STUDY ON VISIBILITY OF LIGHT-EMITTING DISPLAY DEVICES AND DELINEATORS IN ROAD TRAFFIC IN WINTER BLOWING SNOW CONDITIONS

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1. Introduction

Driving information for road traffic is provided by signs and variable-type road information boards. These are invaluable in making driving more pleasant by improving safety and offering a variety of services. In addition, information on surrounding conditions affecting driving is provided by road lighting, delineators which indicate lane shape, curves and hard shoulders for example, as well as by light-emitting devices such as blinker lights at junctions.

As regards operating conditions, it has been confirmed that in snowy regions, in certain weather conditions such as falling snow, blowing snow and lying snow, these road information display devices cannot adequately fulfill the functions required of them. This is one of the problems associated with road traffic. Research into visibility amid weather conditions such as blowing snow is fraught with difficulty since experiments have to be carried out in the natural environment. This study focused on how well road information display devices can fulfill their original functions in visibility conditions of falling or blowing snow in particular. Data were collected through a joint study conducted over a period of three years from 1996 at the Ishikari Blowing Snow Experimental Center of the Civil Engineering Research Institute of Hokkaido and other sites. We evaluated the display visibility of road information display devices based on light-emitting diodes (LEDs) and the emitted luminance and emitted color from these LEDs, and have found a direction for the optimum display luminance and other contributing factors.

2. Visibility Experiments with LED Devices

Elements which determine the visibility of delineators when driving are 1 emitted color, 2 emitted luminance 3 emitted area and 4 height of display. This study is intended to determine the optimum “emitted color” and “emitted luminance” of commonly used delineators through evaluation experiments. Unlike a conventional lamp type, an LED type display device features a long service life and, when many LEDs are combined, provides a fairly high level of luminance. According to reports on experiments of the display color, since the background color is generally white in a snowy landscape, easily visible colors against this background color have been black, blue, green, orange and purple while yellow, red and gray have been found to be less visible. Since black is not an emitted color, blue, which has a long wavelength, was considered as having good visibility. However these

reports concern the color of solid objects. The experiments for this study evaluated emitted colors and verified whether the same results were obtained. During the first year, the subjects in the visibility experiments were asked to reply to a questionnaire, while during the second year visibility was evaluated from the images on a 24-hour video. (This was because of difficulties in encountering blowing snow conditions.)

The light-emitting device used in the experiments was a 12 cm-square light source composed of monochromatic LEDs which emit red, yellow, green, blue or white light.

Table 1

Emitted color	Standard luminous intensity(cd)	Directivity mesial angle (°)	Light emitting area	Emitted luminance
Red	0.8	30	120 mm square	(high) 4600cd/m^2
Yellow	1.3			(medium) 2500cd/m^2
Green	2.2			(low) 400cd/m^2
Blue	0.65			

The questionnaire consisted of a seven-stage evaluation as shown below.

Evaluation	Points
Invisible	1
Barely visible	2
Lower limit of usefulness	3
Adequate brightness	4
Upper limit of usefulness	5
Start to feel dazzled	6
Dazzling (cannot look directly)	7

Photo 1 Experimental Materials

3. Results of LED Display Visibility Experiments

3.1 Results of Visibility Experiments in Fine Weather

The results of visibility experiments on an LED display device in fine weather, are as shown in Figures 1 and 2. During the daytime (white, snowy mountain in the background), visibility was best with “blue” and “red,” followed by green and yellow in that order, while visibility was poorest with white. Poor results were obtained with white. At night no color was found to be better or worse than any other. Therefore, where the background is white,

the visibility of a light-emitting device of the same color is poor.

During the daytime, optimum brightness was felt by many subjects where the emitted luminance was “high,” while at night an emitted luminance ranging from “medium” 2500cd/m^2 to “low” 400cd/m^2 produced good results. .

Figure 1 Results of LED Display Visibility Experiments (Daytime)

