Problems in Visibility Measurement of Road in Blowing Snow

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ABSTRACT

Visibility in snowstorms can vary greatly by height or location. To clarify the difference of a spatial visibility in the road section, authors measured the snow mass flux (the mass of the snow particle that passed through the unit cross-sectional area at the unit time) on the flat road and the low-embankment road in the Ishikari Blowing Snow Test Field. Mass fluxes of snow were measured by the net-type snow traps at 15m windward from roadside (reference point), above the shoulder and roadway. The ratio of the visibility by the height of 1.2m on the roadway to the visibility of the reference point was 0.1-1.4, and the ratio of the visibility by the height of 2.4m on the roadway was 0.2-2.1. In the extreme case, the visibility on the roadway was 60m while the visibility of the reference point was 660m. Especially, the visibility on the roadway has worsened remarkably compared with the visibility of the reference point when the snow bank on the road side is high. These results mean that the visibility measured with visibility meters installed at environmental sensor stations (ESS) and the visibility that had been seen by drivers while driving in snowstorm are different. That is, it is necessary to consider spatial differences of the visibility at the snowstorm when the measurement value of the visibility is interpreted.

Keywords: visibility, blowing snow, road

1. INTRODUCTION

The risk of large-scale multiple collisions caused by reduced visibility from fog or snowstorms makes it important to detect such conditions promptly and provide information to drivers to ensure road safety [1].

According to the World Meteorological Organization (WMO), meteorological visibility is defined as the greatest distance at which a black object can be seen and recognized when observed against the sky during daylight, or could be seen and recognized during the night if the illumination were raised to the normal daylight level. Visibility is measured by a human observer by selecting an object at a known distance. However, problems such as the influence of the observer's subjectivity and the impossibility of continuous monitoring have recently made observation using visibility meters more popular. These meters measure the transmittance or reflectance of the atmosphere, and find visibility from the measured value, known as the Meteorological Optical Range (MOR). The MOR is defined as the distance required to reduce the luminous flux in a collimated beam from an incandescent lamp at a color temperature of 2,700 K to 5% of its original value due to absorption and scattering by suspended particles in the atmosphere [2].

At present, visibility meters are generally used to monitor reduced visibility on roads. Although there are no specific uniform installation standards, they are often installed at a height of 1.5 to 2.0 m along the roadside. According to Federal Highway Administration (FHWA) criteria, visibility meters should be installed at a height of 2 to 3 m on a meteorological tower located approximately 10 to 15 m from the roadside [3]. In contrast to the case with fog, however, visibility in snowstorms can vary greatly by height or location. It is thus important to know the extent of the difference between the values measured by roadside visibility meters and actual visibility on the road. The authors therefore studied variations in roadside visibility and examined the problems related to visibility measurement.

2. OVERVIEW THE STUDY

The relationship between visibility and snow mass flux (i.e. the mass of snow particles passing through a unit cross section in a unit time) during a snowstorm can be expressed by the equation below [4].

$$Vis = 10^{-0.77\log(Mf)+2.85} \quad (1)$$

where *Vis* is the visibility (m) and *Mf* is the snow mass flux ($gm^{-2}s^{-1}$).

The authors measured the snow mass flux on a flat road and on a low-embankment road of approximately 2 m in height at the Ishikari Blowing-Snow Test Field, which is located approximately 17 km north of downtown Sapporo. The measured values were converted into visibility expressions using Eq. (1) to illustrate variations in roadside visibility.

Mass flux measurements were taken at a height of 1.2 m and 0.15 m from the surface of a snowfield approximately 15 m to the windward side of each road and at heights of 1.2 and 2.4 m above the shoulder and roadway surface using a net-type snow trap with mouth of 10 cm in diameter (Fig. 1, 2). The heights of 1.2 and 2.4 m are equivalent to the driver's eye level in small and large vehicles respectively. Wind velocity and temperature were measured concurrently. Thirty-four measurements were made in total, on January 30 and 31 and February 12 and 14, 2003.

Furthermore, when a net-type snow trap is used, it is necessary to take the capture rate into consideration. Based on the study by Takeuchi and Fukuzawa [5], it was corrected to 85% at a wind velocity of 5.0 m/s or greater and 75% at velocities from 3.0 to 5.0 m/s.

