EFFORTS TO IMPROVE THE VISUAL ENVIRONMENT ON EXPRESSWAYS THAT PASS THROUGH AREAS OF SNOWSTORM AND DRIFTING SNOW

K. Abe
NEXCO MAINTENANCE TOHOKU Co., Ltd., Miyagi, JAPAN
k.abe.ac@e-nexco.co.jp

T. Takahashi
NEXCO MAINTENANCE TOHOKU Co., Ltd., Miyagi, JAPAN
t.takahashi.sg@e-nexco.co.jp

ABSTRACT

There are few places in the world that experience snowfalls as heavy as those in the Tohoku District. Expressways crisscross the plains and mountainous regions, and during the coldest period of the year the driver’s visual environment deteriorates due to poor visibility caused by snowfalls (blizzards) and drifting snow and because of the burying of roadside visual guidance flags under accumulated snow on the shoulder of the road. These weather-based traffic obstacles are the cause of traffic accidents and road closures, and pose an important problem in maintaining the functionality of the expressways.

So far the following three measures to aid visual guidance have been instigated:

(1) Self-luminous delineators (Using solar-cell batteries in this instance)
(2) Visual guidance flags (Flags that reflect vehicle headlights at night)
(3) Blue Line (The continuous spraying of a line of blue pigment on the banks of snow by the roadside)

KEYWORDS

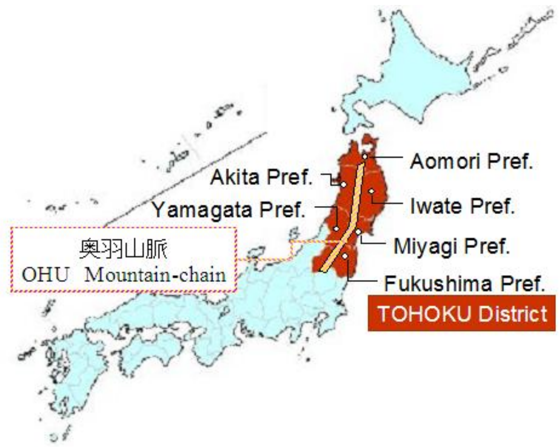
VISUAL GUIDANCE / VISUAL ENVIRONMENT / EXPRESSWAY / SELF-LUMINOUS DELINEATOR / FLAG / BLUE LINE

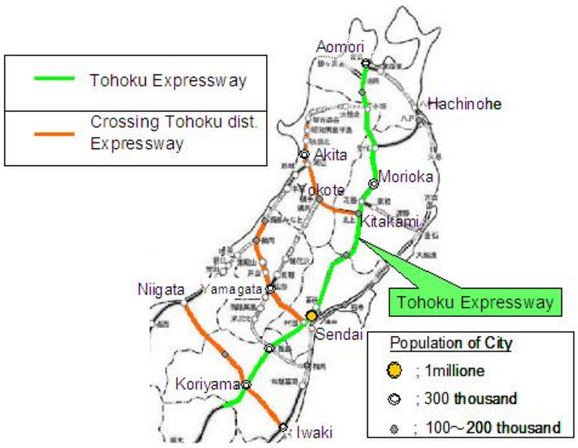
1. INTRODUCTION

1.1 The location of the Tohoku District of Japan, and its expressway network

The Tohoku district is located in the northernmost part of Honshu, the largest island of the Japanese archipelago, between latitudes 41 and 36 N. It measures roughly 500 km north to south and roughly 170 km east to west, and has a total land area of about 63,000km^2.

