Traffic Safety Measures based on the Development and Operation of the Information Providing System Using Hail Detector

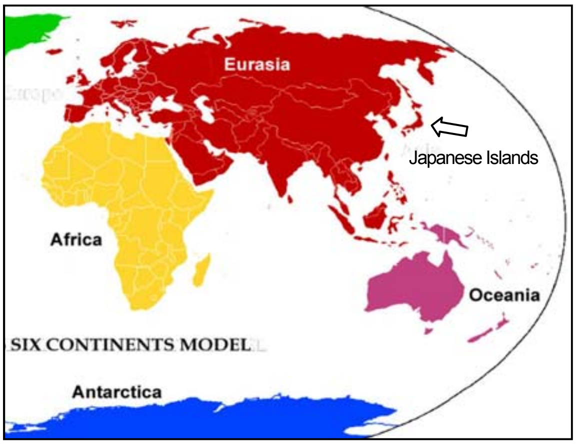
Hirohiko HATTORI & Tadao SATO
East Nippon Expressway Company Limited
h.hattori.ac@e-nexco.co.jp
Takao OHKURA & Kimihiko WAKASUGI
Nexco-maintenance Niigata Company Limited
t.okura.sa@e-nexco.co.jp

ABSTRACT

Since Japan is located in the mid-latitudes, cold air which has blown out of the Siberian anticyclone to the Japanese Islands during winter, causes heavy snow in the region on the Japan sea side. In early winter, amongst series of tunnels area on the HOKURIKU Expressway which faces to the Japan Sea (Asahi IC – Joetsu JCT), hail falls suddenly and heavily from the sky, and roads around the exits of the tunnels turn white and cause many traffic accidents and trouble in road maintenance such as snow cleaning. Thus far, we have provided cautionary information by each IC according to the snow information which we can obtain from patrols or weather observation devices. But, since the caution doesn't match the weather condition sometimes, for example it provides some information even though it is not snowing, it is not very effective. Therefore, to increase the effect of the caution system, it was required to provide information which can tell the real-time change of road status accurately to cars, which are running on the road.

This article reports the development, operation of the information providing system which uses a hail detector and effect by it.

Figure 1-Location Map



1. Introduction

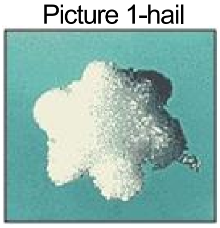
The Japanese Islands are located in Eastern Asia which is the east part of the Eurasia Continent (Figure 1).

The Korean Peninsula and the Japanese Islands,which are located surrounding the coast area of Eastern Asia, have many mountain districts and there are only a few plains by the coast.

Since the weather in Eastern Asia is influenced by the monsoon, the area has a lot of rain during summer. Especially, since Japan belongs to the subtropical zone, the annual range of the temperature and humidity is very wide, such as high temperatures and high humidity in summer, and the opposite in winter.

In winter, the Siberian anticyclone, which has cooled over the Eurasia Continent, catches plenty of vapor when it goes over the warm Tsushima Current in the Japan Sea because of the monsoon from the north-west. The anticyclone changes its type and brings lots of rain to the Japan Sea coastal area by crashing into the backbone mountain-chain of the Japanese Islands. Even when the temperature on the ground is 0 degree Celsius, if the air temperature at a height of 1500m was -6 degree Celsius, or it is -30 degree Celsius at a height of 5500m, it snows on the ground. Also, if the temperature at a height of 5500m is -36 degree Celsius, it would snow heavily. And if the temperature at a height of 5500m is -40 to -42 degree Celsius, it would snow extremely heavily. In this way, the difference of the temperature between the ground and the sky develops a cumulus convection to form cumulonimbus clouds.

Picture 1-hail



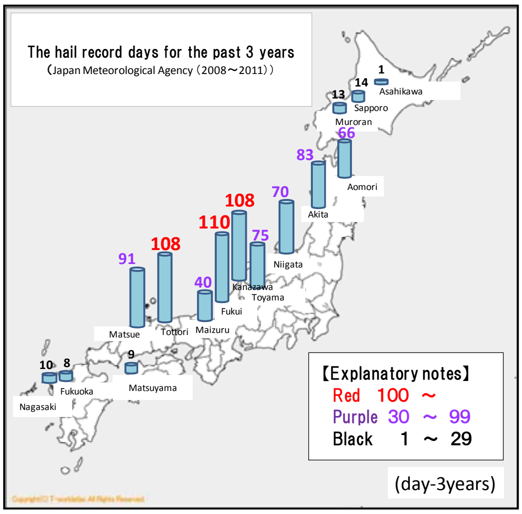
In this weather condition, hail will be observed with strong thunder.
Hail is a lump of ice whose diameter is less than 5 mm.
It could occur when the temperature is close to 0 degree Celsius. (Picture 1)

