New road surface maintenance of expressway using an On-Vehicle Salinity Sensor System which measures the salinity continuously

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ABSTRACT

For NEXCO East Tohoku, managing expressway of northeast of Japan, snow-ice maintenance is very important. Especially, salt-spreading operation is to be paid careful attention. To keep the suitable salinity, a control of salinity is needed. Yamada Giken started to develop on-vehicle type sensor, and applied it 6 years ago. NEXCO East Tohoku introduced On-Vehicle Salinity Sensor System and makes use of it for roadway surface maintenance.

The feature is to measure the salinity along an expressway automatically, linearly and continuously. Based on the result, road surface situation is broken down insufficient, marginal and sufficient.

NEXCO East Tohoku operates salt-spreading, making use of data measured by 16 patrol cars with the system, and realizes detailed road surface maintenance.

In addition, the critical points are drawn scientifically according to understanding of the entirety of an expressway, analysis of dilution ratio and low road-surface-temp point. Finally, the situation is rendered visible and the system contributes to the improvement of traffic safety in winter.

Meanwhile, due to no need to get out of patrol car, it also contributes to secure the safety and the efficiency.

In the future, we would like to pursue the improvement of performance.

1. Introduction

The latitude of Japan is almost the same as that of the Mediterranean. (Fig. 1) It often snows hard on the Sea of Japan side of the country. This is because a large volume of water vapor from Siberian monsoons

Figure 1— Comparison of latitude with the map of Japan

courses over the Sea of Japan and collides with the mountain chain of peaks about 2,000 meters high along the islands. In addition, because of the low latitude, the insolation is large even in winter. Snow-ice on the road surface melts during the day and is frozen at night in many cases. Japan is a long archipelago stretching from north to south. The amount and type of snowfall vary depending on the regions. [1]

For East Nippon Expressway Company Limited Tohoku Regional Head Office (hereafter referred to as NEXCO East Tohoku), which maintains expressways in the northeast area of Japan, the snow-ice maintenance operations are especially important. Scrupulous attention is required to salt-spreading operations. NEXCO East Tohoku introduced On-Vehicle Salinity Sensor System six years ago for assistance in operations of road-surface maintenance.

Here, the outline of the system and the purpose of the introduction are clarified, and the actual management condition is reported.

2. Background of the development of On-Vehicle Salinity Sensor System

Control of salinity is required to keep the proper saline level for spreading the anti-icing agent. For this purpose, salinity was measured at some points on the expressway beforehand. Yamada Giken started developing the on-vehicle sensor for continuous measurement, and put it into practical use six years ago.

3. Outline of system and method of information display

3.1. Outline of On-Vehicle Salinity Sensor System

The outline of the system is shown. (Fig. 2) The on-vehicle computer (ECU) is connected to the salinity sensor, road-surface temperature (R.S.T.) sensor, thermometer, GPS, in-vehicle monitor, and communication device. (The image camera for visually monitoring the road surface condition was added later.) The measurement data is transmitted in real time every 5 seconds, and is displayed using exclusive software of the PC in the snow-ice control center.

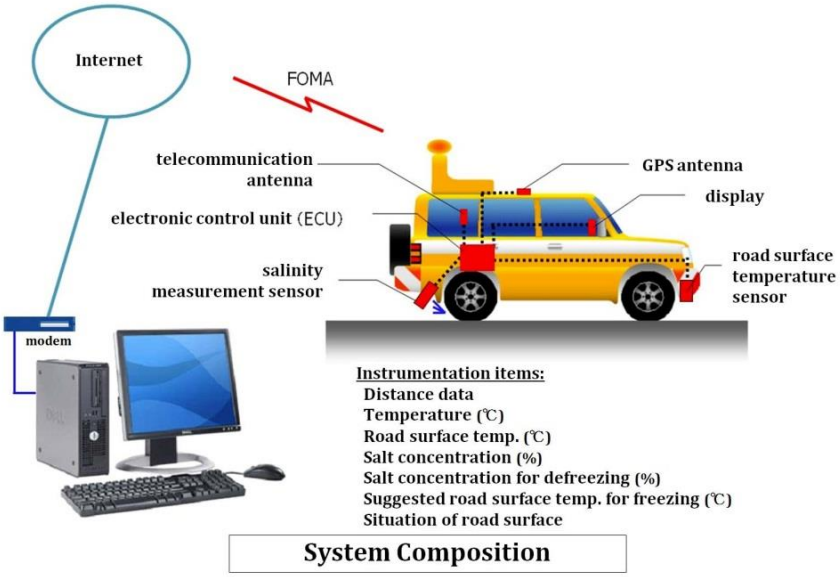

Figure 2 – System Composition

The salinity sensor is installed to ensure that water splashed on the back of the tires adheres to the measurement section. The salinity of the solution is optically measured. (Fig. 3)