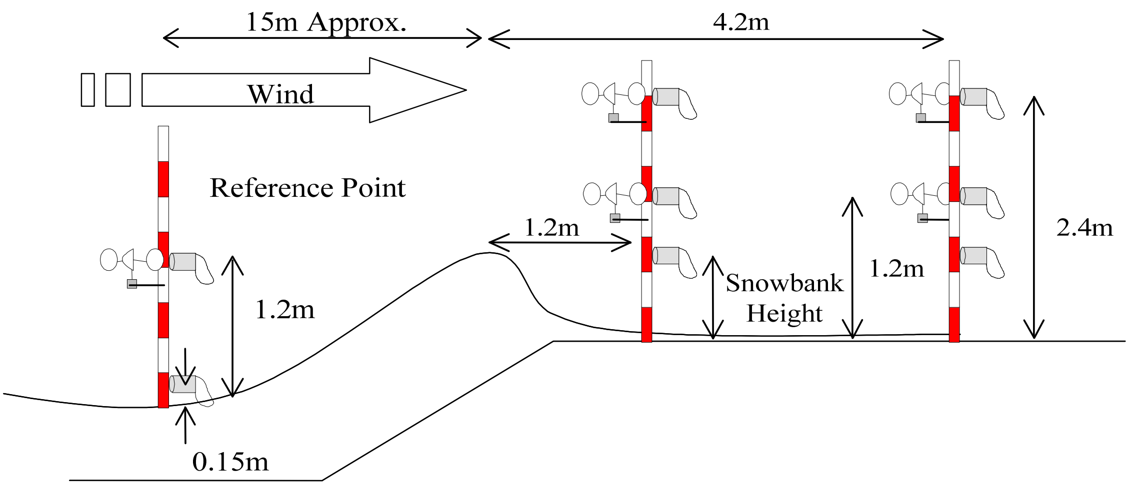

Fig. 1 Overview of mass flux observation

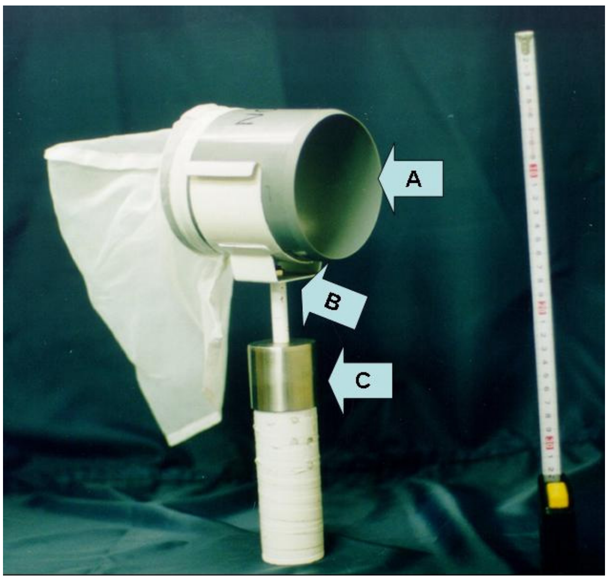

Fig. 2 Net-type snow trap (A), and mount (B). Part (C) contains the bearing. The trap mouth faces windward.

3. RESULTS OF THE STUDY

Figure 3 show examples of calculated visibility from snow mass fluxes measured around the roads (Left: flat, Right: embankment). It is found that the visibility is different remarkably by height. Also, the visibility on roadway is quite different from that at reference point. The results mean that the visibility measured at roadside may not representative the visibility above roadway. Then the authors study the relationship between the visibility above roadway and that at reference point.

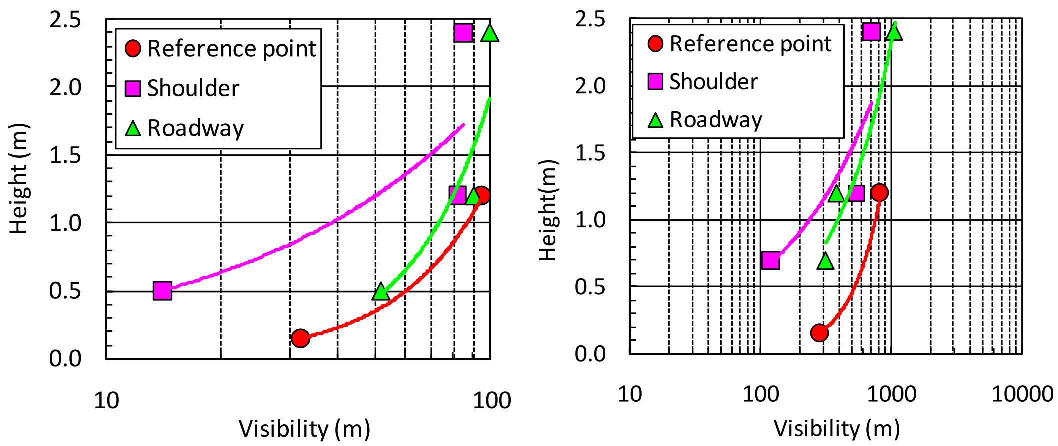

Fig. 3 Examples of measurement of visibility around the roads (Left: flat, Right: embankment). Height means the distance from the snow surface to the measuring height at reference point, and from the road surface at shoulder and roadway to the measuring height.

