A Study on Laboratory Testing and Performance Evaluation Method for the Development of an Anti-dew Road Sign

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Abstract: Condensation is a state change when the temperature drops below the dew point, and the moisture contained within the atmosphere forms dew on surfaces.
This type of condensation caused problems on roads and road facilities. Especially, if vapors occur in the form of dew on road signs, problems in retro-reflectivity, visibility, and legibility of road signs may occur, resulting in difficulty in providing information.
In order to make improvements for such problems that arise as condensation forms on road signs, dew-resistance films, illuminated road signs, and heating cables are currently being used. However there is no test method to analyze the effectiveness of anti-dew road sign method. Therefore in this research, an experiment method was developed to simulate real-world conditions and verified the performance of an anti-dew road sign using thermo-hygrostats in the laboratory. Comparisons were also conducted between the value of theoretic concepts and the value of the research.

Keywords: Road Sign, Condensation, Anti-dew Road Sign, Dew-resistance Films, Road Sign Visibility, Road Sign Retro-reflectivity

1. INTRODUCTION

Condensation is defined as the change of physical state when the temperature of the atmosphere with moisture content drops below the dew point temperature and forms into a liquid state. Condensation, as dew, mostly occurs in buildings and as such can cause problems.

However, the problem regarding condensation can also occur in roads as well. Especially, if condensation occurs on road signs, the visibility of road signs become unclear, which causes difficulties for road signs in providing information, which is its function. According to indoor experiment, once the condensation occurs on road sign the retro-reflectivity reduced compare with the normal condition. (KICT, 2012)

Condensation on road signs occurs throughout the 4 seasons, but in many cases it forms during winter when the temperature drops below the dew point temperature. When the temperature is above 0℃, such occurs in the form of dew, and occurs as frost when the temperature is below 0℃.

Condensation on road signs displays similar forms as contaminants on signs. D. de Ward et al (2005) conducted an experiment on 105 participants. In that experiment, he used an LCD projector to differentiate reflectivity on the signs and provided information to the participants. Only 6% of the participants complained about having difficulties in reading the signs due to condensation. Also, 25% of drivers answered differently as what was actually written on the signs due to the stained and dark state of the signs.

In the same way, condensation on road signs interferes with the legibility of the sign, causing errors to occur when drivers determine their routes. It can also lead to increased travel distance as well as an increased accident rate.

Figure 1. Condensation occurrence on road signs in Korea (left) and Germany (right)

In order to solve such problems, some alternatives such as using heated cables on road signs or illuminated road signs have been used. However these methods are high cost alternatives in terms of installation and operation due to the high cost of electricity. To solve these problems, some countries such as Europe, Korea and Japan are now using dew-resistance films. But problems of difficult installation and durability occurred in the field, thus new products are being developed for field adaptability.

Condensation occurs because of the vapor included within the atmosphere as well as temperature differences. In this research, the new concept of an anti-dew road sign was developed which uses an insulation material between the aluminum panel and a retro-reflective sheet to minimize the temperature difference for the prevention of dew on a road sign, instead of the existing anti-dew road signs that uses electricity.

However, this consumes much time and costs in order to implement these experiments outdoors so that the functions of the products can be verified. Also, the prompt collection of experimental results is necessary in order to secure the products depending on the results. In order to develop anti-dew road signs in this research, methods that can implement experiments with a thermo-hydrostat were developed, and values of theoretic results and experimental results were compared.

2. LITERATURE REVIEW

Lee and Cho (2004) conducted comparison and analysis sources of external illuminated signs to prevent condensation. Halogen lamps, fluorescent lamps, high-pressured sodium lamps, and induction lamps were selected as sources. As a result, the most effective method for increasing the readability of signs is to use outer lighting schemes. Especially, when induction lamps are used as sources, suggested strengths include a reduction of energy consumption as well as convenient maintenance.