As of March 2009 the expressway network in the Tohoku District comprises some 1,400 km of road that are open to traffic. Of this 1,266 km of road where traffic is comparatively heavy are operated by East Nippon Expressway Company Limited (hereafter NEXCO East) as toll roads. Maintenance work and the collection of tolls are carried out by 15 operation offices. (Fig.1)(Fig.2)





<Fig.1-Location of the Tohoku district> <Fig.2-The expressway network>

（The figure on the right is taken from the National Expressways Construction Association 'High-Standard Trunk Road Network Map'）

1.2 The climate and topography of the Tohoku District and the impact on its expressways of snow storms and drifting snow

The Japanese Archipelago is located in a temperate monsoon region. The Tohoku District is situated in a cool zone within this, has four distinct seasons and plentiful precipitation, and is covered by the polar air mass for long periods. The Ohu mountain chain (altitude 1,000 to 2,000m) forms a ridge down the center of the Tohoku District, and this combined with the winter distribution of atmospheric pressure typical of Japan causes heavy snows to fall on the lowland areas between the mountains and the Japan Sea.

The Tohoku Expressway, which is the main route of the expressway network in the Tohoku District, runs north-south on the eastern side of the Ohu mountain chain, through hilly country and low-lying areas used mainly for agriculture. With the exception of the northern section, the Tohoku Expressway does not get that much snowfall; but snow that has once fallen and settled is picked up by the strong winds that blow down from the Ohu mountain chain, so that snowdrifts are a frequent occurrence.

On the other hand, the three expressways that cut more or less right across the Ohu mountain chain run through areas at the western foot of the mountains where the annual snowfall reaches 6 to 12 m.

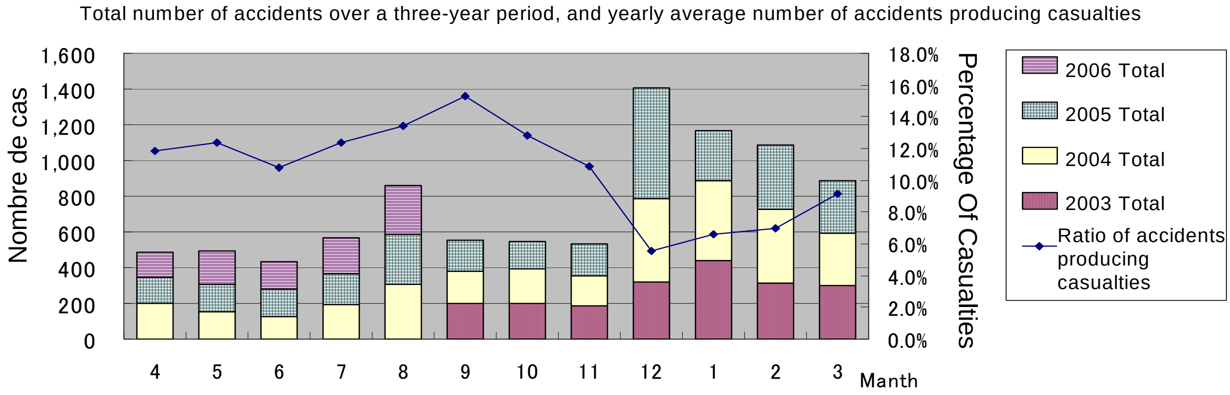
2. CHARACTERISTICS OF WINTER TRAFFIC
－TRAFFIC ACCIDENTS AND ROAD CLOSURES ARE FREQUENT OCCURRENCES－

The total number of accidents occurring on expressways in Tohoku over a period of three years in the past (September 2003 to August 2006) average out at roughly 3,006 accidents per year, of which 292 per year were accidents producing casualties and 15 were fatal accidents.

Fig.3 shows the monthly variations in the total number of accidents including those involving damage to property and the yearly average number of accidents producing casualties. This shows that many traffic accidents occur during the winter months (December to March); while most of these are accidents involving damage to property with no casualties, traffic safety in the winter months is a major issue.

In particular, the expressways may be closed to traffic when visibility is impaired due to heavy snowfall intensity or drifting snow, in order to prevent one accident being the cause of more traffic accidents.

A breakdown of the causes of road closures on sections of road between interchanges from 2005 to 2009 shows that the most common cause, accounting for 40% of the total, was poor visibility due to snow storms, followed by traffic accident (20%) and earthquake (5%).