Figure 4 shows a scatter diagram of visibility at a height of 1.2 m at the reference point and at heights of 1.2 and 2.4 m above the roadway. It can be seen from the figure that, while visibility at the 2.4-m level was similar to that at the reference point, it tended to be lower at the 1.2-m level. This was because the spatial density of blowing snow particles decreased dramatically with increased height in a phenomenon that differs greatly from reduced visibility caused by fog.

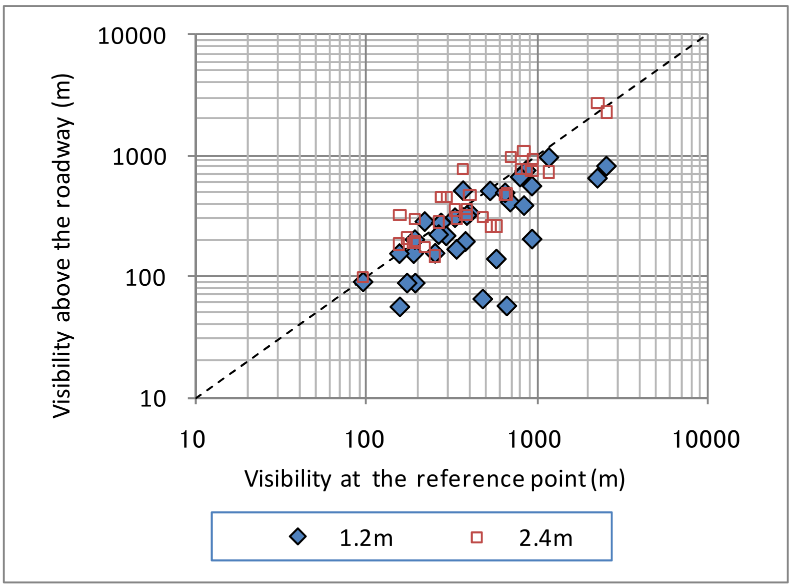

Fig. 4 Visibility at the reference point (1.2 m in height) and above the roadway (1.2 and 2.4 m in height)

4. ANALYSIS OF OBSERVATION RESULTS

The ratio of visibility at the reference point to that above the road was calculated by dividing the values for each case by the height of roadside snow banks (below 0.8 m and 0.8 m or higher) for the different road structures (flat and embankment). Figure 5 shows the mean and the standard deviation of the ratio of visibility.

It can be seen that, with snow banks of below 0.8 m, visibility at a height of 1.2 m above the roadway was 20 to 30% lower than that at the reference point on both flat land and embankment. When snow banks were 0.8 m or higher, visibility above the roadway was less than half that at the reference point. There was even a case where visibility 1.2 m above the roadway was 60 m while that at the reference point was 660 m.