Lee et al.(2010) conducted an experiment on how the amount of hydrophile of anti-dew film influences the preventive function of condensation. Hydrophiles cause condensation to occur on 3 other types of anti-dew films, so according to the measurement results of changes in brightness depending on time, if the contact between water drops exceeds 25˚, it is suggested that the anti-dew effect will decrease.

In order to experiment on the influence of angles and contact for the occurrence of water drops and condensation, Kindron(2005) used 5 pairs of wooden boxes that have 30°, 45˚, 60˚, 75˚ (experimental group), and 90˚(control group) to measure the amount of condensation.

The experiment results regarding the occurrence of condensation displayed that the amount of condensation rises as the angle lowers, and the conclusion suggested that when this is compared with the control group (90˚), the amount of condensation is equal to about 99.8% (Standard Error: ±11.9), 78.2% (Standard Error: ±17.9), 42.0% (Standard Error: ±18.3), 33.8% (Standard Error: ±10.8), 25.6% (Standard Error: ±9.7).

In order to measure a different amount of condensation depending on the roughness and production location of the surface, Kindron.(2010) measured the amount of condensation using 4 types of materials at different locations. The CPM (Cloth Plate Method) was used to measure the amount of condensation, and it was evident that more condensation occurred on parts that were less rough. The suggested conclusion stated that the increased amount of condensation is proportional to the height of the sign.

Jensen et al.(1993) used sources of 9500candela and a video camera to record dew every 5 minutes at 1 second intervals. The state of whether anti-dew film existed or not were distinguished and placed on 4 signs (60cm×60cm, 2mm Aluminum Sign) and were observed for 38 days. As for the observation results regarding the occurrence of dew, the signs that had anti-dew film attached showed a lower number of occurrences compared to signs that did not have anti-dew film attached, and it was also suggested as the element that influences the occurrence of wind, relative humidity, and the amount of clouds.

Kindron(2000) distinguished the climate conditions and habitation that influenced the occurrence of dew and fog and measured the amounts. It was measured during the fall between 1987~1989 in Israel, and mountaintops with air blasts, the foot of the mountain where shade exists, and regions that do not have air blasts were selected. As for the measurement results in the amount of dew and condensation, the amount of fog was greater on mountaintops as well as at the lower foot of the mountain where sunlight and shade both exist compared to regions that do not have air blasts. Statistically, differences in the amount of fog were suggested as significant.

In order to observe the formation process of condensation through the use of a metalloscope, Xu et al.(2002) used the cooling system of signs to observe pictures of dew over time. Especially, in order to observe dew formation on the surface of signs, signs were distinguished between clean signs, dusty signs, and signs having salinity.

The observation result showed that dew seemed to form more easily on dusty and saline signs than on those with a clean surface.

This showed that research regarding examination results based on existing literature of the amount of dew on a road sign and reflectivity and those of comparison and analysis for the prevention of dew are insufficient. In this study, the amount of condensation and retro-reflectivity were measured by each alternatives to condensation that occurs on signs in order to verify the effects through comparison and analysis.

3. CONCEPT OF CONDENSATION AND CLIMATE CHRACTERISTICS OF KOREA

3.1 Concept of vapor condensation

During condensation, a constant amount of vapors are included, and the maximum amount of condensation is set depending on the temperature. If condensation becomes equivalent as saturated vapor volume at certain temperatures, from that point on, condensation that exceeds the amount of saturated vapor volume cannot exist as a gaseous state. As a result, condensation takes place.

Thus, in condensation, when the temperature of the atmosphere that includes moisture falls below the dew point temperature, and moisture contained in turn forms into vapor. Figure 2. shows a theoretical concept of the occurrence of condensation and saturated vapor volume for each temperature.

