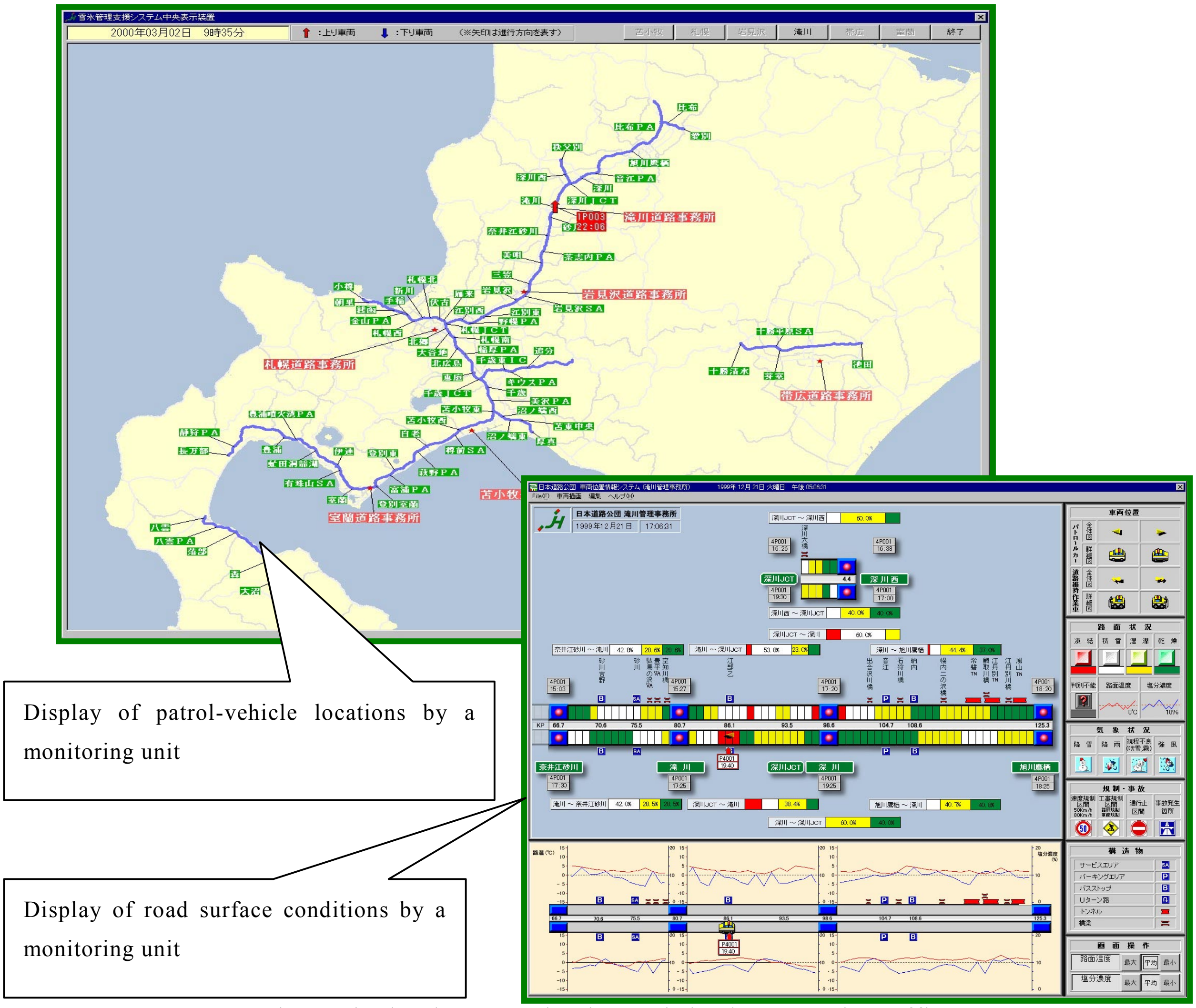

Fig.3 Display by a monitoring unit in the operation office

3.2.3 Summarized results of testing of the road-observation system

A test of the road-observation system was conducted, confirming that the system might be at a level of no general problems for practical operation. The results of the test so far are described below in brief.

(1) *Sensor for detecting road surface conditions*

There was a case in which the scattering of antifreeze on a dry road resulted in an erroneous determination that the road surface was snowy, due to the whiteness of the antifreeze. However, the introduction of a criterion map based on property indexes, as shown in Fig.4, has improved the determination to a level of general acceptance.