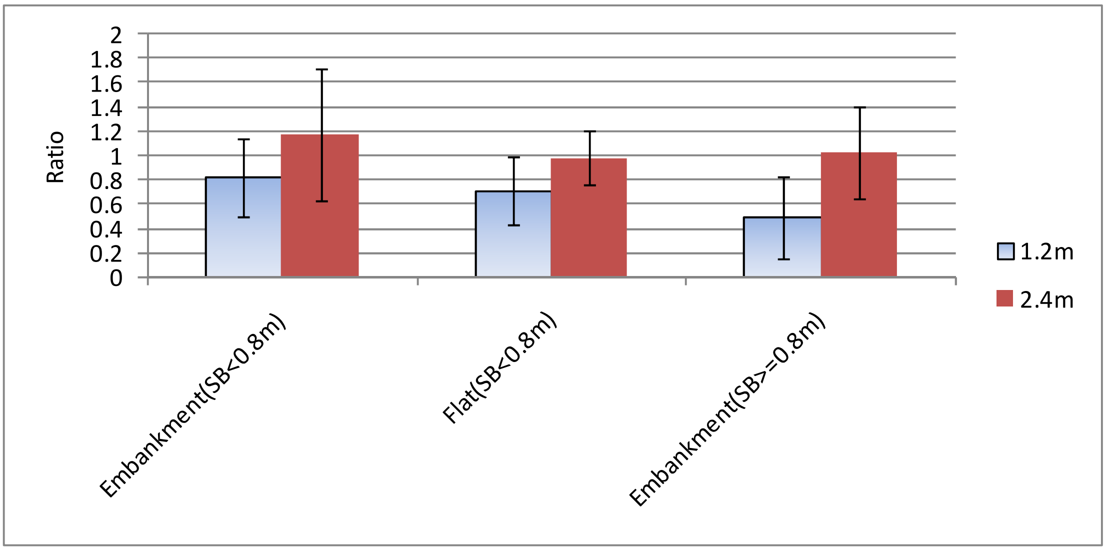

Fig. 5 Mean and standard deviation values of the ratio of visibility at the reference point to that above the roadway. SB means the height of snow bank.

The above results suggest that visibility measured with a visibility meter installed at a roadside meteorological station may differ from that on the road itself. The relationship between visibility on the roadway and that at the reference point was therefore calculated to correct roadway visibility values.

(1) With snow banks below 0.8 m

From the measurement results (Fig.6), the equations below were obtained. The values V_{120}, V_{240} and V_{ref} represent visibility at 1.2 m above the roadway, 2.4 m above the roadway and at the reference point, respectively.

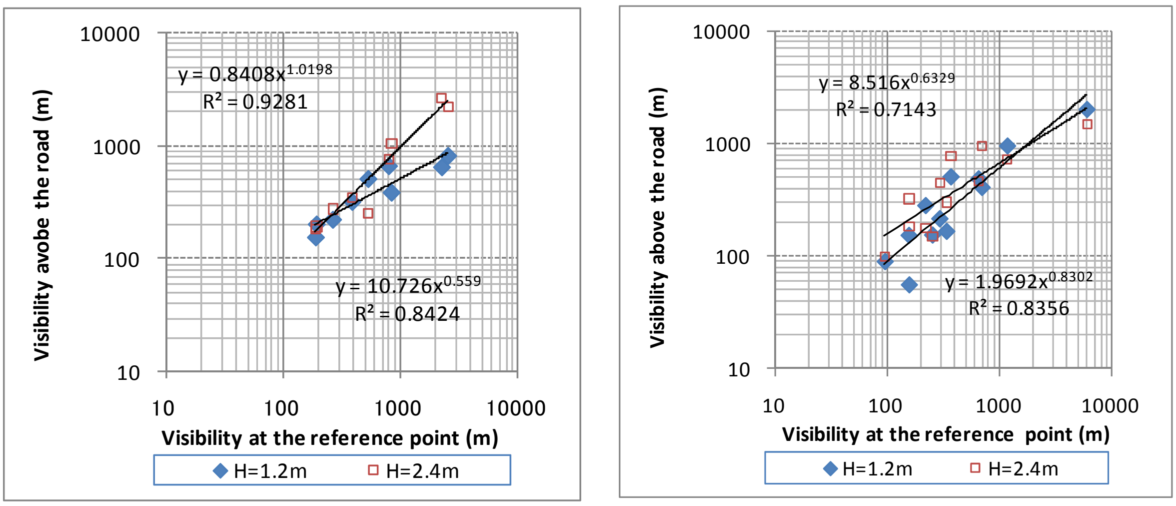

Fig. 6 Visibility at the reference point and on the roadway (left: flat, right: embankment)

i) For the flat road

$$V_{120} = 10.726 V_{ref}^{0.559} \quad (2)$$

$$V_{240} = 0.841 V_{ref}^{1.020} \quad (3)$$

ii) For the embankment road

$$V_{120} = 1.969 V_{ref}^{0.830} \quad (4)$$

$$V_{240} = 8.516 V_{ref}^{0.633} \quad (5)$$

For the flat road (Fig.6 left), the correlation between the visibility at the reference point and that above the roadway is strong. The visibility at the 2.4-m level is similar to that at the reference point. Though the visibility at the 1.2-m level is lower than that at the reference point, the correlation between both visibilities is strong. In addition, the visibility at the 1.2-m level is similar to that at the reference point when the visibility at the reference point is below 500 m.

For the embankment road (Fig.6 right), the correlation between the visibilities at the 1.2-m level and that at the reference point is slightly weaker than for the flat road. Wind turbulence, occurred by the embankment, effects on the snow mass flux. Thus studies of a high-embankment section will also be necessary, since these correlations may vary by embankment height.