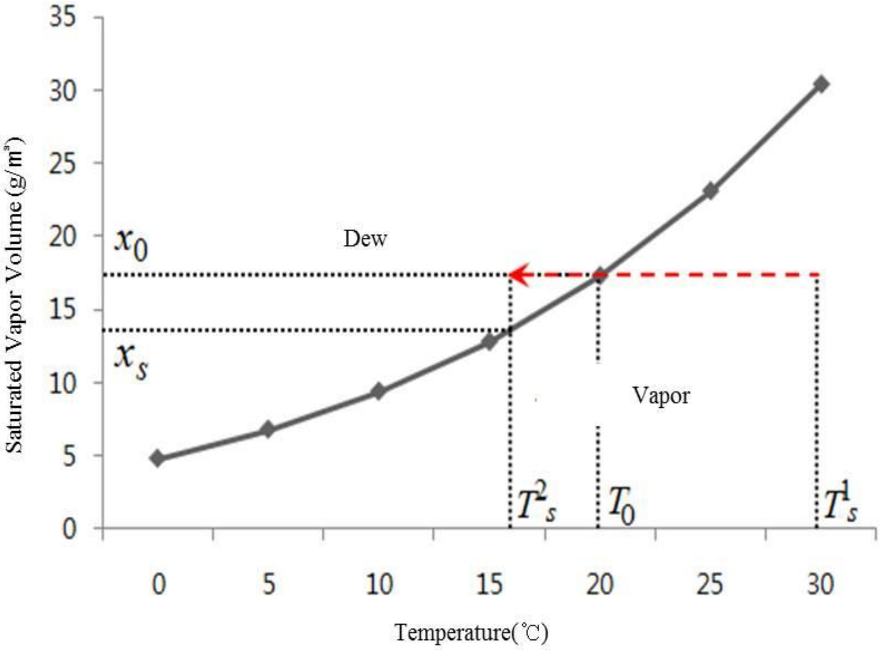


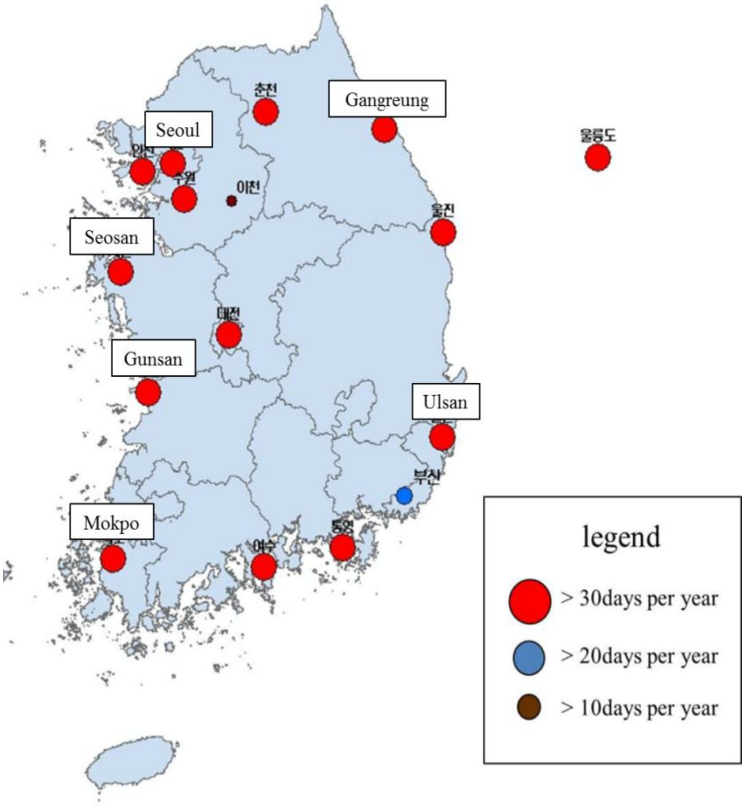
Figure 2. Concept of vapor condensation and amount of saturated vapor for each temperature

From Figure 2. if the temperature of road sign drops under the dew point, it can be occurred the condensation on the road surface and it will reduce the legibility of road sign. Therefore, the methods or technologies need to be developed not to drop under the dew point for temperature of road sign surface. However to generate and measure the quantity of the condensation on road surface in the field is difficult and time-consuming way. In this study, we proposed the indoor experiment which can be substituted real world test for generating and measuring the condensation on road surface.