<Fig.3-Total number of accidents over a three-year period by month, and yearly average number of accidents producing casualties (September 2003 to August 2006) >

3. WINTERTIME ROAD MANAGEMENT AND VISUAL ENVIRONMENT STRATEGIES

3.1 Snow removal operations

Ordinary snow removal operations are carried out in a formation comprising 2 or 3 snow removers followed by a traffic sign vehicle guarding the rear of the formation. (Pic. 1)

As the bank of snow formed when the plough of the snow remover pushes snow onto the shoulder of the road grows larger, snowbreak fences and visual guidance facilities become buried in the snow, obstructing visual guidance to drivers and, depending on the circumstances, causing them to lose sight of the direction in which they should be traveling. Thus in between snow removal operations rotary snow ploughs are used to throw the banks of snow piled on the shoulder clear of the road, combined with human muscle power used to uncover visual guidance facilities; but this is not necessarily satisfactory. (Pic 2)

<Pic.1- Snow removal operations >

<Pic.2- Removal of snow bank by rotary snow plough >

<Pic.3- Snowdrift prevention forest and snowbreak fence >

3.2 Visual environment strategies to cope with snow storms and drifting snow

On sections of road where snow storms and drifting snow are of frequent occurrence, NEXCO East has up until now planted snow drift prevention forests and erected snowbreak fences.

The total length of snow drift prevention forest that has grown to a height of 5 m and higher (Japanese cedar trees, Norway spruce, Sakhalin fir, etc) has reached some 135 km (as of the end of 2007). However, the inability to secure a wide enough strip of land for planting limits the effect of the snow drift prevention forests, and generally snowbreak fences to a height 3 to 5m higher than the road surface are erected along the top of the shoulder slope. (Pic 3)

The total length of snowbreak fence erected has reached some 200 km, mainly to the north of Sendai.

However, on many sections of the expressways that run across the region, in many cases the direction of the prevailing winds and the direction of the road are the same, so that snow drift prevention forests and snowbreak fences do not function all that effectively.

Of course, when visibility is impaired due to snow storms or drifting snow, this results in long sections of road having to be closed to traffic at the same time, in order to prevent accidents.

For this reason during times of impaired visibility supplementary schemes to provide visual guidance for drivers and indicate the position of obstacles such as snow banks have been studied and adopted as new road safety measures.

4. SOME INSTANCES OF NEW MEASURES TO IMPROVE THE VISUAL ENVIRONMENT

4.1 Self-luminous delineators

Convex mirror-type delineators are erected on expressways as standard visual guidance facilities. In addition to these, self-luminous delineators (visual guidance lights with a light-emitting source) have been erected in areas where impaired visibility is a frequent occurrence. In the past incandescent lamps were used, but in recent years an LED (light emitting diode) system is used. (Pic 4, Pic 5). So that these self-luminous lights can promote visual guidance, a system is adopted whereby they flash on and off in unison on continuous stretches of road. In the case of an LED system, the maximum luminosity is in excess of 30cd. The self-luminous delineators take their power from the power lines, and have been erected along some 300 km of road (As of March 2008). At roughly 90,000 yen per light (installation cost + material cost), these lights are expensive.

In 2006 solar cell LED lights, which can be erected easily, needing no power cables and each costing roughly one-tenth the cost of an electrically-powered light, were adopted on a trial basis. (Pic 6) The solar cell self-luminous delineators do not match ordinary electrically-powered lights in terms of the brightness of the light they emit, but they are very serviceable in that they can be set up simply by being fixed by a metal band to existing snow poles at a height of 2 m.

