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Identification of the Difference in Transmittance in Fog Depending on Illumination Color Temperature and Visibility

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ABSTRACT: *In foggy situation, the driver has difficulties in securing the visibility which is vital for the safety. Roadway lighting is intended to provide the driver with vosibility which however can hardly perform such a role in foggy condition. But regrettfully, the study on roadway lighting has yet to make any progress. Generally, lower color illumination temperature reportedly provides the better transmittance in foggy environment and thus is more appropriate in foggy weather, which however has yet to be verified. This study thus is intended to identify the transmittance efficiency of low color temperature illumination on road and transmittance comparison test depending on visibility distance and color temperature. Consequently, lower color temperture illumination was found to have provided the higher transmittance than higher color temperature in foggy condition within the driver's visibility distance*

Keywords: *Color Temperatures, Road Lights, Visibility, Fog Transmittance*

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I. INTRODUCTION

Roadway lighting, among the road facilities, is the only way of securing the visibility for the driver at night or inclement wearher. Roadway lighting can hardly play its role when the road is foggy, making it difficult to secure necessary visibility distance for the driver as well as influencing on driver's response time which is important to secure the safety for the driver, which eventually has negative impact on traffic flow and a serious traffic accidedent from time to time. According to the statistics, the fatality in foggy condition is signficantly higher than others. But the study on roadway ligthing with regard to driver's visibility in foggy road environment has been rarely conducted. Generally, a low-temperature yellowish lighting with a high wavelength range reportedly has a higher transmittance in foggy condition, which however has yet to be verified theoretically or experimentlly and moreover no stuyd indicates how to apply it to road traffic condition. This stuyd thus is aimed at identifying the appropriate roadway lighting temperature for the driver through the transmittance and comparison test depending on temperature by visibility distance.

II. LITERATURE REVIEW

Traffic accident depending on climatic condition presented in 2016 statistical analysis of traffic accident published by the Road Traffic Authority is shown in Table 1, which indicates the fatality in foggy road was significantly higher than any other conditions.

Table 1 Traffic accident depending on climatic conditions

Classification / Weather	No of accident		Death toll (person)			Injured (person)	
		(%)		(%)	Fatality (%)		(%)
Total	232,035	100.0	4,621	100.0	2.0	350,400	100.0
Fine	199,816	86.1	3,699	80.0	1.9	300,311	85.7
Cloudy	9,581	4.1	364	7.9	3.8	14,632	4.2
rainy	19,938	8.6	463	10.0	2.3	31,042	8.9

Foggy	428	0.2	42	0.9	9.8	887	0.3
Snowy	1,009	0.4	31	0.7	3.1	1,739	0.5
Others /unknown	1,263	0.5	22	0.5	1.7	1,789	0.5

Source : Road Traffic Authority, 2016

International classification of the foggy condition depending on visibility is as Table 2 below. When the visibility is less than 200m, it's defined as the thick fog and when less than 40m, it's the dense fog and the thick fog refers to the visibility distance which is the most critical to the driver.(Moore and Cooper, 1972)

M E White and D J Jeffer (1980) insisted that the driver tends to become sensitive when the visibility distance is 150m or less in his behavioral analysis of the driver.

Table 2 International classification of visibility

Visibility	Description
Less than 40m	Dense fog
40 ~ 200m	Thick fog
200-1000m	Fog
1-2km	Mist(if mainly due to water droplets) Haze(if mainly due to smoke or dust)
2-4km	Poor visibility
4-10km	moderate visibility
10-40km	Good visibility
over 40km	Excellent visibility

Source: Meteoro-logical Office, 1969

Son, Young-tae et al (2013) collected the weather and traffic and conducted the study on variation of traffic characteristics on highway depending on change to visible distance. As a result of statistical analysis (variance analysis) to verify the traffic flow difference by visible distance, difference in traffic and speed by visibility distance was found and thus he mentioned the need of road design and operation approach in consideration of inclement weather that reduces the visibility.