3.2 Korean climate characteristics

Prior to conducting the experiment on condensation, past meteorological resources for 2008 were used to compute the climate characteristics of Korea. There are a total of 79 weather stations in South Korea, and temperatures, humidity, and dew point temperatures were used to measure the possibility of whether condensation could occur.

As a result of examining the possibility for the occurrence of condensation, such are mainly distributed in coastal areas, and mostly took place during January to March, during the winter season. Also, out of 79 weather stations, 14 stations that consists of 18%, displayed an annual occurrence of over 30 days of condensation.



month	1	2	3	4	5	6	7	8	9	10	11	12
possible days of dew occurrence for 79 stations	427	402	117	65	8	2	9	1	0	0	6	16

Figure 3. Distribution of the possibility of annual and monthly condensation occurrence

Korea's monthly average temperature, monthly average maximum temperature differences per day and monthly maximum humidity are displayed as shown in Table 1.

According to Table 1. relevant factors with condensation include the greatest temperature change during a day, greatest temperature change of about 15℃ for the most humid days in Korea, 90% of summer days as the most humid, 80% for Spring, Fall, and Winter. The average daily maximum temperature difference (℃) per season is as follows;

- Spring (Mar-May) : 15.4℃
- Summer (June-Aug.) : 10.8℃
- Fall (Sept. – Nov.) : 13.7℃
- Winter (Dec. – Feb.) : 14.1℃

As above, it is shown that condensation mainly occurs during the winter season. In this research, when making a prototype of anti-dew road signs with the use of insulation, the climate factor for the construction was based on a single day in winter with the greatest temperature difference of about 15℃ and about 80% of humidity was applied.

Table 1. Characteristics of Climate in Korea

category	year \ Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly average temperature	2008	-0.14	-0.40	6.84	12.81	17.07	20.15	25.66	24.42	21.25	15.73	7.88	2.22
	2009	-0.98	4.06	6.75	12.31	17.96	21.48	23.39	24.26	20.70	15.25	7.76	1.04
	2010	-1.76	2.24	5.24	9.62	16.77	21.93	25.07	26.57	21.66	14.41	7.04	0.97
	2011	-4.75	1.84	4.43	10.96	16.99	21.56	24.80	24.88	20.81	13.73	10.93	0.70
	average	-1.91	1.93	5.82	11.42	17.20	21.28	24.73	25.03	21.11	14.78	8.40	1.23
Monthly average humidity	2008	63.94	52.70	63.57	61.72	64.95	75.01	80.13	77.29	75.61	69.98	66.06	62.02
	2009	59.53	63.61	58.32	57.45	62.60	70.53	80.49	76.45	73.86	66.28	66.92	62.28
	2010	62.81	65.24	65.67	60.11	65.57	69.88	79.91	81.87	78.11	71.74	60.58	61.50
	2011	56.23	64.52	52.51	59.28	66.64	73.72	82.32	82.22	73.34	68.76	70.58	59.36
	average	60.63	61.52	60.02	59.64	64.94	72.28	80.71	79.46	75.23	69.19	66.04	61.29
Max. temperature difference per day	2008	11.74	16.56	15.64	16.63	15.98	11.89	10.27	11.05	12.83	15.32	14.10	14.21
	2009	15.46	14.33	15.12	17.41	16.64	13.14	9.06	10.47	12.94	16.67	12.24	12.64
	2010	14.69	12.24	11.09	14.10	15.47	15.14	9.15	8.90	10.75	13.70	16.75	13.26
	2011	15.35	15.04	15.55	16.46	14.05	12.88	8.50	8.58	11.56	15.02	12.05	13.32
	average	14.31	14.54	14.35	16.15	15.54	13.26	9.25	9.75	12.02	15.18	13.78	13.35
Max. humidity per day	2008	81.69	75.25	85.78	86.27	88.32	90.58	92.36	91.67	91.45	88.58	84.98	80.35
	2009	78.04	83.40	80.83	81.74	85.80	88.81	92.27	90.49	90.20	86.97	82.46	79.60
	2010	79.90	83.26	83.77	83.80	86.39	88.85	91.47	92.71	92.06	88.99	81.57	80.29
	2011	74.12	83.86	76.12	83.83	86.80	90.39	92.54	93.07	90.04	87.87	86.31	77.86
	average	78.41	81.47	81.59	83.90	86.82	89.66	92.16	91.99	90.93	88.10	83.84	79.52