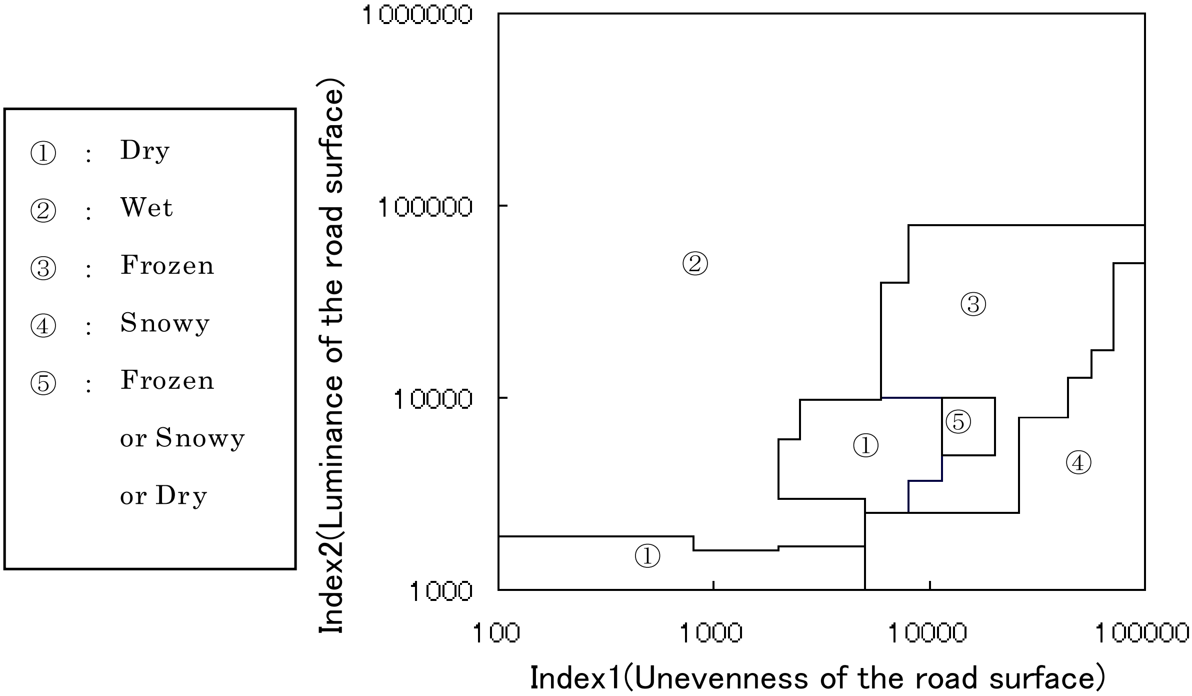

Fig.4 Map for determining the surface state of a road

(2) *Road-temperature meter*

Fig.5 shows the correlation between determination by the present sensor and fixed-point manual determination. The horizontal axis indicates the average of manual determinations. The vertical axis indicates the determination by the sensor. The average difference between the two determinations is about 1.1° C, and it could be an acceptable tolerance.

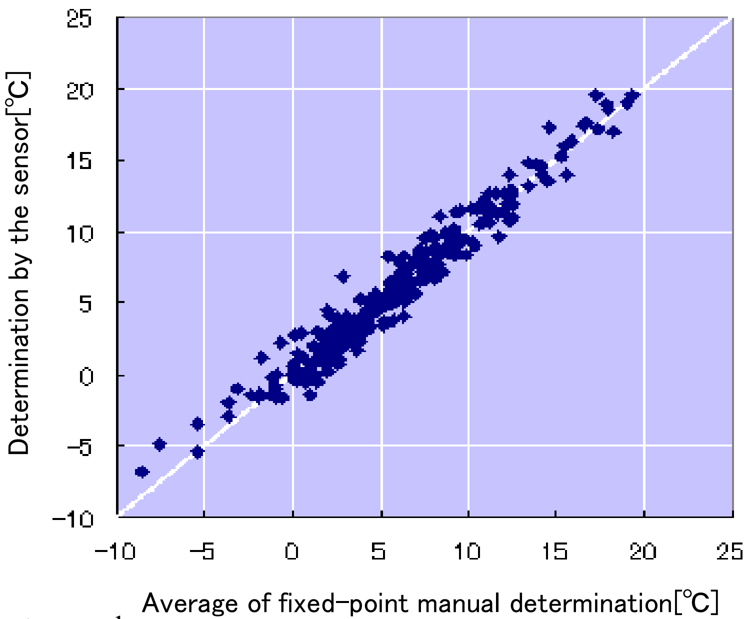

Fig.5 Correlation between determination by the sensor and fixed-point manual determination

(3) *Salt-concentration meter*

The present salt-concentration meter measures the index of refraction of water splashed by a tire to determine the salt concentration. Repeated measurements cause mud and salt to adhere to the sample-collecting surface, requiring a device for periodic wiping.

(4) *Global-positioning system* (GPS)

When there are large obstacles such as a tunnel, no GPS communication is possible. Although a self-navigation system is introduced to cope with these problems, three percent of locations are still not precisely idetified.

