NEW METHOD FOR EVALUATION OF BLOWING SNOW MEASURES THROUGH COLD WIND TUNNEL EXPERIMENT AND CCD IMAGE ANALYSIS

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1. Abstract

This paper describes a new method by which the effect of poor visibility improvement of the blowing snow measures can be quantitatively evaluated through the analysis of CCD image of blowing snow occurring in a cold wind tunnel device. The new method enables the selection of the most effective measure dependant on the in-situ conditions before site installation.

2. Introduction

Poor visibility due to blowing snow on highways may cause severe traffic accidents, road close, etc. in northern Japan. Many different kinds of countermeasures, such as snow break fences and snow prevention forest have been designed and installed along highways in Japan. However, the selection of proper countermeasures is not always easy because of the luck of appropriate method for the selection.

Mass flux of blowing snow is the product of drift density by wind velocity (Budd et al. 1966), and the mass flux has a simple relation with the visibility (Takeuchi and Fukuzawa 1976). In the experiment presented in this paper, many different kinds of models of countermeasures and road structure with scale 1/30 were installed in a cold wind tunnel device. The distribution of drift density was derived through the analysis of blowing snow CCD Image taken in the tunnel, and the distribution of wind velocity was directly measured in the tunnel. A series of experiments suggests a new method for selection of the most effective measure dependant on the in-situ conditions before the installation at site.

3. Experimental procedure

More than 100 experiments were carried out in the cold wind tunnel device. Figure 1 shows the outline of the wind tunnel device used. As for the wind tunnel, the working part is set up by 14m in length and 1.0m×1.0m in cross sectional area in a low temperature laboratory under -10℃. Models of different designs of highway structures and of snow break fences were made on the scale of 1/30 and set up in the wind tunnel. Snow was spread over the wind tunnel floor and blowing snow was produced by setting the wind speed within the range of 5 - 12m/s, supplying the snow particles continuously. By applying laser beam through slit, a series of CCD images reflected from blowing snow particles was taken. The appearance of the snow blowing is shown in Figure 2. The example of CCD image is shown in Figure 3.

The mass flux of snow and the wind velocity were measured by snow particle counter (SPC) and hot-wire anemometer, respectively, at several points in the tunnel, so that the drift density obtained from CCD Image was verified.