If the average temperature of a winter afternoon is assumed to be 8℃ and the temperature difference is assumed to be 15℃, the lowest temperature possible is -7℃. However, the humidity at 8℃ is not in a saturated state, and has been assumed as 80% relative humidity. Therefore, the vapor pressure of 8℃ can be found in the same as that of Formula (1).

$$\mathrm{RH}(\%) = \frac{\text{Current Vapor Pressure(hPa)}}{\text{Saturated Vapor Pressure(hPa)}} \tag{1}$$

Saturated Vapor Pressure at 8℃ is 10.73hPa, and 80% vapor pressure of relative humidity is equivalent to 8.58hPa. Vapor pressure of 8.58hPa becomes the saturated vapor pressure at about 4.8℃.

Therefore, if the relative humidity is 80% at 8℃, then the dew point temperature becomes approximately 5℃, and when the surface temperature of the sign drops below 5℃, it means that condensation could take place. When constructing signs, caution should be taken to ensure the surface temperature of the sign does not fall below 5℃.

4. LABORATORY TEST FOR DEW OCCURRENCE ON ROAD SIGN

4.1 Testing procedure for dew occurrence on road signs

In the case of road sign, the temperature does not descend along with the temperature of the atmosphere, so even if the atmosphere temperature does not reach the dew point temperature, the temperature of the sign decreases below the dew point temperature. Especially, when the temperature of the sign is displayed as lower than the dew point, condensation occurs as water vapor condenses on the surface of the sign. The plates that are generally used for road sign are aluminum which has high thermal conductivity, so when the surface temperature cools down, the sign easily cools down as well. In the same way, if dew occurs in the atmosphere, dew can occur on signs as well.

Insulation is universally used in construction to decrease temperature differences that can cause condensation in buildings. In this research, insulation is placed between aluminum boards and retro-reflective sheets in order to prevent condensation from occurring on road signs.

For this research, in order to judge whether insulation materials are effective for road signs, the amount of condensation on normal signs and signs with insulation materials were conducted as an indoor experiment in order to compare reflectivity that can be detected by drivers.

In order to experiment with the condensation phenomenon of road signs indoors in this research, curing the pavement material chamber, which is composed of thermo hydrostats in curing chambers, were used to cause condensation to occur on road signs.

The process required to cause condensation to occur is as follows:

1. Prepare road signs with normal aluminum and insulation attached on a 30cmX30cm size
2. Experiment whether dew occurs in thermal-hygrostat
3. Measure the amount of dew on each sign
4. Measure the retro-reflectivity for each sign

4.2 Preparation of road sign samples

Considered conditions of insulation for making insulated signs for this experiment are as follows:

- Products that have lower thermal conductivity
- Products having less weight (density) to be able to be posted on road signs
- Products with outstanding workability and durability for attachment onto signs.

Thermal Conductivity and Density for each material are as shown in Table 2.