Sufficient splashed water is required for measurement. If the amount of splashed water is small, the road surface is almost dry and the possibility of freezing is low. However, this is open to debate.

Figure 3 - Vehicle with the system and salinity sensor

3.2. Principle of use of salinity data

To optimize the application amount of the anti-freezing agent, it is necessary to calculate the salinity depending on road-surface condition. The concept is based on NaCl solution state diagram (Fig. 4) using NaCl freezing point graph.[2]

This diagram shows a theoretical road-surface condition by the correlation between the salinity (%) and road-surface temperature (℃). The center line in the yellow field is the freezing point graph. The upper field (Green) shows the optimal state of the solution while the lower field (Red) shows the state when ice starts to deposit. (Not all of it is frozen.) If the anti-freezing agent is sprayed and the road-surface can be maintained in the condition of the upper field rather than in the freezing point in which ice starts to deposit, the condition in which the entire surface is frozen can be theoretically avoided. Even if the temperature is lower than the freezing point, not all of the sprayed salty water is frozen. Therefore, complete freezing does not occur even in the red field. This is the thus-called “prevention of complete icing.”[3]

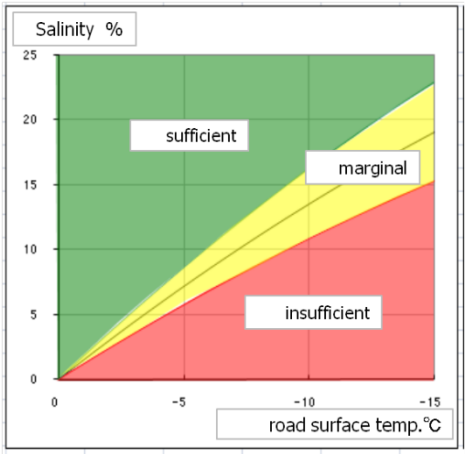

Figure 4 - NaCl solution diagram

It is necessary that the road-surface is in a solution state for applying this figure. The change in salinity in the sherbet, snow, or compacted snow state is drastically influenced by the weather conditions. Special attention is required for application and judgment.

3.3. Representation of measurement data

A feature of the system is that the salinity can be measured linearly and continuously along the route and the condition can be captured in real time. By utilizing the feature, the measured residual salinity and road-surface temperature data are plotted