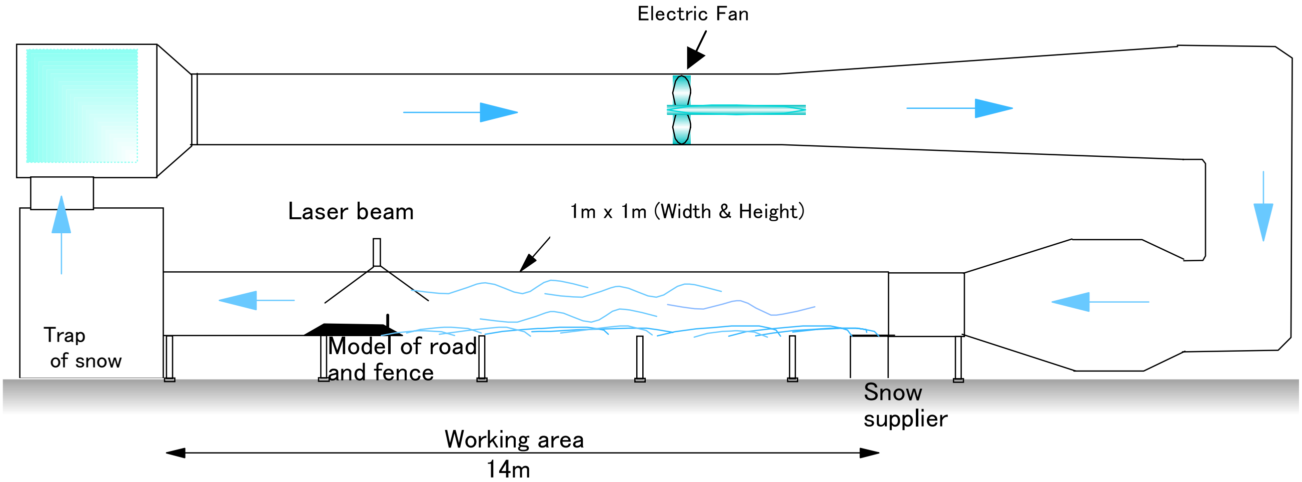

Figure 1. Schematics of the wind tunnel device

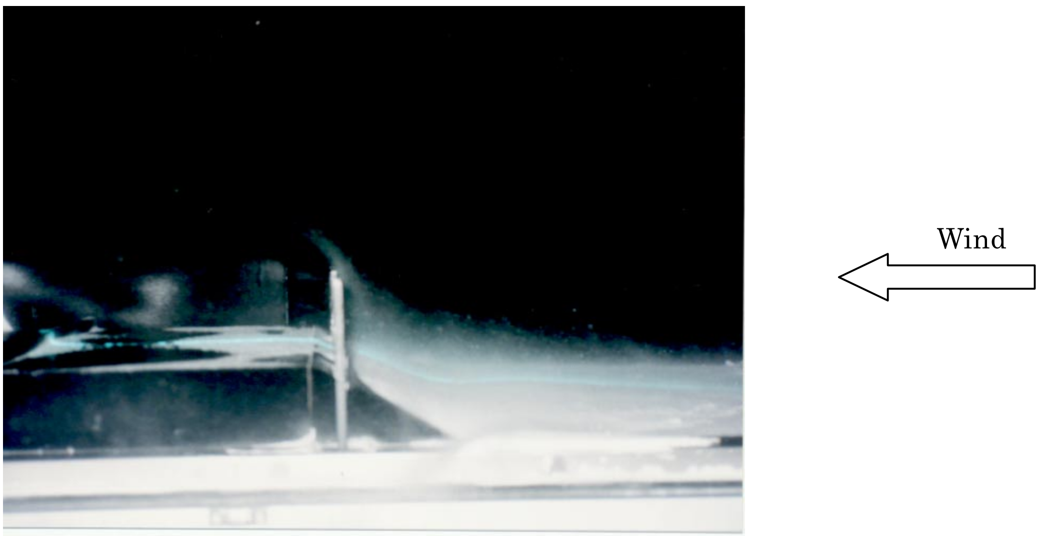

Figure 2 Appearance of drifting snow in the wind tunnel.

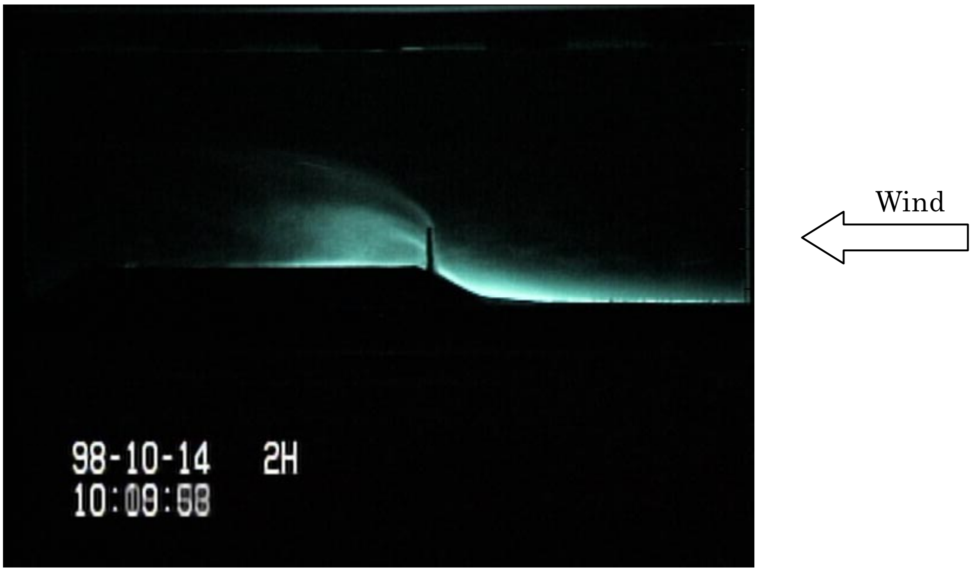

Figure 3. An example of CCD image

Wind velocity: 10m/s, Road height: 3m(in real)

Height of fence: 3m(in real)、Porosity of fence: 40%

4. Analysis of CCD image

A linear relation between gray scale value of pixels in CCD image and drift density of blowing snow was obtained in the experiment. The gray scale value increases with the drift density as shown in Figure 4. This relationship was applied for the conversion of CCD images to drift density.

There may be some difference between this experiment and real road situation in distributions of drift density and wind velocity. Thus the careful inspection of similitude requirements was made, and drift density and wind velocity obtained in the wind tunnel were converted into those in real situation.

The mass flux of drifting snow on site was computed by crossing the drift density to the wind velocity in the site, and based on the relationship between visibility and mass flux of snow the visibility distribution image on highway could then be also computed. This converting method was illustrated in Figure 5.