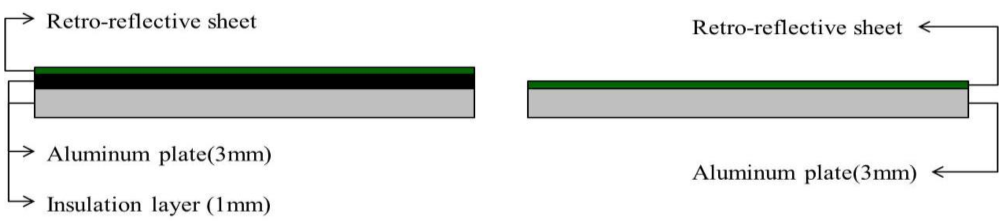
Table 2. Thermal Conductivity and Density of Each Material

Material		Thermal conductivity (kcal/mh℃)	Density (kg/㎥)
Metal	copper	320	8,900
	aluminum	175	2,700
	stainless steel	13	7,400
wallpaper		0.15	700
Glass	plate glass	0.68	2,540
	foam glass	0.24	921
Wood	chestnut	0.16	670
Plastic	acrylic	0.2	1,190
	gum tile	0.19	1,400
Insulation	expanded polystyrene	0.031	30
	urethane foam	0.021	45

When we consider these conditions, urethane, generally used as an insulation material, was designated as an insulating material for the prevention of condensation for signs.

Here the specimen signs are divided into 2 types, being 1) basic types of signs where retro-reflective sheets are directly attached onto aluminum panels 2) Signs where urethane is attached onto aluminum signs, and retro-reflective sheets attached on top.

The size of the sign used in the experiment was 30cmX30cm so that it was possible to conduct the experiment on a thermo-hygrostat.



(a) Inserted-insulation layer road sign (b) Normal road sign

Figure 4. Concept of road sign with insulation inserted which was used in the experiment

4.3 Test in the thermo hydrostat to generate dew

In order to generate dew on both the normal sign and insulated sign, they were simultaneously placed inside the thermo-hygrostat to implement the experiment.

The temperature change of the thermo hydrostat (relative humidity 100%) changed from 25℃ to 5℃. The signs were left in the thermo-hygrostat for about 3-4 hours so that the signs adjusted to the initial temperature.

In Table 1., if Korea's climate characteristics are considered, the temperature difference must be set to 15℃, but this experiment placed meaning for comparing the theoretical calculated value and the actual experiment value regarding the occurrence of dew. Thus, the temperature change was determined at 20℃, above the actual weather status.

Figure 5. Equipment used for the experiment

4.4 Measurement in the amount of condensation for each sign

After comparing the signs when placed in the thermo-hygrostat, the amount of condensation was also compared. An electric scale that can precisely measure up to 1/100g was used to calculate the amount of condensation within the signs.

As soon as condensation occurred on the sign, it was removed from the thermo-hygrostat, and the weight was measured every 30 seconds. When the weight no longer changed, it was considered that all the dew was fully removed and the difference between the initial weight and final weight of the sign should be calculated as the condensation weight.

Theoretically, the amount of condensation that can occur when retro-reflective sheets are directly attached onto aluminum boards is the same as that of Formula 2.

$$V = S_{25} - S_5$$)

Where,

V : Amount of Condensation that depends on high and low temperatures (g/㎥)

Si : Saturated vapor volume at i ℃ (g/㎥)

If Formula 2 is calculated here,

When it is 25℃ in Figure 2., the amount of saturated vapor is 23.04g/m^3, and when it is 5℃, the amount of saturated vapor is 6.80g/m^3, so – 6.80 g/m^3 =16.24 g/m^3

23.04 g/m^3 – 6.80 g/m^3 =16.24 g/m^3

The size of the sign was 30cm X 30cm, so there was a need to convert the deducted amount of condensation in order that it fits the volume.

The deducted result of Formula (2) are concepts of the volume (m^3) or the area (m^2) of the sign, creating possibilities in different units between each other. However, the amount of saturated vapor are related to saturated vapor pressure, and vapor pressure represents the strength applied on the area, so the amount of condensation that can occur on the area of the road sign is explained through Figure 6.