(5) *Communication means*

Commercial cellular telephones are used in a patrol vehicle to communicate with the operation office. There are areas in which such telephone communication is impossible. To overcome this type of problem, a dedicated digital wireless communication system would be necessary.

4. Snow- and Ice-Control Machines

JH possesses more than 1400 snow- and ice-control machines. They are classified into two major types: those for the control of icy roads surface condition and those for the removal of snow. Lately, some of them are equipped with a GPS navigation system to ensure effective operation as trial cases.

For the control of icy roads, we formerly applied either an antifreeze solution (aqueous solution of sodium chloride) or antifreeze particles (sodium chloride) in response to road conditions. At present, we mix such particles with an aqueous solution of sodium chloride immediately before scattering the mixture on a road and this contributes to improve the efficiency of the operation.

Various types of snow removal machines have recently been under development and in trial and practical use. In this report, a brief description of three types: a one-operator snow removal truck, a slush-removal truck, and a rotary-compacting snow-removal truck with snow-removal device around emergency telephones.

4.1 One-operator snow removal truck

4.1.1 Background and purposes

Ice and snow control is carried out under severe weather conditions that may change suddenly. High-level control of the surface of roads is necessary, but could place a large burden on operators due to the task. Moreover, we are facing problems those are both a shortage of skilled operators and a reduction in the number of workers available for snow removal. To cope with the difficulties of employing such operators and workers, we have developed a one-operator snow removal truck that does not require an assistant.

4.1.2 Brief description of a one-operator snow removal truck

Fig.6 shows photographs of a one-operator snowplow. This machine has the following major features: automated operation of a truck grader with automatic transmission, and a video camera for checking behind the snow remover while it is backing up. These devices have improved the operability of the snowplow, making it easier to maintain an even road surface.

Fig. 6 One-operator snow removal truck (external and internal views)

4.2 Slush-removal truck

4.2.1 Background and purposes

Slush removal could be one of the most challenging and important tasks in ice and snow control. It is conducted in many areas, including snowy regions in the central northern part (Hokuriku district) and light-snow regions in the suburbs facing the Pacific Ocean such as Tokyo and Osaka. For example, traffic accidents on slushy roads represent as many as 50 percent of all accidents occurring in winter in the region overseen by the Hokuriku branch of JH. Thus, we have developed and introduced a slush-removal truck with a brush to ensure effective operation on slushy roads even slightly rutted.

4.2.2 Brief description of a slush-removal truck

Fig.7 shows photographs of a slush-removal truck. This truck is equipped with either a brush (approximately 4.2 meters in removal width) or a front snowplow device (3.5 meters in removal width). The brush and snowplow are easily exchangeable, depending on the conditions of a snowy road. The rotating speed of the brush is approximately 700 rpm. With a brush made of polyester, the truck could move at a speed of 30 - 40 km/h. Tests have shown that the system operates well, however it produces an unacceptable amount of noise for residents beside expressways. In the future, to improve efficiency, it might be ideally necessary to develop a device in which it is possible to exchange a brush for a grader.

Fig. 7 Slush-removal truck and front brush

4.3 Snow-removal machine around emergency telephone

4.3.1 Background and purposes

Emergency telephones are placed approximately every kilometer along expressways. They are used for communication with JH when an accident, breakdown, or other emergency problem occurs on expressways. Such a phone should always be usable. However, in cold, snowy areas, an emergency telephone might not be accessible when it snows continuously. In the past, workers manually removed the snow around a telephone, as shown in Fig.8. Such work is not efficient or safe, so we have developed a snow-removal machine, as described below.

Fig. 8 Snow around an emergency telephone and manual removal of snow

4.3.2 Brief description of a snow-removal machine

Fig.9 shows photographs of a snow-removal machine. It has a movable arm with a belt conveyor above a main auger, like a rotary-compacting snow-removal truck having an added arm. The conveyor is hydraulically driven by the truck engine. The machine reduces the operation time to approximately 7 minutes, compared to approximately 30 minutes required for manual operation. This represents a remarkable improvement in work efficiency and safety.

Fig. 9 Snow removal around an emergency telephone using a snow-removal machine

5. Conclusions

The Japan Highway Public Corporation aims to maintain high-quality carriage way space of expressways. The improvement of snow- and ice-control systems would help to achieve safe, smooth, and reliable road transport in winter. They are effective in reducing the cost of work while providing more satisfactory service. Furthermore, in consideration of increase the rate of the aged workers and the shortage of skilled workers, JH engineers feel it necessary to further improve machines efficiency for snow and ice control. Therefore, we will continue our best efforts to improve the efficiency of machines and equipment and make further advances similar to those outlined in this paper.