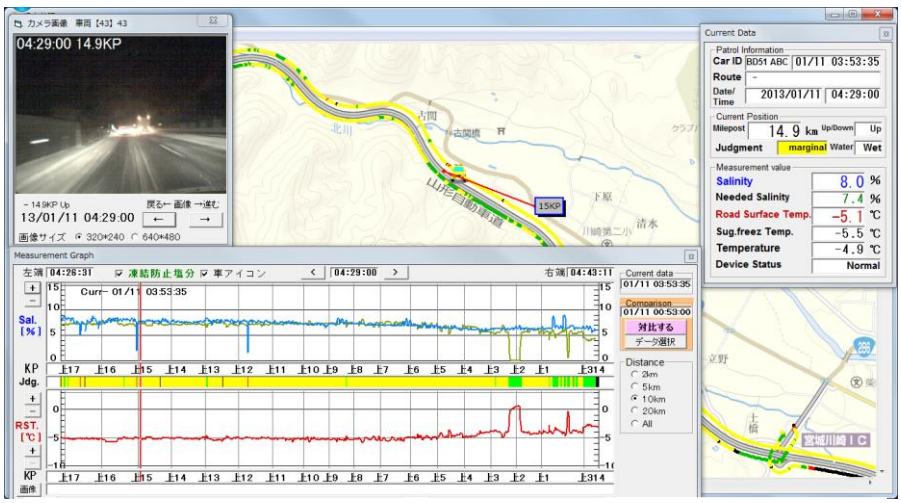

Figure 5 - Route software

on the NaCl freezing point graph; the amount of salinity required to prevent freezing at the current road-surface temperature is instantly calculated. Based on the result, the road surface condition is classified into 3 categories: Insufficient, Marginal, and Sufficient. Using the route software (Fig. 5), the condition is communicated to the snow-ice control center and classified into red, yellow, or green colors. In the vehicle, the measurement values and judgment can be confirmed on the monitor in front of the front passenger seat. (Fig. 6)

Figure 6 - In-vehicle display

4. Example of management using On-Vehicle Sensor

To utilize these features, NEXCO East Tohoku attached this system to 16 patrol cars. Based on the acquired route condition data, the anti-freezing operation is executed to enact careful road-surface maintenance. The examples are shown below.

4.1. Case example of additional application based on data measured by patrol cars

Fig. 7 shows the measurement data of an operation office on January 11. The road-surface analysis of the comparison data (previous patrol) during patrol measurement at 00:53 was almost at “Marginal”, and the salinity was close to the theoretical freezing salinity (4-5%). According to the weather forecast, snow was predicted. From 02:30, after completion of patrol, 0 – 10 KP of salt was applied. As a result of application, it was confirmed that the salinity increased during the next patrol at 03:53 (6-8%). The road-surface temperature lowered. It can be seen that the road-surface analysis showed the condition as being close to the theoretical freezing salinity, but road-surface safety could be secured.