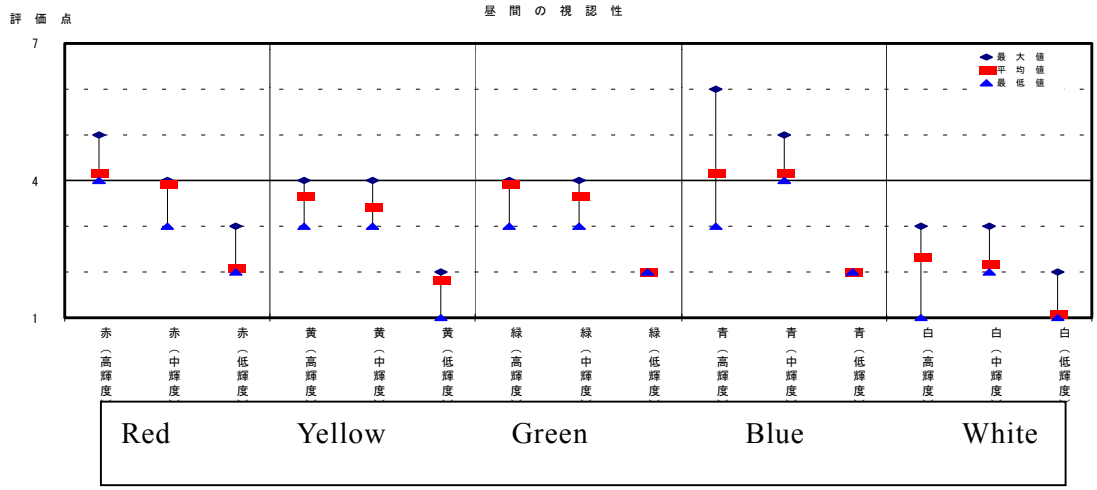
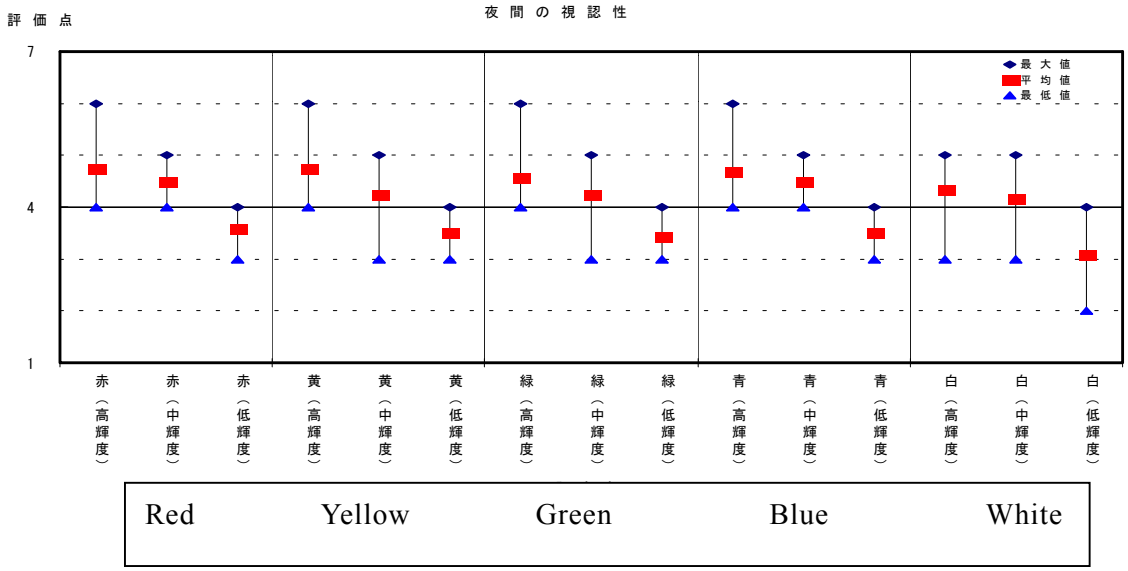


Figure 2 Results Of LED Display Visibility Experiments (Night)



測定日時:1999年2月6日 9時7分
天候:雪　気温:－4．2℃
視程:100～400m

1－1: low luminance

1－2: medium luminance

1－3: high luminance

1－4: Max luminance

3-2 Results of Visibility Experiments in Blowing Snow and Considerations

Video images of blowing snow conditions were evaluated and the following results were obtained from.

(1) During blowing snow too, as in fine weather, visibility was best when the emitted colors were blue and red.　(Images 1-3)

(2) When the device was lit at the rated luminance of the LEDs, the visibility of “green” which has the highest luminance was best.　(Images 1-4)

(3) At night, halation made the images impossible to evaluate.

(4) In poor visibility conditions (visibility: 100-400m), nothing was visible without a luminance of 4600cd/m^2 or more. (Images 1-2, 1-3)

Although these results do not clearly show that video images and what people directly see are identical, the results were the same as those for visibility evaluations in fine weather. During falling snow and blowing snow too, there was a tendency for blue light to be the emitted color which gave the best visibility. At night it was impossible to make any evaluation due to halation (too bright).

Therefore, yellow and orange are normally used for the emitted color of delineators;

however, in cold regions, blue, which gives good visibility, is more effective as the emitted color of delineators. Since blue has never up till now been used in a delineator, drivers may initially be puzzled. Nevertheless, it is recommended that a multi-functional delineator which is effective in blowing snow and falling snow conditions be produced by combination of blue light with yellow or other color light as used in a conventional delineator. In recent years, green has also come to be used for the lamp color of delineators. Green as the emitted color on a delineator used in snowy regions is effective in increasing visibility.