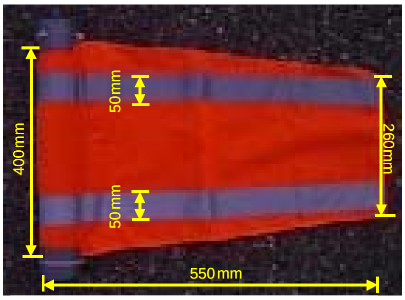
<Pic.4 -Incandescent lamp>

<Pic.5 -LED>

< Pic.6-
Solar cell-powered LED >

4.2 Visual guidance flags

Roadside delineators suffer loss of function if snow adheres to their luminous surface, and so a flag with a reflector attached was designed. The flag can be fixed to the uppermost part of an existing snow pole; in addition to the flag itself providing visual guidance to drivers as it flutters, by fluttering it can prevent snow sticking to the snow pole. During the winter the flags are set up at intervals of 50m at a height of 2.8m above the road surface on the shoulder and on both sides of the median strip, to clearly indicate both sides of the roadway. (Pic 7)(Pic.8)(Pic.9)



< Pic.7-
Visual guidance flags >

< Pic.8-Installation >

< Pic.9-
Reflection Camera flash) >

c. Blue line

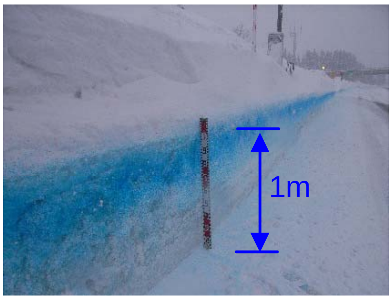
The Blue Line is a clearly-visible band of blue-colored liquid sprayed in an unbroken line onto the bank of snow piled on the shoulder of the road, in an attempt to help drivers understand the position of their own vehicle in relation to the geometric alignment of the road and the position of the snow bank.

The liquid sprayed onto the snow bank is water mixed with a pigment that is harmless to living creatures and to the environment (water : pigment = 1000 : 1.5)

The Blue Line is sprayed onto the snow bank from spraying equipment (power sprayer + water tank) mounted on a 2t truck. The 2t truck runs at a distance of approximately 1.5 m from the snow bank and the blue-pigmented liquid is sprayed from a nozzle fitted to the lower part of the bed of the truck. The liquid is sprayed a distance of 1.5 m and spreads out to color the snow bank with a band about 30 to 40 cm wide. The angle of spray is adjusted so that the top edge of the Blue Line is roughly 1.0m from the surface of the road, which is equivalent to the position of the guard rail. (Pic.10)(Pic.11)(Pic.12)

< Pic.10- Spraying equipment >

< Pic.11- Spraying the Blue Line >



< Pic.12- The Blue Line after spraying >

5. VERIFICATION OF THE EFFECTIVENESS OF MEASURES TO IMPROVE THE VISUAL ENVIRONMENT

5.1 Method of investigation

In a poor visual environment, the driver needs to be able to understand and be aware of the existence of visual guidance facilities if he is to understand the road alignment and location of obstacles. Accordingly a fixed-point observation survey of existing electrically-powered self-luminous delineators (with incandescent bulbs) using a video camera was carried out over a period of one month (February to March 2009). The images taken and visibility data accumulated were analysed and a study made of how well the delineators could be seen when visibility was poor.

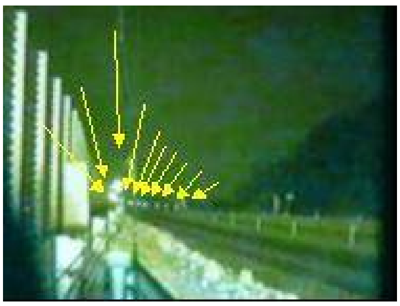
In addition frequent users were asked to participate in written and oral questionnaires regarding visual guidance measures using these facilities, and the results were sorted and studied.

5.2 Fixed-point observation by video camera

5.2.1. Method of observation

A fixed CCD camera was set up on the outside of the snowbreak fence at 13KP on the Akita Expressway (on the eastern side of the Ohu mountain chain), where visibility is frequently impaired due to snow storms. The CCD camera was set up at a height of 1.2 m from the road surface, this being estimated to be the viewpoint from an ordinary motorcar. Together with the video capture, visibility was measured using a backward-scatter visibility meter. Pic.13）