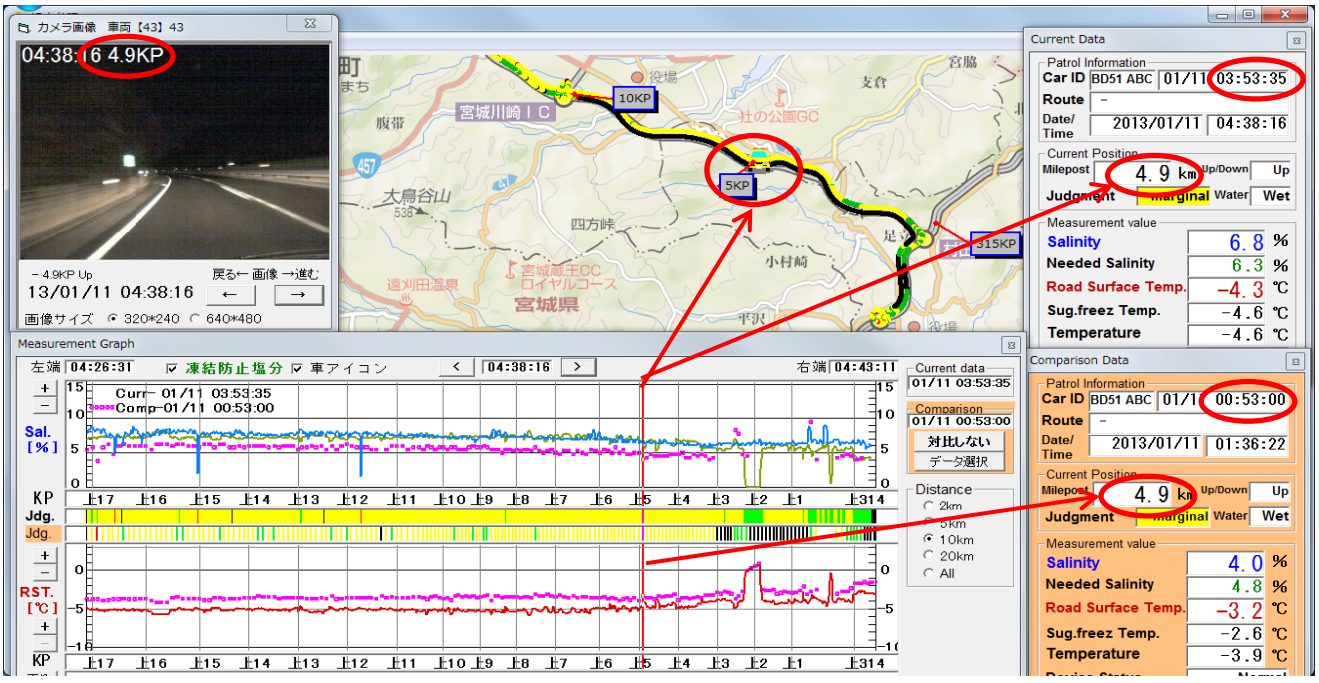

Figure 7 - Route software displaying measurement data on January 11

4.2. Case example of deferring of additional spray based on data measured by patrol cars

Fig. 8 shows the measurement data on January 2. Compared to the measured road-surface temperature (approx. 4°C) during patrol at 18:48 (previous patrol), the salinity was sufficient (0.5-2%). If the data was unknown, the salt that was usually applied experimentally was deferred. When data was examined during the following patrol at 22:20, the road surface temperature (3℃) was still above 0℃. The salinity was lower than the previous measurement, but it was confirmed that there was no problem caused by deferring the application. It was also confirmed that there was no residual salt. After the measurement, salt was applied from 23:40 for safety's sake.

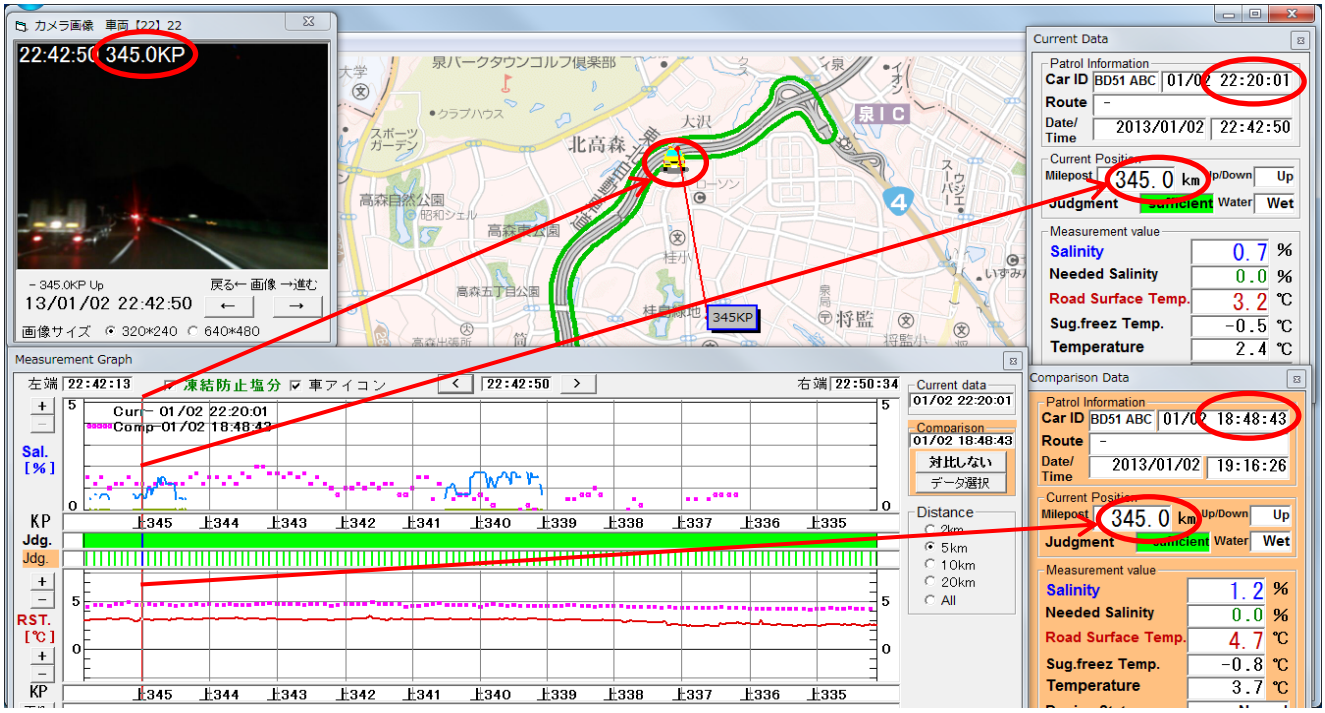

Figure 8 - Route software displaying measurement data on January 2

4.3. Visualization of route

As shown in the above graph, the route can be visualized by checking the condition of the entire road-surface to be maintained.