K. Otas et al (2012) explained about the transmittance of the light in foggy condition as follows. When the light penetrates into the fog, electromagnetic waves interact with floating moisture in the air which causes the light beam to decrease. Transmittance of the light beam can be explained typically by Beer-Lambert-Bouguer law.

$$\mathbf{I} / \mathbf{I_o} = \boldsymbol{\tau} = \mathbf{e}^{-\mathbf{ax}} \qquad \textbf{Eq. (1)}$$

Where, $\mathbf{I_o}$ = initial light intensity

$\mathbf{I}$ = light intensity after passing through a layer of fog thickness $\boldsymbol{x}$

$\boldsymbol{\tau}$ = transmittance

$\mathbf{a}$ = extinction coefficient (fog density)

Absorption and scattering occurred in the medium result in extinction of the light. Fog particle is a water drop and thus absorption of the light is insignificant that may be disregarded and thus extinction of the light results from scattering.

HuaizhouJin et al (2015) identified the relations between color temperature and visibility through the test using the subject and a scale model so as to determine the appropriate illumination color temperature. Illumination color temperature used for the test includes 1870K, 2490K, 3007K, 4075K and 5020K and the time taken to become adaptive, accuracy in distinguishing the color of the object and transmittance in fog were measured. As a result, the lower the color temperature the shorter the time taken to become adaptive and though transmittance was acceptable, accuracy in distinguishing the color at2490K and 1870K was lower than higher color temperature. In conclusion, 3000K was found most suitable color temperature for roadway lighting.

Huei-Kyung Yang et al (2001) conducted the test with the 3 types of color temperatures (2700K, 4000K, 6500K) as test parameters in a bid to evaluate the degree of worker's fatigue depending on lighting color temperature and consequently, visual and mental fatigue was the least and the concentration was the highest at2700K. On the contrary, mental fatigue was the most and the concentration was the lowest at 6500K and visual and mental fatigue was the most and the workability was the lowest at 4000K.

A precedent study indicated that the driver did not secure sufficient visibility distance on road due to foggy condition which caused abnormal traffic flow and eventually led to the traffic accident. In some studies, a

low color temperature provides a good transmittance in fog and thus is appropriate as roadside lighting but neither clarified the effect of the fog on the driver nor the difference in transmittance by color temperature depending on variation of visible distance. Thus, it's necessary to compare the transmittance by color temperature in fog density which is critical to driver's safety.

III. TEST CONDITION AND METHOD

3.1 Test condition

The test was conducted inside the container which receives no natural light. As the container is not influenced by the wind, it's desirable to maintain the uniform fogy condition.

Illumination in high color temperature 6500K and low color temperature 2700K was provided at 1m height from the ground level as Fig 1

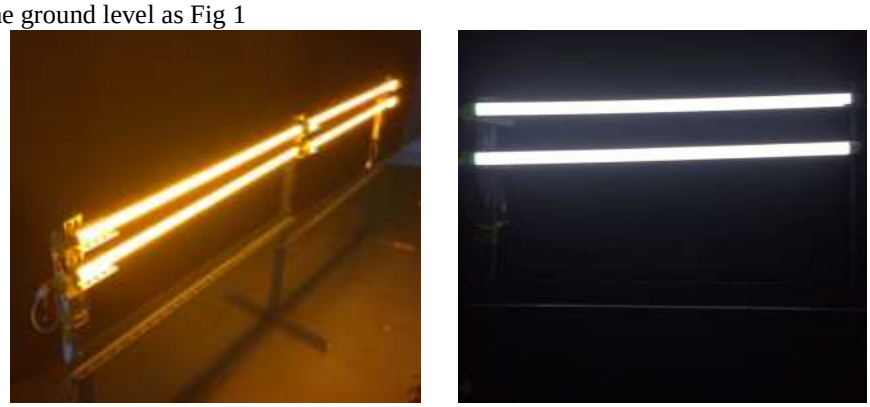

Figure 1 Illumination in 2700K(left) and 6500K(right)

Intensity of illumination was measured by a point luminance meter 'LS-100'from the manufacturer KONICA MINOLTA at 1m height from the ground level and the interval between the lightings was set as 2m(Fig 2)

Figure 2 Luminance Meter

Fog machine was used to create the fog and the visibility distance variable by fog density was measured by fog detector at 10m interval. Fog detector displays the visibility distance ahead at every 10 seconds through the computer.