The area between the Asahi IC to Joetsu JCT on the HOKURIKU Expressway is a mountain road which runs by the Japan Sea coast and 70% of the structures are a series of tunnels. There are 26 tunnels within 69km, and there are many bridges, too (Figure 2). Since it is close to the coast line, the weather on this route has a tendency to change suddenly. Because of the instability in the atmosphere in early winter, hail occurs frequently on the Japan Sea side (Figure 3). Then, the road surface by the exit of the tunnels turns white in a moment and it causes many traffic accidents. Therefore, we provide “Snow present at the exit of the tunnel” information at each IC section in a wide range according to the snow information which we obtain from our patrol or weather observation devices. But there were some cases in which the information didn’t match the actual weather, for example the information was provided though it wasn’t snowing. In this way, it has been considered that the impact of the caution alert seems weak. So, to gauge the change of the road surface of the exit of the tunnels accurately and provide a real-time accurate caution alert to the cars which run in tunnels, we developed the weather observation device which is specialized for hail, and established the real-time information providing system.

This article reports the operation status and its effect.

Figure 2-Target Chart

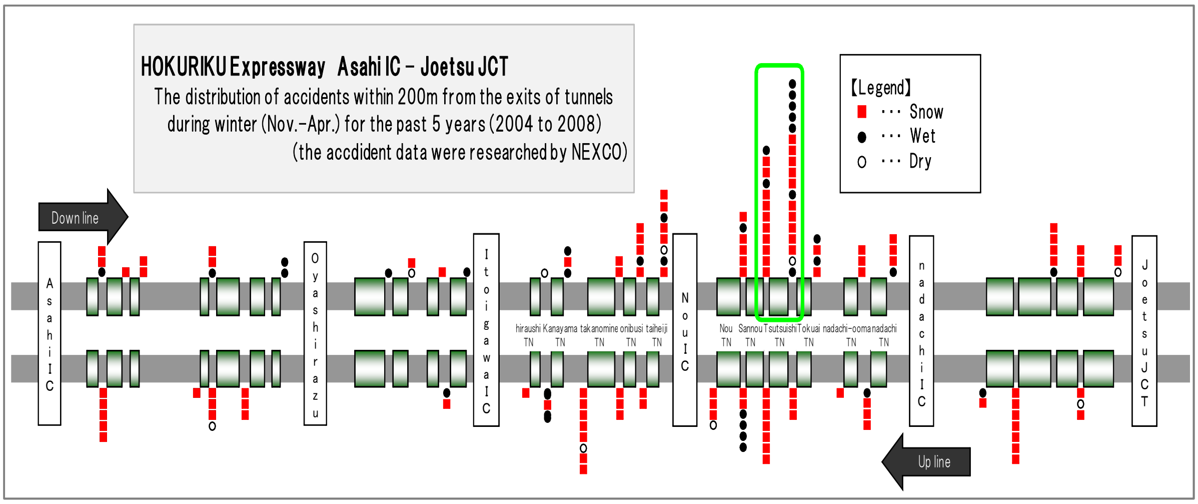
Figure 3-Hail distribution



2. The current condition and task of road management

In Niigata prefecture, the number of traffic accidents during winter is about three to four times than any other seasons. Most of these accidents are caused by a skid, and it has been considered that the road surface condition has a great influence. Concerning accidents within our jurisdiction between the Asahi IC to Joetsu JCT on the HOKURIKU Expressway, many accidents are concentrated on the exits of the Sanno tunnel and the Tsutsuishi tunnel on the down line (Figure 4).