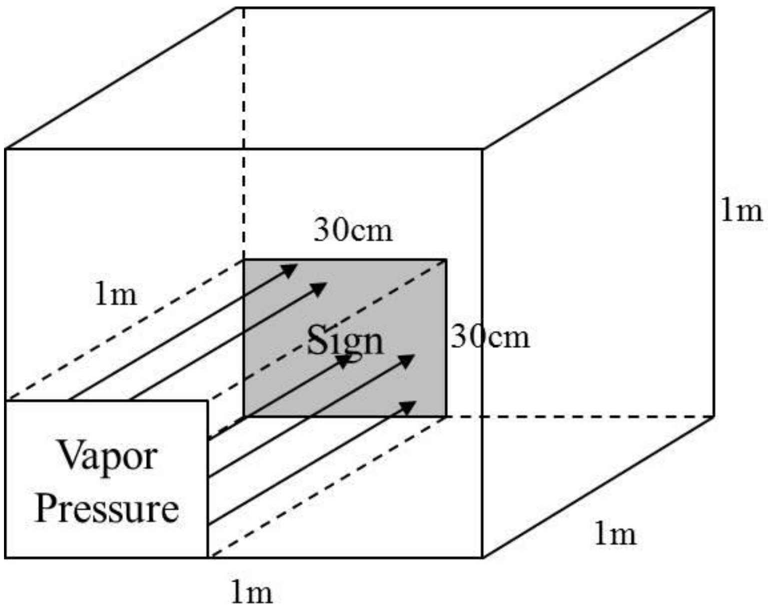


Figure 6. Concept of condensation that occurs on sign

Thus, the amount of condensation that can occur on the chart can be calculated as follows:

$16.24(g/m^3) \times (0.3m \times 0.3m \times 1m) = 1.46\ g/m^3$

Theoretically, the amount of condensation that can occur on a normal sign within the thermal-hygrostat can be 1.46 g/m^3.

4.5 Measurement of reflectivity for each sign

Road signs reflect the lights coming from the oncoming headlights of vehicles to provide information to the driver, so the retro-reflectivity of reflectivity in road signs must maintain a certain value. Generally, reflectivity used in Korea applies super-high-intensity retro-reflective sheets, and for each sheet, the coefficient of reflection followed by the entrance and observation angle are as that of Table 3.

Table 3. Standard of Coefficient of Reflection for Retro-reflective Sheet in Korea

(unit : cd/lx·㎡)

Observation angle	Entrance angle	White	Yellow	Red	Green	Blue	Brown
0.2˚	-4˚	700	525	105	70	42	21
0.2˚	30˚	325	245	49	33	20	10
0.5˚	-4˚	250	190	38	25	15	7.5
0.5˚	30˚	115	86	17	12	7	3.5

The reason for the measurement of reflectivity is to measure the dew elimination time for normal signs and anti-dew signs having inserted insulation. In the case of signs that use insulation to prevent condensation, even if condensation takes place, reflectivity was measured to check whether such can be removed more quickly compared to normal signs. In the same way as measuring condensation, in the case of reflectivity, the signs removed from the thermo-hygrostat were measured using a retro-reflectometer at 30 second time-intervals.

4.6 Experimental results in occurrence of dew

In this experiment, exclusive dew occurrence experiments regarding road signs were conducted 4 times and simultaneous experiments on normal signs and insulating materials were conducted 4 times. A total of 8 condensation occurrence experiments were conducted in the thermo-hygrostat in the experimental lab.

Condensation that occurred in the thermal-hygrostat was measured by units per 30 seconds as the amount of condensation was measured. Results are as shown in Table 4.