4. Visibility Experiments on Road Information Display Devices

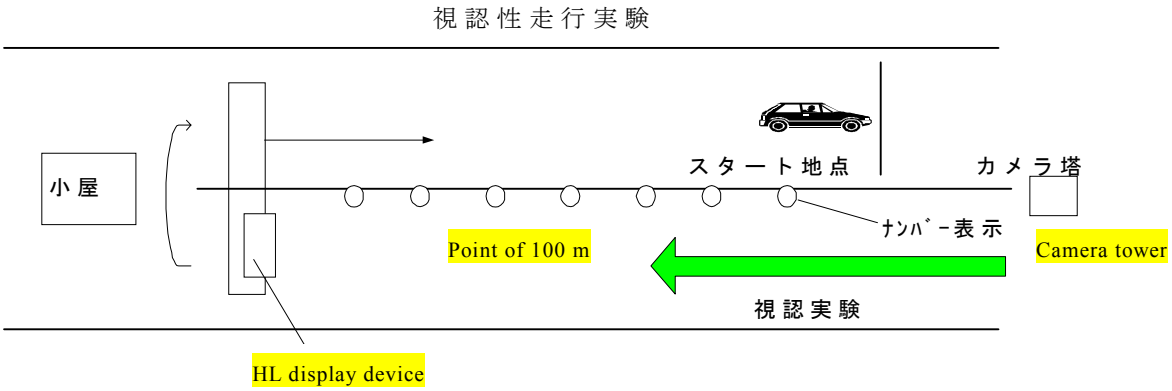
The basic function of road information display devices is to transmit information, so visibility and legibility are most important. Winter road conditions are different from normal road conditions. In winter road conditions, displays have to be visible and legible even in poor visibility conditions, for example, against a white background, or during falling or blowing snow, though such conditions cannot be said to be ideal in terms of visibility. Experiments were therefore performed with the aim of verifying the visibility conditions in a winter road environment and improving the visibility of the display devices.

The experiments examined the extent to which road information display devices maintained visibility in blowing or falling snow conditions in a cold, snowy region. In order to improve the visibility of the display, experiments were carried out on the following four points and the results evaluated.

(1) Improving brightness of display
(2) Enlarging letters (reduction in information volume)
(3) Addition of patterns
(4) Color information (experiment of display of a single letter)

The experiments were carried out under the conditions shown in Figure 3. (Usually the distance of legibility for letters is calculated from a prescribed formula, but since in reality a variety of conditions gives rise to the possibility of differences in recognition, experiments on actual visibility during driving were thought to be more effective.).

Figure 3 Visibility Experiment on Road Information Display Devices



5. Results of Visibility Experiments on Road Information Display Devices

As shown in Figure 4, experiments on the visibility of display devices revealed that an increase in the luminance level did not result in improved visibility. However, improved visibility was obtained when the letters were enlarged.

Next, according to the results of experiments on the effectiveness of color information, as shown in Figure 5, visibility was best with red and purple. These results apply to a white background on a fine day. During actual blowing snow conditions, no clear improvement in visibility was obtained as a result of evaluating images made where the luminance of the test device was raised to the highest level possible. However, once again an enlarged display was effective to a certain extent.