3.2 Test method

First, after spraying the fog into the test chamber to maintain the visibility distance at 10m, the minimal value for fog detector, luminance was measured and recorded whenever the visibility distance is changed while removing the fog slowly. Measuring was repeated 5 times at the visibility distance in consideration of the instantaneous change of fog uniformity and the error of luminance meter and the mean value was set as the luminance value at visibility distance. This process was conducted in lighting condition of 2700K and 6500K respectively.

IV. TEST RESULTS

Measured value was compiled in a 10m-unit as Table 3.

Table 3 Comparison of mean luminance and transmittance by visibility distance depending on color temperature

Visibility (m)	2700K		6500K		A - B
	Mean luminance (nt)	(A)Transmittance (%)	Mean luminance (nt)	(B)Transmittance (%)	
20	11556.7	72.7	12390.0	71.2	1.5
30	12327.1	77.6	12532.2	72.0	5.6
40	12941.7	81.5	13331.5	76.6	4.9
50	13341.3	84.0	13663.3	78.5	5.5
60	13572.9	85.4	14617.5	84.0	1.4
70	13948.0	87.8	15150.0	87.0	0.8
90	14328.0	90.2	15400.0	88.5	1.7
100	14502.9	91.3	15251.2	87.6	3.7
110	14690.0	92.5	15527.7	89.2	3.3
120	14878.8	93.7	15866.2	91.2	2.5
130	14968.0	94.2	16173.7	92.9	1.3
140	15065.7	94.8	16295.0	93.6	1.2
150	15156.0	95.4	16435.0	94.4	1.0
160	15268.3	96.1	16626.6	95.5	0.6
170	15278.8	96.2	16700.0	96.0	0.2
180	15395.6	96.9	16749.0	96.2	0.7
190	15452.2	97.3	16753.3	96.3	1.0
200	15486.0	97.5	16936.6	97.3	0.2
210	15505.0	97.6	17043.3	97.9	-0.3
220	15581.7	98.1	17101.6	98.3	-0.2
230	15613.8	98.3	17110.0	98.3	0.0
240	15662.5	98.6	17205.0	98.9	-0.3
250	15718.3	98.9	17226.6	99.0	-0.1
260	15751.7	99.2	17218.0	98.9	0.3
270	15798.0	99.4	17294.9	99.4	0.0
280	15820.0	99.6	17312.5	99.5	0.1
290	15850.0	99.8	17370.0	99.8	0.0
300	15886.7	100.0	17404.0	100.0	0.0

A visibility distance 80m in fog which was not realized in color temperature 6500K was excluded from the analysis. Because of different initial luminance, it's inappropriate for comparing the transmittance as a simple luminance value and thus, transmittance in fog was calculated using the Beer-Lambert-Bouguer law (Eq.1) and comparison of transmittance in fog was compared. At visibility distance 300m when analyzing the transmittance, 300m of visibility distance was set as the luminance (initial luminance value) at fog-free condition for analysis because of no change in luminance. The row on the right in Table x shows the difference in transmittance between 2500K and 6500K. If this value is positive (+), illumination transmittance at 2700K is better than 6500K and vice versa when this value is negative (-)