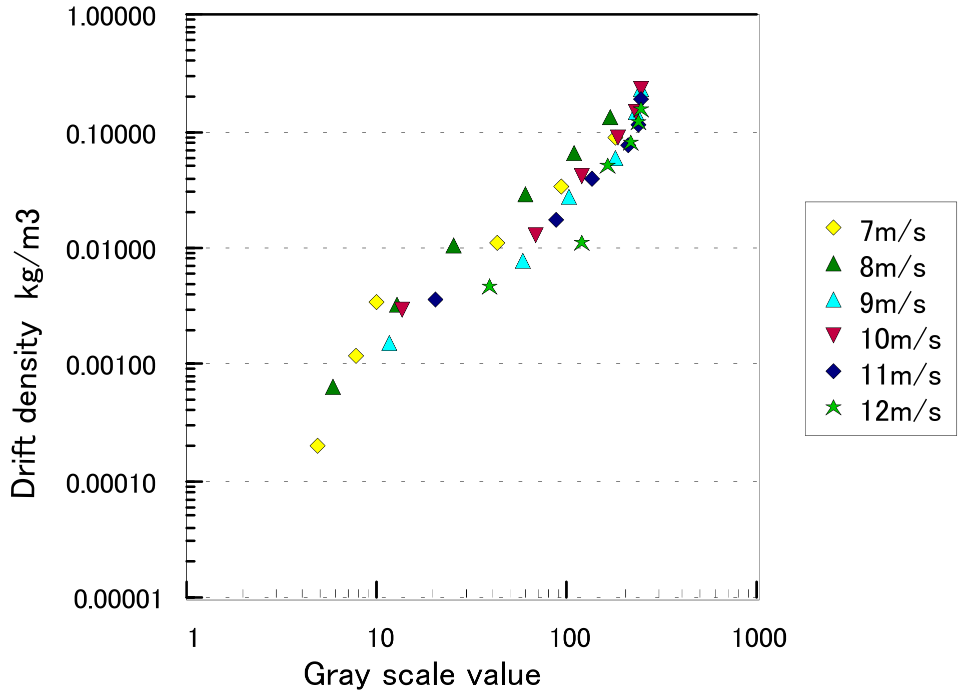

Figure 4. Relation between drift density of snow and gray scale value of pixels in CCD image