Figure 4-Distribution of accidents

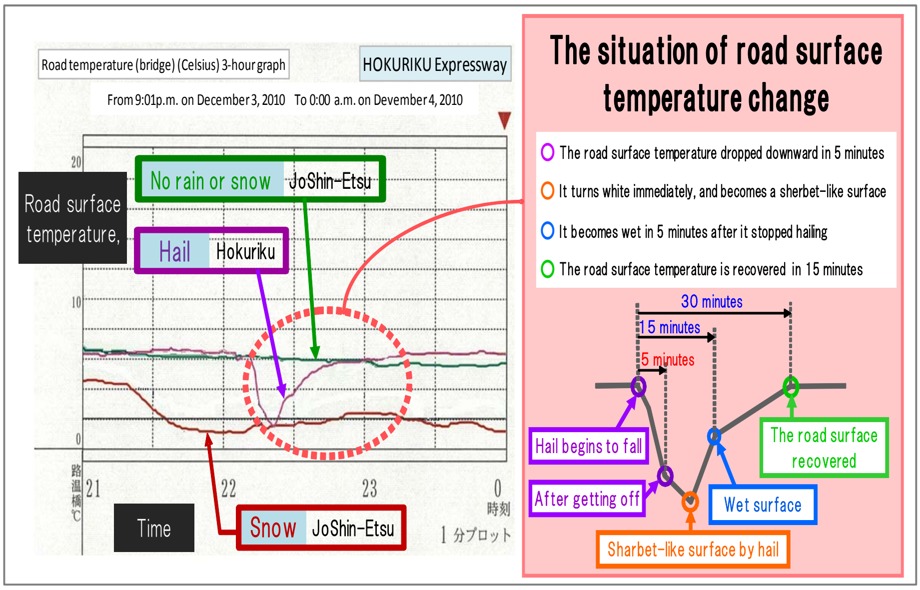


Various measures to decrease traffic accidents during winter have been taken thus far. Reinforcing and re-planning the snow cleaning truck distribution, road heating, water sprinklers for the roads, are examples of these measures. However, these measures weren't very effective for hail which occurs frequently on the Japan Sea coast side. It is because changes to the road surface in a very short space of time is one of hail's characteristics (Figure 5), and the range of the area which has this phenomenon is very limited compared with snow and rain. The feature is influenced greatly by tunnels. Though the road before a tunnel may be wet, the surface at the exit becomes sherbet-like frequently, especially where the tunnels are sequenced. Since the sudden change of the road surface influences driving operation greatly, it causes slipping. Though we provide "Snow at the exit" caution alert on the information board, since there were many cases in which the information didn't match the actual weather condition, the reliability of the information was decreasing.

This is why we assume that the impact of the caution is not good enough.

Therefore, our task is to reduce traffic accidents and to provide suitable information which reflects the sudden change in the road surface conditions, and to conduct quick and efficient snow control work.

Figure 5-A graph of the transition of the road surface temperature



3. The occurrence circumstances of hail and accidents

Since there were many accidents, whose cause could be the occurrence of hail, on November 21, we conducted the hail occurrence situation research with the hailstone detector, and we analyzed the tendency as to how hail causes the occurrence of accidents. The target area was between the Itoigawa IC to Joetsu JCT, which we selected according to the accident distribution status in during winter (Figure 4) from the past 5 years.

Figure 6-Hail and accidents (Nov.20 to Dec.31,2011)

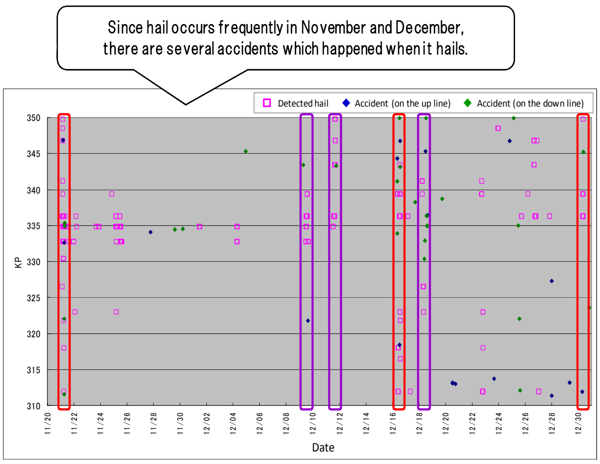


Figure 7-Hail and accidents (Jan.1 to 31,2012)