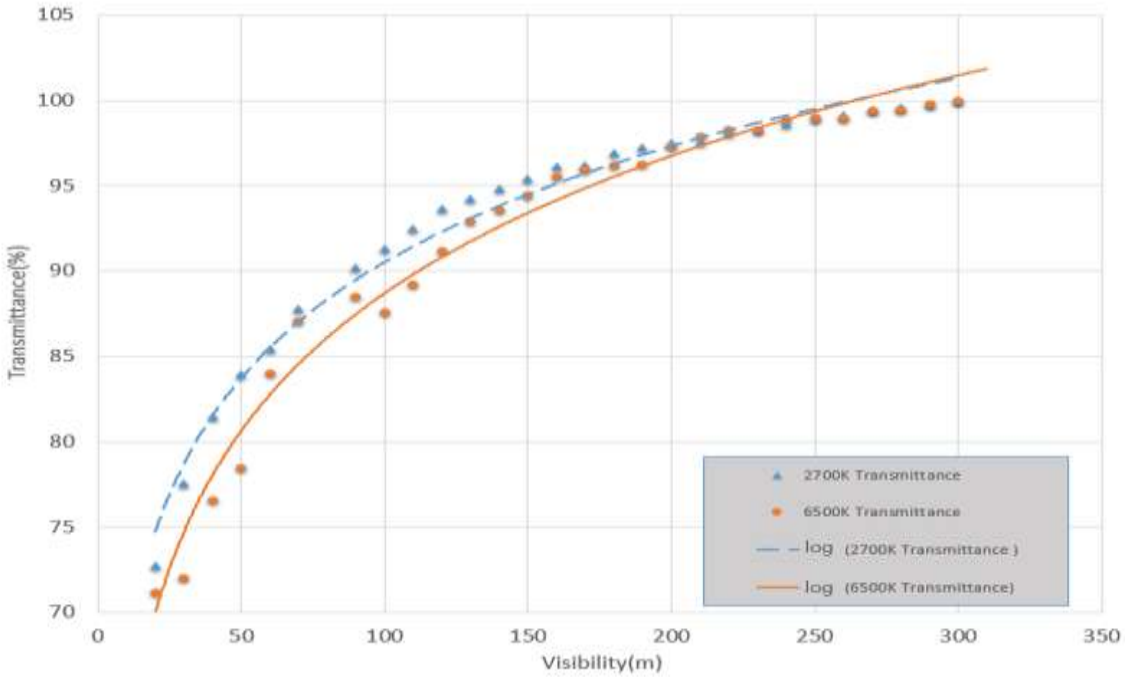

Figure 3 Comparison of transmittance depending on color temperature

Fig 3 is the graph which is schematized from Table 3. Viewing Fig 3 and Table 3, when the visibility distance is 200m or less which is critical for driver's safety, fog transmittance at 2700K is relatively higher than 6500K. But at visibility distance 150m or longer, the difference in transmittance between two color temperatures is reduced to less than 1% which tends to be further reduced to almost no difference from 200m and the transmittance at 6500K often becomes to less than 1%. That is, at the visibility distance less than 150m which is very critical to the driver, transmittance of lower color temperature is rather higher than higher color temperature, which is safer to the driver.

V. CONCLUSION

In this study, transmittance test was conducted at 2700K and 6500K, respectively, in a bid to identify the difference in transmittance by visibility distance depending on difference in illumination color temperature and consequently, when the visibility distance was 200m or less because of the fog, transmittance at 2700K, the low temperature color was higher than that at 6500K. When the visibility distance was 200m or longer, transmittance remains unchanged despite of the difference in color temperature.

Considering that the visibility distance which is critical to the driver is 200m or less, lower color temperature appeared to be safer to the driver.

Since this study was conducted at the limited condition, the value obtained from the study cannot be defined absolutely as the general tendency, but yellowish lighting was proven numerically to have had a higher fog transmittance through the experiment. In addition, the lower the fog density the longer the visibility distance and thus the difference in transmittance depending on color temperature tends to be decreased as indicated by the result of the study. Should the study further continue with more detail color temperatures and filed test using more subjects follow, more accurate outcome is expected.

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