< Pic.13- Observation equipment in position >



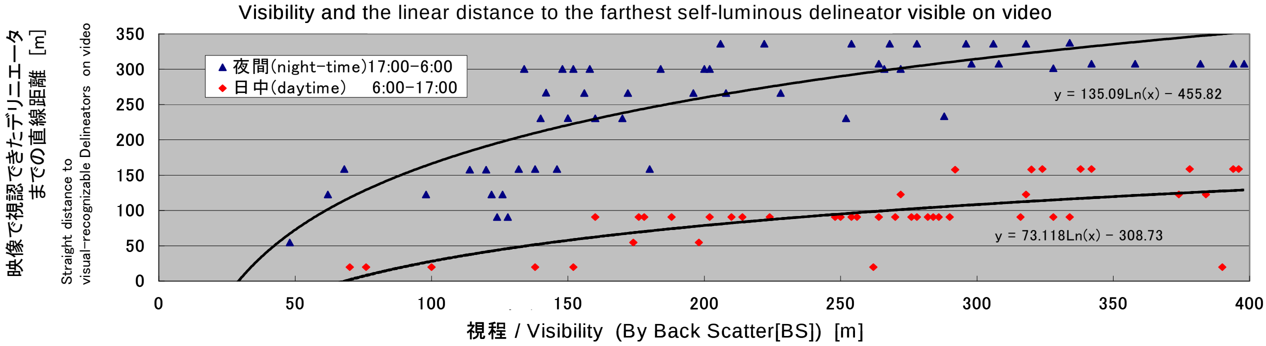
< Pic.14- Good visibility >

< Pic.15- Poor visibility >

5.2.2 Results of video analysis

The observation point is located on a R=1,000m curve to the right, and as can be seen in Pic 14, when there is good visibility of 350m 10 electrically-powered delineators (to a distance of 337 linear meters from the camera) can be ascertained, and it is possible to make out the curvature of the road alignment. However, when a snow storm reduces the visual field to a rather poor 48 m, it is possible to make out only 2 of the electrically-powered delineators.（Pic.15）

The relationship between measured visibility and the linear distance to the farthest visible electrically-powered delineator, classified into daytime and night time, is shown in Fig.4.



＜Fig.4 -Relationship between visibility and the linear distance to the farthest self-luminous delineator visible on video＞

From Fig.4 it can be seen that at night time the distance at which the electrically-powered delineators can be seen is greater than the measured visibility; even when visibility is poor due to a snow storm it is possible to impart to the driver the alignment of the road over a greater distance than the range of visibility.

During the daytime, on the other hand, due to the bright surroundings the distance at which the light emitters could be discerned was diminished compared to the night time. The distance at which the lights could be seen was 2 to 3 times greater at night than during the day because of the greater contrast in light intensity between the lights and their surroundings.

5.3 Evaluation by frequent users

5.3.1 Self-luminous delineators

Of the new measures to cope with impaired visibility, the electrically-powered delineators were given the highest evaluation by frequent users.

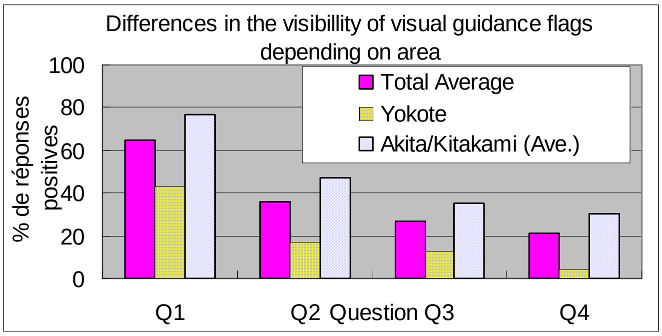
While other visual guidance strategies rely on the driver taking note of the various facilities and using them as marks to aid driving, the self-luminous delineators themselves stimulate the driver’s vision and provide a clear, unbroken indication of the alignment of the road. In addition the regularly-spaced blinking of the self-luminous delineators remain as an afterimage in the mind’s eye of the driver even when there is a sudden impairment of visibility, so that the more the visibility environment deteriorates, the more striking is their effect.