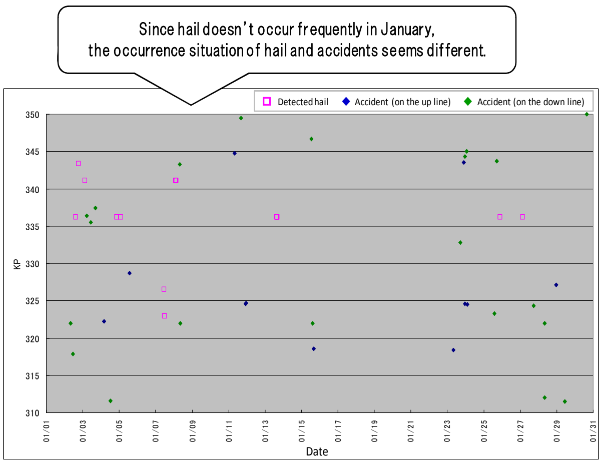


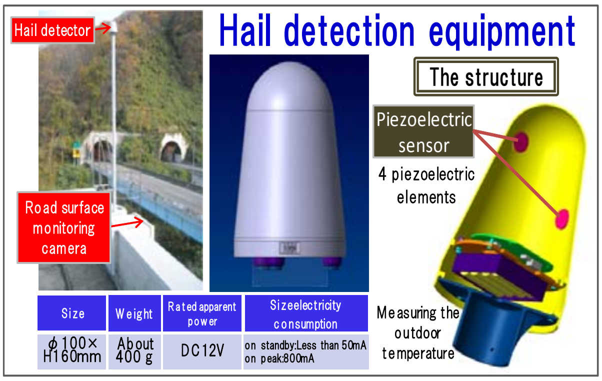
Figure 6 and Figure 7 show the time of hail occurrence, which was detected by the hail detector from Nov.20, 2011 to Jan.31, 2012, and the number of accidents (including property damage accidents), which happened about 310-250KP where the hail detectors are set, by each KP. It can be considered that hail influences on the road surface for 15 minutes after it occurs (see Figure 4). But since hail often occurs on and off, we abstracted the followings (the ones in the □ in Figure 6) as the accidents which happened within 30 minutes after hail occurred.

We found out that the occurrence of hail and the occurrence of accidents were almost synchronized, according to the occurrence status of hail and accidents. Also, since the spot of the occurrence of hail matches the spot of accidents, it can be assumed that hail makes the road surface condition worse and it causes an accident. But, though we had hail in January 2012, there were no accidents which happened in the same spot at the same time. We consider the reason why the same kind of accidents didn't happen as follows. Since there was snow on the road, drivers paid more attention to the road surface when they drove, regardless of the hail. Therefore the influence of hail was much smaller than in November or in December.

4. Development of a hail detector

4.1 Devised to detect hail certainly

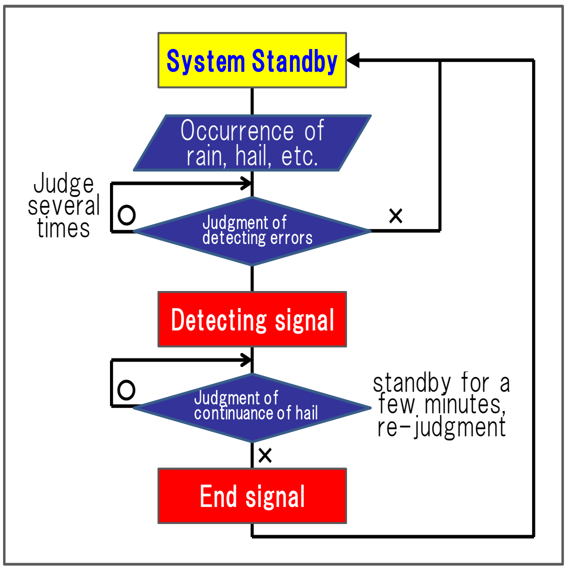
Picture 2-The installation situation of hail detection equipment



Since rain and snow, which fall in a comparatively wide range, can be detected by the existing weather observation facilities, it is not necessary to use this detector to detect them.
Therefore, we focused on the "sound" of hail, which occurs when "providing granular" hit the ground. Also, to make it more accurate, we pursued the ability to detect hail from any angle, on structures which don't have snow on them, the detection flow without errors, and the ways to provide suitable information for customers. As a result, we developed the "Piezoelectric resin dome hail detector," in October 2010, under the concepts of "obtaining real-time information" and "providing highly reliable information." (Picture 2)

4.2 The features of the “hail detector.”

Figure 8-Assessment program for information feed



The following are the features of the hail detector.