Figure 4 Road Information Display Visibility Improvement

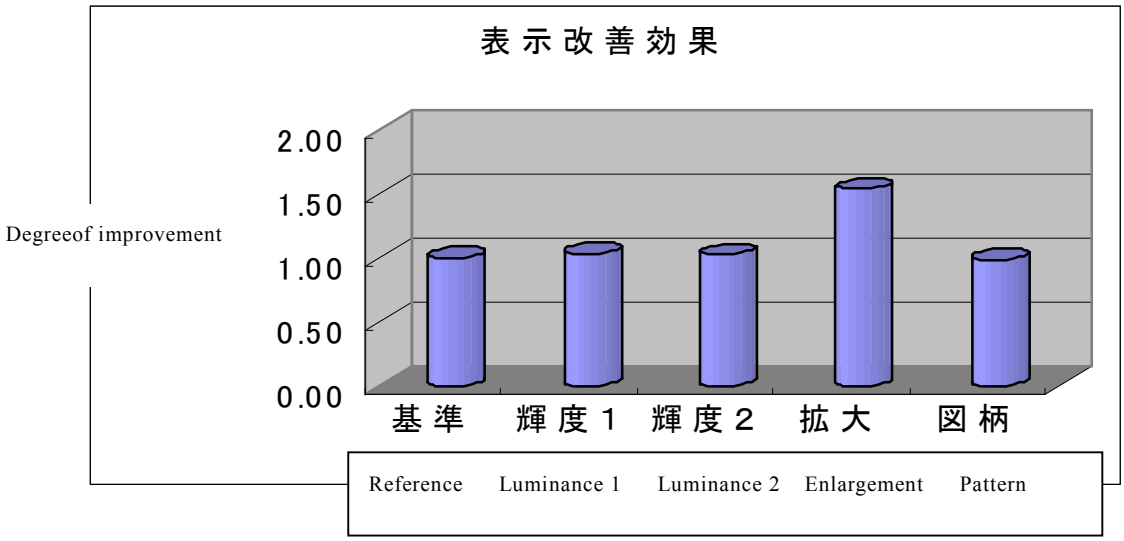
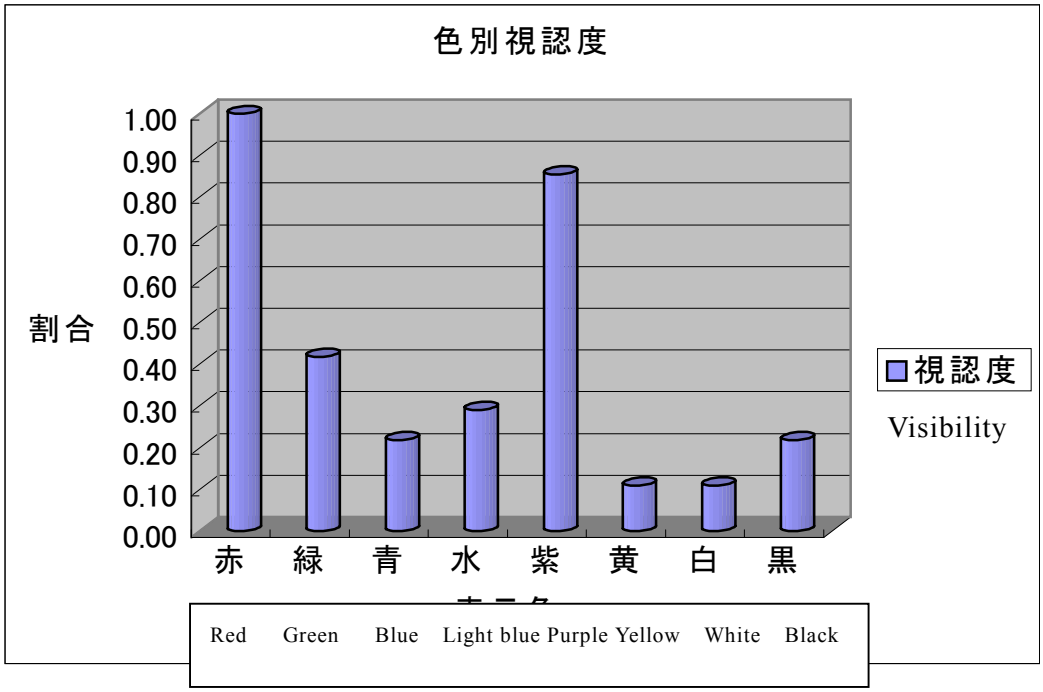


Figure 5 Road Information Display Visibility by Letter Color



These results show that a slight increase in the luminance of the display does not improve visibility, but that enlarged letters, due to a broader display area, make up for the fact that parts of the display cannot be seen due to falling snow, so that the letters are more or less legible even if only by guesswork.

6. Future Issues

The visibility improvement effect of emitted colors such as blue and green at the short wavelength end of the spectrum was confirmed by experiments conducted over two years on the visibility of LED display devices. These results confirmed that it is effective in promoting safe driving in cold, snowy regions to vary the emitted color depending on the situation: “yellow” when there was no snowfall, and “blue” or “green” when visibility was impaired by snow and blowing snow. In addition, an advanced delineator system was proposed. This would be capable of selectively using light colors depending the situation, emitting “red” light as a warning when there was an accident. By combining lighting and flashing patterns with emitted colors, a safer, more advanced driving assistance system could also be achieved. In future, multi-colored, multi-functional delineator systems including sensor systems should be configured and their effectiveness verified in the field.

Furthermore, reduced visibility in falling snow conditions is directly connected with the reduced visibility of the light-emitting device. It has been reported that, due to the characteristics of the wavelength of the emitted color, the extinction coefficient of visible and infrared light during snowfall increases as the wavelength increases.[3)] This fact would seem to support the results of the experiments which showed that blue light, which has a relatively short wavelength compared to other visible light, is effective.

Future issues in connection with experiments on the visibility of road information

display devices must include an evaluation of whether or not devices with flashing displays and the addition of patterns improve visibility against a snowy background in poor visibility conditions in the same way as large letter displays were found to be effective in the course of the present experiments.

References

1) Hiroshi Kansaku: Illuminating Engineering Institute of Japan, Newsletter [Vol. 55 No. 3 (1971)]
2) Delineator Installation Guidelines and Commentary, Japan Road Association, October 1984
3) Seagraves, M.A.: Visible and Infrared Extinction in Falling Snow [Appl. Opt. 25-7 (1986)]