Solar cell-powered self-luminous delineators do not give off as strong a light as the electrically-powered ones, and when the two are compared the visual guidance effect of the solar cells is relatively short. Even so, many of the frequent users acknowledged their visual guidance efficacy, so they do have a certain degree of effect. Conceivable methods of enhancing their visibility include increasing the brightness of the light they emit and placing them closer together, but there is concern that when visibility improves drivers will then find them dazzling. More detailed study is needed.

5.3.2 Visual guidance flags

Visibility of the flags depends in large part on the effectiveness of the reflective properties of the reflecting material used. As for the visual guidance effectiveness of the flags, the replies received from frequent users under a variety of visibility and snowfall conditions are shown in Fig.5. The visual guidance effectiveness of the flags even in situations of poor visual environment was acknowledged; the reason the number of replies acknowledging their effectiveness became fewer as the visual environment deteriorated was that in a heavy snowfall or snow storm the light from the headlights was obstructed by snowflakes so that the proper reflective effect could not be obtained. In the Yokote area in particular, which not only has one of the heaviest annual snowfalls in the Tohoku District but also experiences long periods of heavy snowfall, the visual guidance efficacy of the flags is not so high when compared to neighbouring areas (Akita, Kitakami). (Fig. 5)

Is there effective visual guidance in the following situations?	
Q1	When night time visibility is ‘Good’.
Q2	When daytime visibility is ‘Poor’ due to snow storm
Q3	When night time visibility is ‘Poor’ due to snow storm
Q4	When nighttime visibility is ‘Poor’ due to heavy snow fall



<Fig.5 -Differences in the visibility of visual guidance flags depending on area>

However, the reason the flags are rated more highly for night time snowstorms (Q3) than for night time heavy snowfall (Q4) is because the movement of the flags gives them a higher degree of visibility.

Many frequent users were of the opinion that the present height at which the flags are erected, 2.8m above the road surface, is too high: the poorer the field of visibility, the greater the tendency for the line of sight to be lowered, and so it would be more effective to successively lower the height of the flags, to the extent that they do not become buried in the roadside snow bank as it grows.

5.3.3 Blue Line

The efficacy of the Blue Line is acknowledged in the evaluation by frequent users: close to 80% answered that ‘The band of blue color on the snow bank can be seen even when the field of vision is poor’ and that ‘It’s a help when driving in conditions of poor visibility’. However, at night time the percentage of those who acknowledge the efficacy of the Blue Line drops to 46%. The reason for this, as many of those surveyed pointed out, is that in addition to the visible distance being limited to the range of the headlights, the haze phenomenon caused by drifting snow particles makes it still more difficult to make out the

Blue Line.

Even at night time, however, the freshly-sprayed, bright blue coloration clearly indicated the position of the snow bank and played a part in the early lifting of road closures due to poor visibility.

With regard to the height and thickness of the Blue Line, over 80% of people said that the present height and thickness were just right: the Blue Line successfully marks the intended position of a virtual guardrail.

However, when snow-removing operations are repeatedly carried out after the snow bank has been sprayed the displaced snow sticks onto the sprayed surface and the Blue Line can no longer be seen: if the spraying can be done at the same time as the snow removal operations or in a joint operation, the high level of effectiveness of the Blue Line in alleviating impaired visibility can be maintained at all times.

6. CONCLUSION

It is not easy to avoid impaired visibility due to snowstorm and drifting snow by means of snow drift prevention forests and snowbreak fences, and so measures have been enacted to support safer driving.

The self-luminous delineators, visual guidance flags and Blue Line are each acknowledged to have the effect for which they were intended, but the level of efficacy depended on the time of day or night, and the degree of poor visibility. In future it will be necessary to select measures according to such factors as the volume and frequency of snowfall, wind conditions, road structure and size of the snow bank.

In addition, while it is not easy to obtain a quantitative understanding and evaluation of the efficacy of these measures to deal with poor visibility and to prevent accidents, it is important that improvements to the evaluation method continue to be made and that an objective assessment of the measures be made.