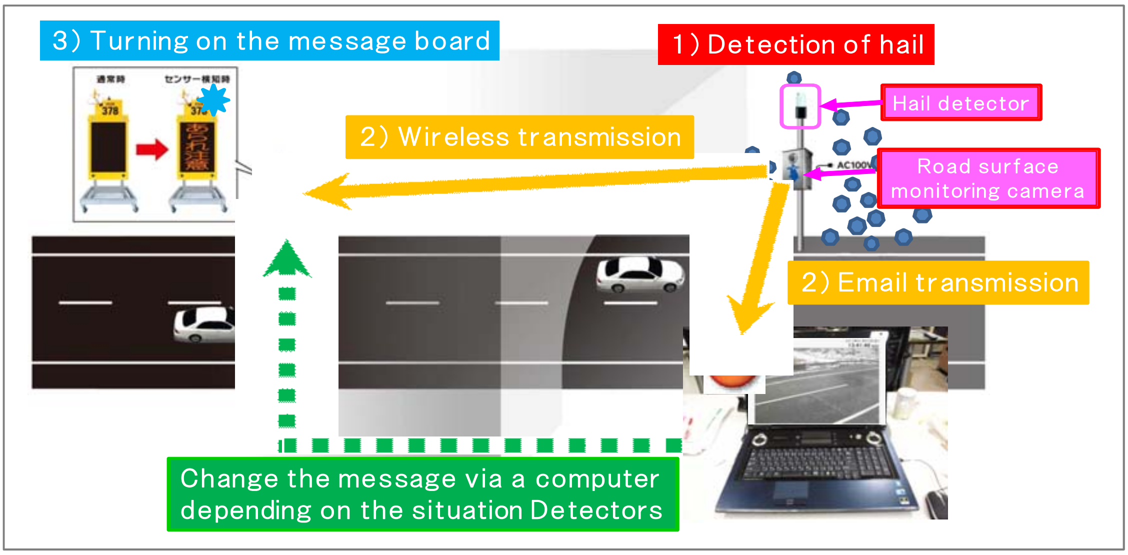
1) The “Piezoelectric dome shape, “ which existing weather observing devices technology has not utilized until now, has a structure on which snow never sticks.
2) Since we focused on hail, it has a simple structure.
   Because it’s small and light, it is handy to use and it can save energy and costs.
3) Since it is an energy-saving design, it is environmentally-friendly.
4) As the Assessment program (Figure 8) shows, since it conducts multiple assessment to provide real-time information after it has detected hail, the possibility of detecting an error is very small.
5) It is easy to link-up or connect with quick message boards and monitoring cameras. The following is a report concerning the establishment, operation of the information providing system which uses a hail detector and effect by it.

5. The establishment , of the “real-time information providing system”.

In the 2010 fiscal year, we took the following measures by giving priority to “providing real-time information.” Figure 9 show the information providing system with the hail detector. We observed sudden changes of weather by setting up the hail detectors and the road surface monitoring cameras at the exits of tunnels. (picture 2)

Also, we automatically send the information to the snow/ice control office in the management office, and operate the system to display “hailing at the exit ⇔ Caution” message on the quick message boards in tunnels in real-time by wireless transmission.

Figure 9-The information providing system using hail detector



6. Evaluation of the effect of providing hail caution information

6.1 The methods to verify the effect, and the purpose of the effect

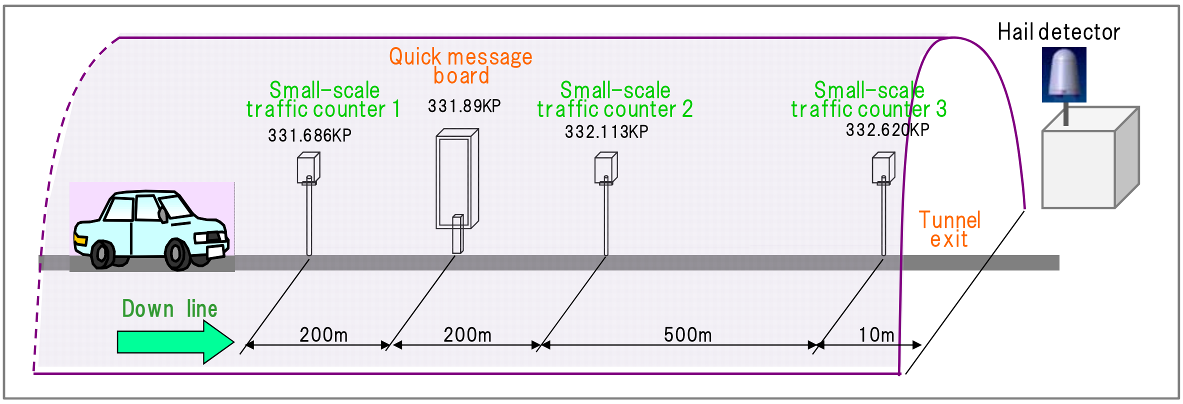
To evaluate the effect of providing caution information for hail, we compared the changes in the speed of cars, which run through the exits of tunnels both at times with/without the caution, and we analyzed the tendency of reducing driving speeds with the information. We used the data from the small-scale traffic counters which were set up near the message boards to measure the change in driving speed. Figure 10 shows the position of the counters.