In addition, because the data of visibility below 100 m are limited, additional observation will be needed when the visibility is below 100 m.

(2) With snow banks of 0.8 m or higher (embankment section)

When snow banks are 0.8 m or higher, the correlation between visibility at the reference point and that above the roadway became weaker (Fig. 7). At the height of 1.2 m above the roadway in particular, no correlation was observed with the visibility at the reference point, in addition the visibility is much lower than that at the reference point. We should know that there is much difference in visibility between roadway and roadside when snow banks are 0.8m or higher.

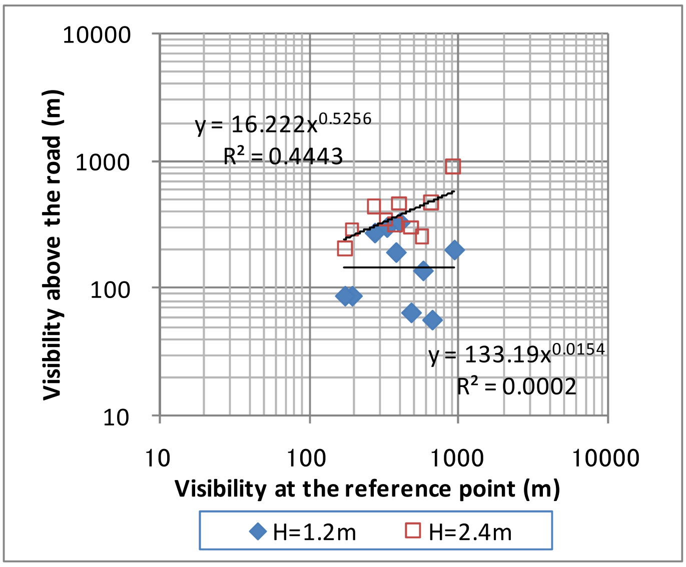

Fig. 7 Visibility at the reference point and on the roadway (embankment)

5. OTHER PROBLEMS CONCERNING VISIBILITY MEASUREMENT

The previous chapter revealed that visibility measured at a roadside meteorological station might differ from that on the road depending on road structures and roadside snow banks. Other problems must also be considered when using a visibility meter to monitor reduced road visibility.

First is the problem of the observation height. The concentration of blowing snow varies greatly by height, meaning that the values obtained may also vary depending on the height at which a visibility meter is installed. If its installation level is high, reduced visibility caused by drifting snow cannot be detected. If it is low, the results are strongly influenced by dense drifting snow near the snow surface.

In the case of snowstorms, temporal variations in visibility are also significant. The visibility value may thus differ considerably depending on whether the mean or lowest value is adopted as the representative value. If the lowest value is used, it is also necessary to consider the number of seconds necessary for the evaluation.

Besides the issues of measurement involved with visibility meters, there is also the problem of the discrepancy between visible distance for drivers and meteorological visibility. This is caused, in addition to the difference between the value measured with a visibility meter and the actual human visibility range, by differing conditions of general illumination (e.g. day, night and twilight) and the existence of road lighting, light-emitting delineators and other roadside facilities.

In aviation, a value called the Runway Visual Range (RVR) is used in addition to visibility. This is the maximum distance in the direction of takeoff or landing at which the runway, or the specified lights or markers delineating it, can be seen from the eye level of an aircraft pilot (approx. 5 m). The MOR, or Meteorological Optical Range, is a value that indicates atmospheric turbidity objectively, and is not affected by lights or markers delineating the runway. While the RVR may vary by runway lighting or other artificial environments, it is an indicator more suitable for aviation than meteorological visibility.

In road traffic, visibility from the driver's point of view and vehicle operation may be affected by road lighting, light-emitting delineators and other roadside facilities, compartment lines, the tail lights of vehicles in front and other road environmental conditions. It is thus considered necessary to introduce an indicator of road visibility from the viewpoint of drivers in addition to the MOR measured with a visibility meter.

6. CONCLUSION

Snow mass flux observation was conducted to clarify problems concerning visibility measurement during snowstorms. The results indicated a difference of up to ten times between visibility measured at a road meteorological station and that on the road itself. It was suggested that some points require consideration concerning visibility measurement during snowstorms due to large temporal and spatial variations in the measured values. It was also considered necessary to introduce an indicator for visibility estimation in road traffic to represent visibility from the driver's point of view. When considering indicators for the evaluation of visibility during snowstorms, it is considered important to determine the above visibility-affecting factors in a quantitative manner.

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