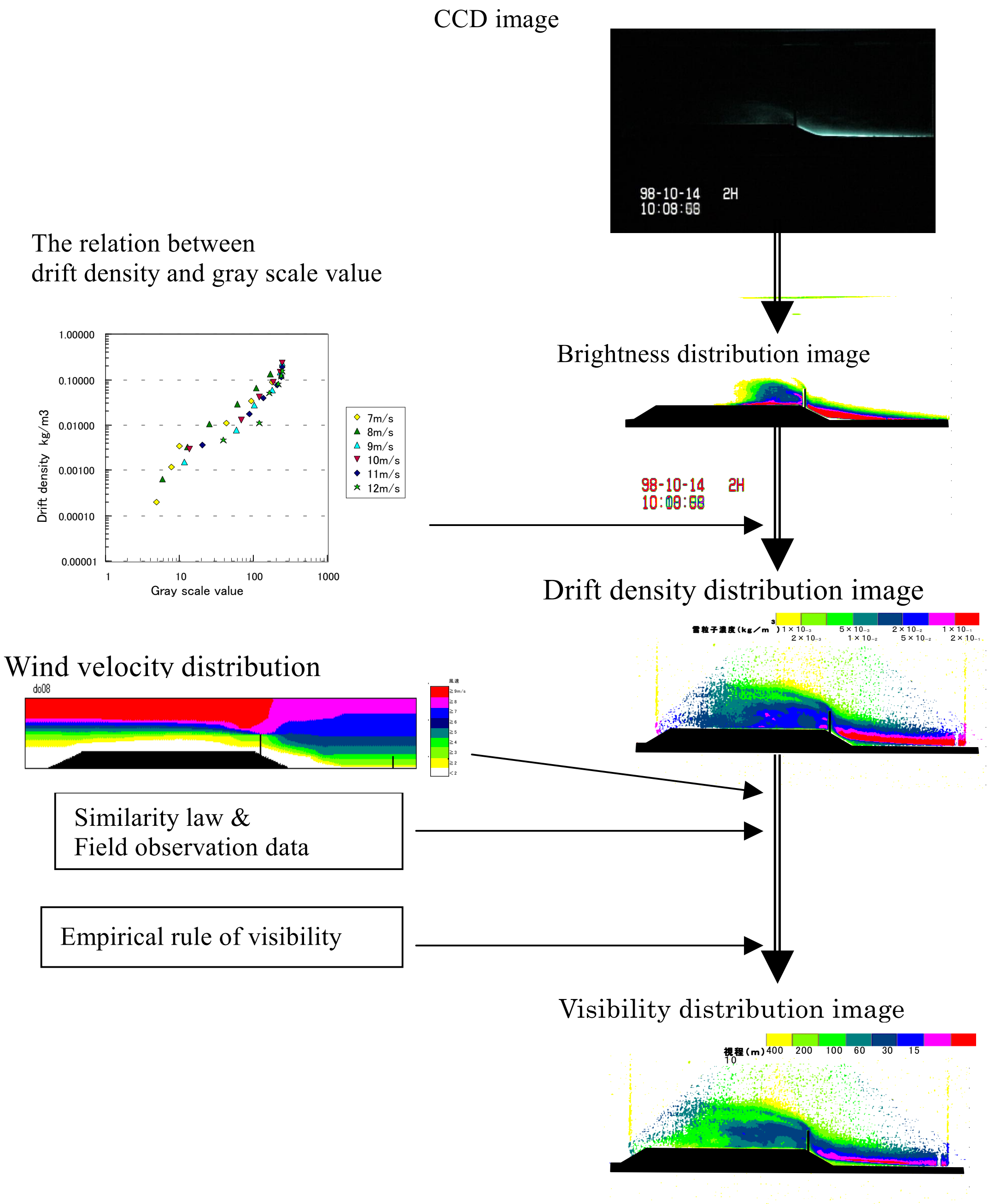

Figure 5 Conversion of CCD image into visibility distribution image

5. Evaluation of effective measures for visibility improvement

For many kinds of countermeasures in different shape, porosity, height, position, etc., visibility distribution images were computed. An example is shown in Figure 6. Moreover, Figure 7 shows the visibility along traverse section of road at three different heights(1.2m 1.5m and 2.0m) of driver's eye. The difference in visibility distribution implies the difference in effect of countermeasures. Thus, evaluation of ountermeasures for visibility improvement became possible.