We expected the following by providing the hail caution information in real-time.

1) Improvement of the caution impact for improvement in reliability of the information.

2) Reducing the driving speed at the exits of tunnels and reducing the number of skid accidents, etc.

Figure 10-Assessment program for information feed



6.2 Verification of the effects of the status of reducing driving speed

6.2.1 *The basic analysis for the speed distribution*

There are measurement errors between the actual speed and measured value, the gap from the measurement error will be included if you compare the measurement value ① to ③ from the small-scale traffic counters mutually. Therefore, we calculated the “correction value of the speed,” which normalizes the measured value of the small-scale traffic counter ① to ③.
We divided the measured value with the correction value and conducted the analysis.(Table 1)

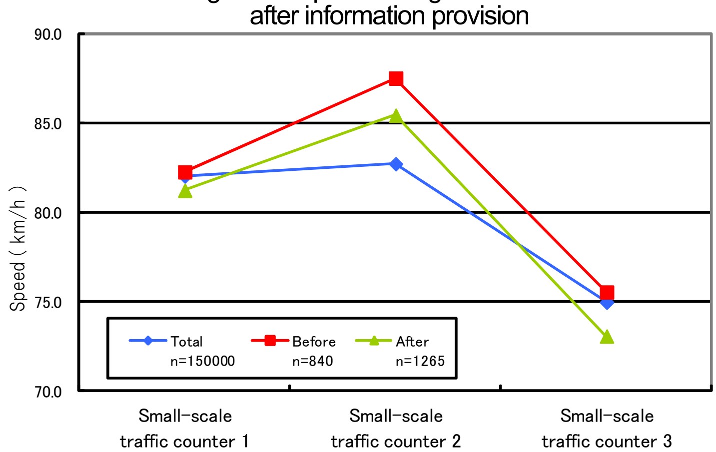
No.	Running speed (km/h)	Measured valued (corrected) Down line 331.7 (km/h)	Down line 332.1 (km/h)	Down line 332.6 (km/h)	Note
1	100	87.8	86.6	92.7	
2	100	89.1	107.4	97.6	
3	80	72.0	76.9	67.1	
4	100	86.6	89.1	84.2	
5	100	89.1	87.8	80.5	
6	100	87.8	86.6	92.7	
7	100	90.3	93.9	81.7	
8	100	84.2	92.7	83.0	
Average value		87.84	92.01	87.49	Average except No.3
		↓ If the average value of the small-scale traffic counter 1 was “1.”	↓ 1.047	↓ 0.996	

Table 1-The correction value for the speed

6.2.2 *The speed distribution status before and after we provided the information*

We checked if a caution alert information was provided or not, then abstracted data in 10 minutes before the information as “before information,” and the ones at the time when the information was provided as “after information” to compare the change of the speed before and after the information was provided.
Figure 11 shows the transition of the comparison of the average speeds in the whole period (1 month) and in bad weather (when it hails), concerning the speed status, which is measured by the small-scale traffic counter, before and after we provided the information.