By visualization, the dilution degree between certain KPs or on slopes and bridges is analyzed and areas of low road-surface temperature are also analyzed. Dangerous points are scientifically extracted, and thus-called thermal map and critical application map can be prepared. This enables confirmation of current features of the route. In addition, ① the safe condition of the route can be confirmed, and ② instead of the usual application on entire routes, partial-route application only on dangerous points is possible. The amount of application can be reduced, leading to reduction of cost and environmental load. That is, expectations of improvement of traffic safety in winter and cost reduction can both be realized.

5. Securing operators' safety

Before the system was introduced, in order to measure the salinity, the patrol car was pulled over and operators got out of the car. They took the solution of one point and measured it using the hand salinity-measurement device. (Fig. 9) The problems were ① it was very dangerous to get out of the car on the road, ② the data was measured not on the road but on its shoulder, and ③ the measurement points varied depending on operators. By introducing the on-vehicle salinity sensor system, these problems can be solved. Because it is not necessary to pull over the car, operation time can be reduced, improving the operation efficiency and accuracy.

Figure 9 - Measurement after getting out of car

6. Future vision of continuous measurement system

Needless to say, the residual salinity is measured to examine the additional salt application timing. It is ideal to calculate the sections and amount of additional salt application and reflect the data to the operators of the patrol cars. An effective method of utilizing the salinity control diagram that considers the measurement data and regional features is currently being examined for trial calculation of the additional salt application amount. (Fig. 10)[4]

In this case, it is necessary that the road surface state is the solution state. By integrating this figure into the route software and calculating the application sections and required application amount, the amount of the anti-freezing agent to be loaded on the vehicle can be adjusted.

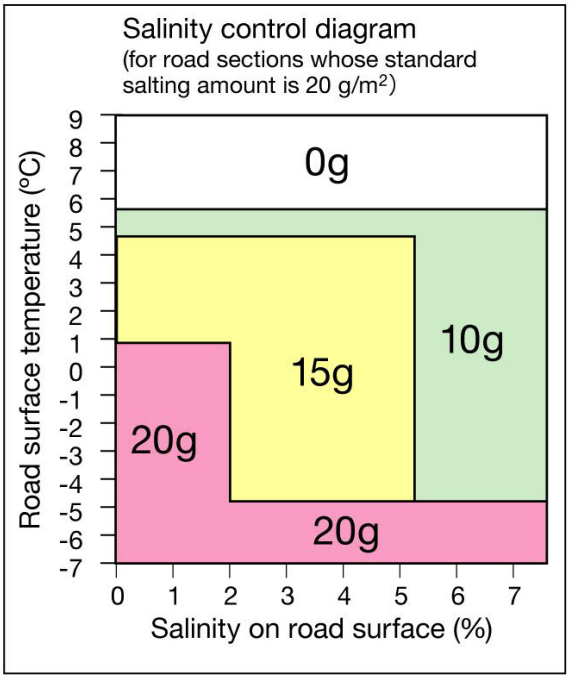

Figure 10 - Salinity control diagram

In addition, if this information can be transmitted to the salt-spreading vehicle and the salt application device can be automatically adjusted, "automatic spraying" requiring no operators might become feasible.

7. Conclusion

By utilizing the continuous salinity measurement device, road-surface condition can be monitored linearly in real time. By utilizing the measurement data, a new approach to the optimum spraying operation considering safety and efficiency has become possible. Needless to say, visual observation by patrol is necessary. However, by adding the imaging data, assistance in monitoring site condition has become possible.

There is no doubt that application of the anti-freezing agent in the snowy regions continues to be an important safety measurement. To assist in this operation, it is necessary to improve the device. To be more specific, the device should be improved so that the data can be measured at the areas where there is little water splashed by tires. The sensors should be downsized and functions should be added to improve the performance. In addition, the allocation condition of vehicles with the system is reviewed to construct the framework for automatic spraying and establish the new scientific road-surface maintenance method of expressways.

References

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