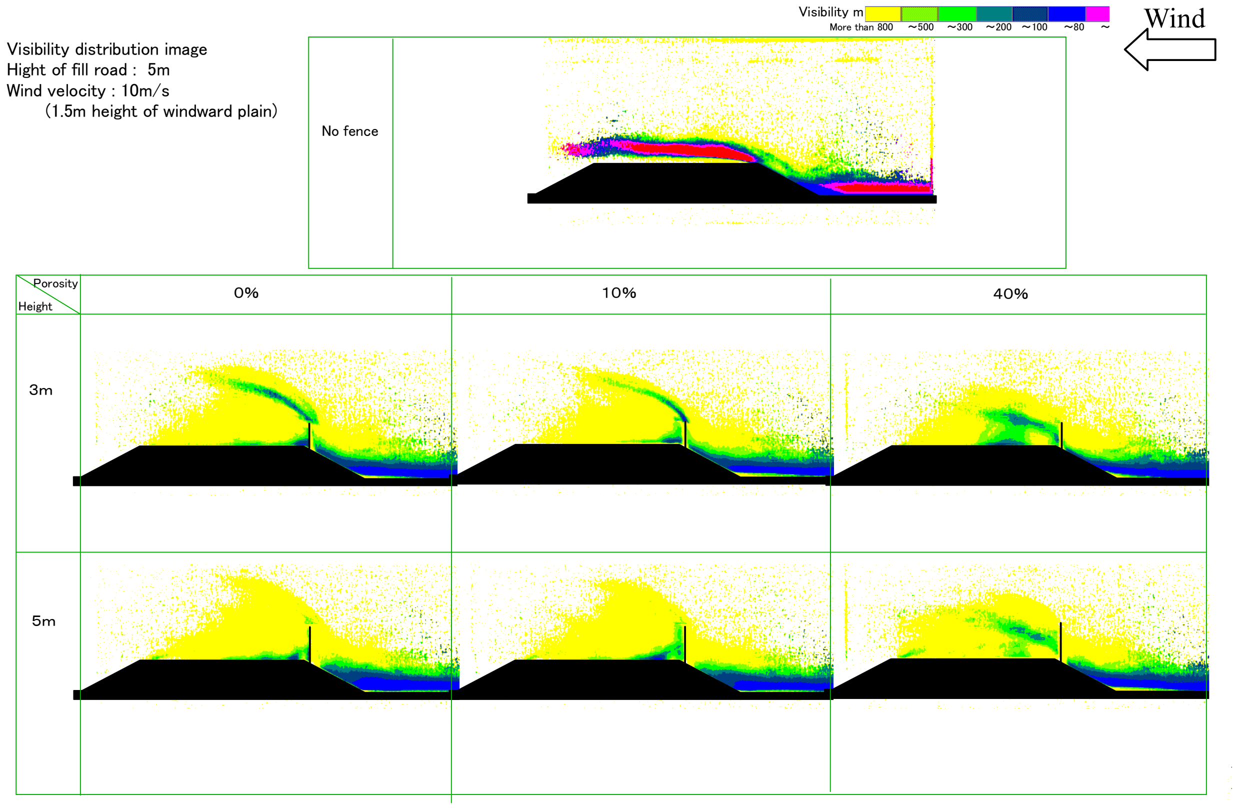

Figure 6. An example of visibility distribution images
Height of road fill : 5m
Wind velocity : 10m/s (1.5m above ground level at windward side)

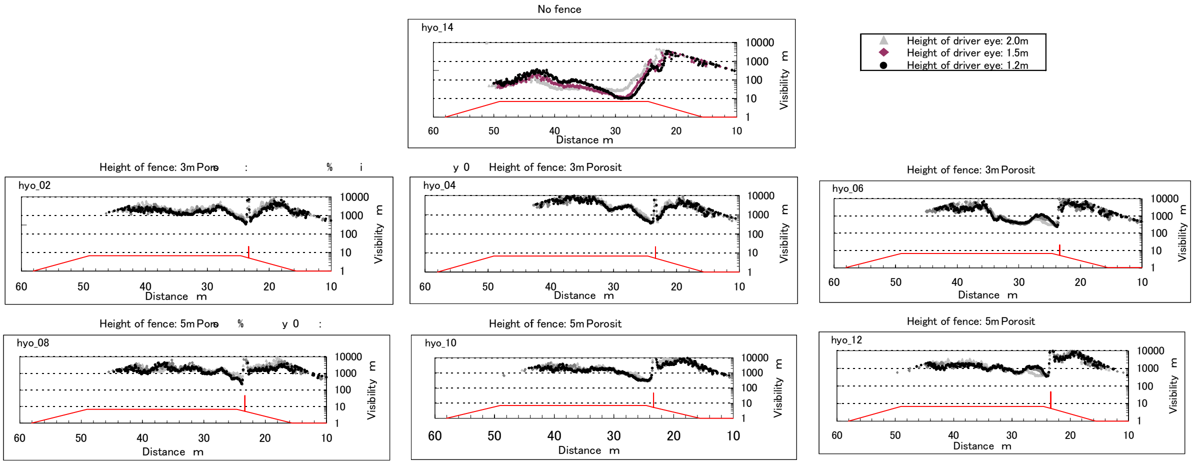

Figure 7. Visibility along transverse section of road at three different heights (1.2m 1.5m and 2.0m) of driver's eye

An example of the results derived from presented evaluation method applied for the porosity of fence is indicated in Table-1. It shows that the porosity less than 40% brings better visibility. No significant difference was observed in the in height of fence of 3m-5m.

Table 1. Example of evaluation result

Type of measures	Comparison item	Evaluation of effect
Snowbreak Fence	Porosity of fence	・The smaller the porosity is, the visibility is getting better. ・When the porosity is large, the windward side lane tends to decrease the visibility.
	Height of fence	・There is no significant difference in visibility for the fence of 3m-5m in height. ・When the porosity is large, fence height works to improve visibility.

6. Conclusion

The new method enables the selection of the most effective measure in accordance with the shape of highway fill and climatic conditions in winter season before the installation. Examination items chosen in the experiments are listed in Table-2.

Table-2. Examination items of present cold wind tunnel experiment

Type of measures	Examination items
Snowbreak fence along Highway	Porosity of fence
	Height of fence
	Basic structure of endurance return fence
Supplementary fence on the windward	Installation position
	Porosity of fence
Snowbreak Forest	Installation position
	Number of rows
	Tree interval
	Tree type (evergreen, green conifer and fallen leaf tree with broad leaves)
	Effect for wind blowing parallel or nearly parallel to the highway.

7. References

Budd, W. F. Dingle, R., and Radok, U. 1966. Byrd snow drift project. In studies in Antarctic meteorology, Antarctic research series, vol. 9.

Takeuchi,M. and Fukuzawa, Y. 1976. On the light attenuation and visibility in snow drift. Journal of Japanese Society of Snow and Ice vol.38.