Figure 11-Speed changes before and after information provision



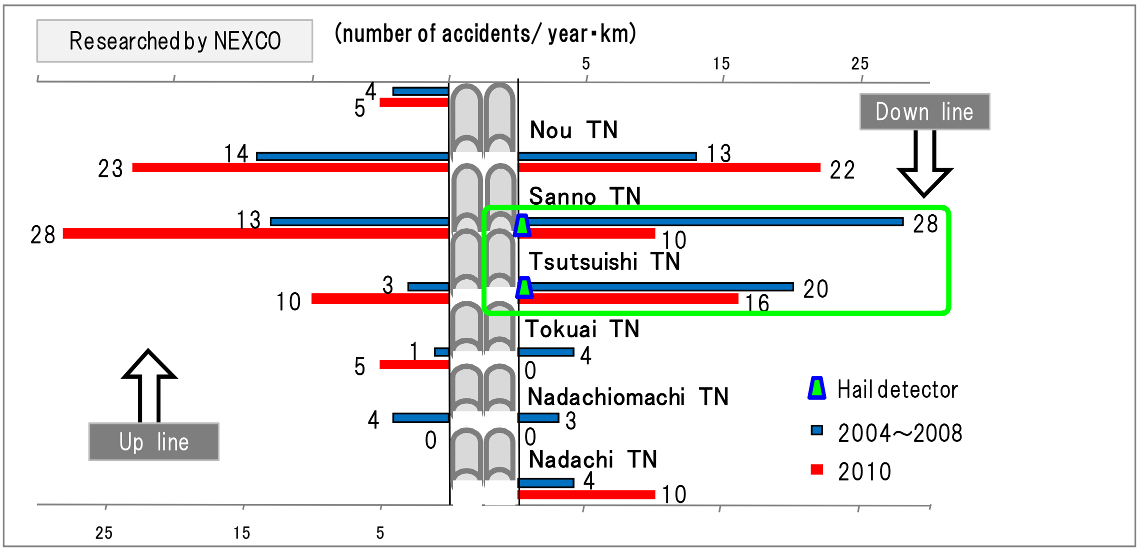
Concerning the whole month data, the average speed in tunnels are almost steady, but the speed is reduced at the exits. But in the data at the time of bad weather conditions, which means 10 minutes before hail started, since it is easier to drive in tunnels than outside, the speed in the tunnels was getting faster and it was reduced in the whole month average value at the exits. The average speed after we provided the real-time information, was increased gradually in the tunnels, but it was reduced more than the average of “before information” at the exits of the tunnels. It is assumed that this is an effect of the caution information. Though it was only a little, it showed the tendency of reducing driving speeds. This is why it is necessary to keep providing highly accurate information and keep observing in the long term.

6.3 Reducing accident effects by introducing the information providing system

6.3.1 *Analysis of accident occurrence circumstances at the exit of a tunnel*

Figure 12 shows the accident occurrence circumstance within 200m from an exit of a tunnel during winter in comparison to the average value for 5 years (from 2004 to 2008 fiscal year), and in the 2010 fiscal year. Since the winter in the 2010 fiscal year was very cold and experienced heavy snow, there are many accidents in this range. But, the accidents at the exits of the Sanno tunnel and the Tsutsuishi tunnel on the down line, where we conducted the real-time information providing, were smaller than the average value of the past 5 years. It can be assumed that providing hail caution information brought some good effect on the accident occurrence circumstances. How to observe and provide information for the other tunnels, which tend to have more accidents, is our task after the 2011 fiscal year.

Figure 12-The accidents occurrence status within 200m from the exits of tunnels during winter, which is compared with the data of the past 5 years



6.3.2 *Analysis in the area between Nou IC to Nadachi Tanihama IC*

To grasp the transition of the number of accidents at the exit of the Sanno TN (332.5kp) and at the exit of the Tsutsuishi TN (334.8kp) on the down line, where we have been providing the hail caution information since December 2010, we clarified the accident occurrence circumstance within 5km before and after the Sanno and the Tsutsuish TNs (Nou IC – Nadachi Tanihama IC) to analyze the tendency of accident occurrence in the spot where we provide the information.

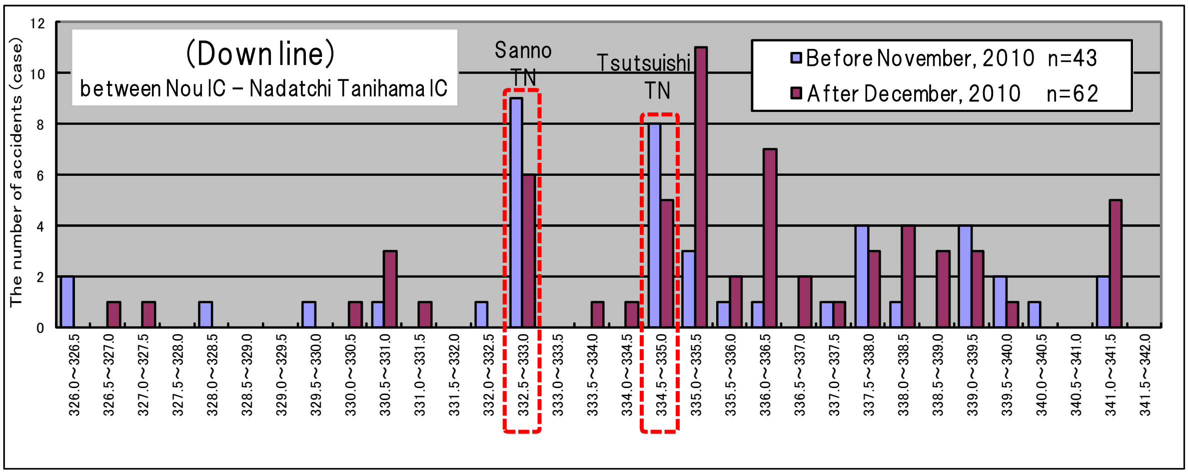
Also, the period, the number of accidents, and the area, which our clarification of the accident occurrence circumstance covered, are as follows:

1) Period covered: Winter (Nov.- March) in 2008 to 2012, which was for two years after we started providing information alerts

2) Accidents covered: All the accidents, including ones with property damage

3) Area covered: Between Nou IC to Nadachi Tanihama IC on the down line of the HOKURIKU Expressway

Figure 13-The transition of the number of accidents before and after we started providing information

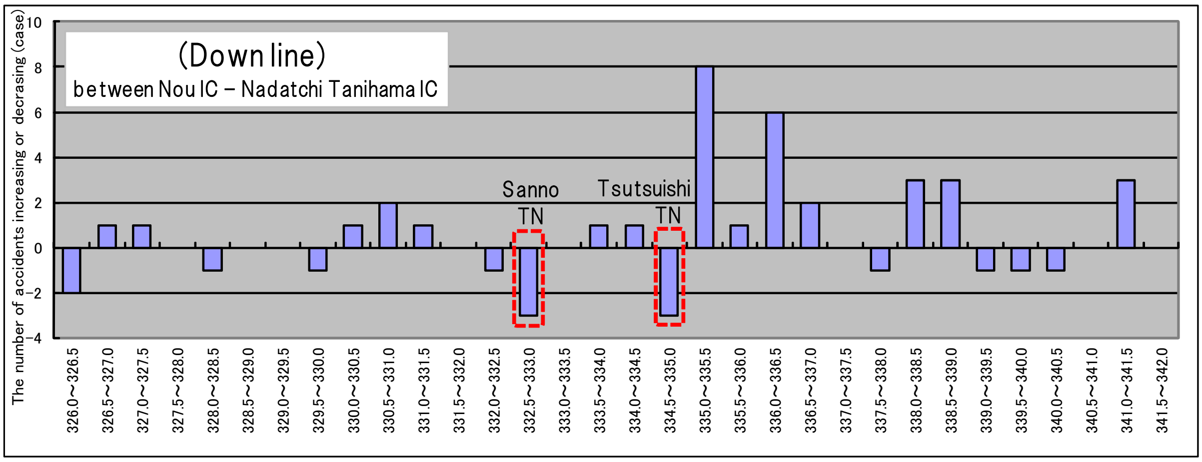


■Transition of the number of accidents

Figure 13 shows the number of accidents which was aggregated by 0.5kp pitch for two years before and after we started providing the information. Figure 14 shows the number of increasing or decreasing.

The number of accidents after we started providing the information at the Sanno TN and the Tsutsuishi TN is greatly decreased compared with the other spots. It can be considered that it is an effect of the hail caution information stream, which we provided in 2011 that is the covered period for this aggregation of the accidents.

Figure 14-The number of accidents increasing or decreasing before and after we started providing the information.



7. Conclusions

The system with the hail detector has features such as “it never misses hail” and “it can grasp the real-time status.” We provided the caution information stream using this system, and as a result, the number of traffic accidents at the exits of the Sanno tunnel and the Tsutsuishi tunnel on the down line decreased, we concluded. It could be said that the reliability of the information has become higher and the effect of the caution information stream has improved by using this system.

In the winter of the 2012 fiscal year, which is the third year of providing the information, we operated a full-scale over the entire route, picking up the spots where hail occurs frequently and might cause many accidents. Since we have cooperated with a weather forecast company, the hail detector is instrumental in a quick snow control situation. Though hail makes the road surface white and slippery in a very short space of time, it will be melted immediately when it stops falling. Therefore we provided information for when the road surface has the sherbet-like condition, or emphasized caution at the exit with blue flushing lights, according to the duration of hailing. In this way, we tried out best to improve the reliability of the information.

What we tried to achieve is to provide a safe driving environment. We believe that the credibility of the information which we provided is one of the most important elements. Therefore, the following three tasks are necessary. 1) obtaining highly accurate information, 2) to insure a stable detecting function, 3) and to provide real-time and highly reliable information

Since the information providing system with the hail detector can be linked-up or be connected with other devices easily, it can be expected to be used for road management during winter. It will be our pleasure if this system helps.

We will examine the system and further increase the accuracy of the hail prediction ability for more efficient snow control work. And we would like to keep maintenancing an environment in which every driver can drive safely even when the weather suddenly turns bad, by providing suitable information and quick snow control.

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