Table 4. Test result of dew amount in lab

# of test / time	Normal road sign alone				Normal - insulation road sign comparison test							
	#1	#2	#3	#4	#1		#2		#3		#4	
	normal	normal	normal	normal	normal	insulation	normal	insulation	normal	insulation	normal	insulation
30sec	749.24	749.28	748.5	748.77	748.1	797.21	747.9	793.88	748.1	793.72	747.1	796.21
60sec	749.07	749.15	748.39	748.68	748	797.12	747.8	793.81	748	793.64	747	796.12
90sec	748.95	749.06	748.31	748.6	747.8	796.99	747.7	793.73	747.95	793.6	746.8	795.99
120sec	748.85	748.94	748.24	748.54	747.8	796.91	747.6	793.64	747.85	793.5	746.8	795.91
150sec	748.77	748.83	748.19	748.45	747.7	796.8	747.7	793.62	747.9	793.41	746.7	795.8
180sec	748.69	748.76	748.1	748.38	747.5	796.7	747.6	793.6	747.8	793.4	746.5	795.7
210sec	748.59	748.67	748.03	748.32	747.5	796.61	747.5	793.44	747.7	793.28	746.5	795.61
240sec	748.53	748.6	747.96	748.27	747.4	796.53	747.4	793.35	747.65	793.21	746.4	795.53
270sec	748.45	748.53	747.91	748.2	747.3	796.43	747.3	793.26	747.55	793.14	746.3	795.43
300sec	748.39	748.48	747.83	748.15	747.2	796.33	747.3	793.19	747.5	793.09	746.2	795.33
330sec	748.34	748.4	747.79	748.1	747.1	796.27	747.3	793.11	747.5	793.03	746.1	795.27
360sec	748.27	748.36	747.73	748.06	747	796.19	747.2	793.05	747.4	792.94	746	795.19
390sec	748.21	748.3	747.68	748.01	747	796.13	747.1	792.96	747.35	792.89	746	795.13
420sec	748.16	748.25	747.62	747.97	746.9	796.06	747.1	792.91	747.3	792.85	745.9	795.06
450sec	748.1	748.19	747.58	747.93	746.9	795.99	747.1	792.82	747.3	792.77	745.9	794.99
480sec	748.05	748.15	747.53	747.89	746.8	795.96	747	792.83	747.25	792.74	745.8	794.96
510sec	748.01	748.1	747.48	747.85	746.8	795.91	746.9	792.79	747.15	792.71	745.8	794.91
540sec	747.97	748.05	747.45	747.82	746.8	795.9	746.9	792.8	747.15	792.69	745.8	794.9
570sec	747.92	748.02	747.41	747.79	746.7	795.88	746.9	792.74	747.15	792.66	745.7	794.88
600sec	747.88	747.98	747.38	747.77	746.7	795.87	746.9	792.76	747.1	792.63	745.7	794.87
630sec	747.85	747.95		747.75	746.6	795.87	746.8	792.76	747.05	-	745.6	794.87
660sec	747.81	747.93		747.72	746.5	795.86	746.8	-	747	-	745.5	794.86
690sec	747.78	747.91		-	746.6	795.85	746.7	-	747	-	745.6	794.85
720sec	747.74	747.89		-	746.5	-	746.7	-	746.8	-	745.5	-
750sec	747.71	747.88		-	746.5	-	746.7	-	746.8	-	745.5	-
780sec	747.69	747.87		-	746.5	-	746.6	-	-	-	745.5	-
810sec					746.5	-	746.6	-	-	-	745.5	-
840sec					746.4	-	-	-	-	-	745.4	-
amount	1.55	1.41	1.12	1.05	1.7	1.36	1.3	1.12	1.3	1.09	1.7	1.36

In the experiment results, it was shown that the amount of condensation on normal road signs displayed an average of about 1.39g, thus having a 0.07g difference with the theoretical amount of 1.46g. This means that an error rate of about 4.8% was shown, but in experiment 4 where a relatively small amount of condensation occurrence was eliminated, only 1.44g resulted. In other words, the error rate between the theoretical occurrence rates was only 1.4% with 0.02g.

When conducting experiments indoors, the surveyed scale of the experimental lab with an average temperature of 22℃ and 22% relative humidity were aimed to be maintained, but errors can be seen as results of not being able to maintain constant temperature and humidity. The amount of condensation that occurs through the thermo-hygrostat is adequate for explaining the temperature of the atmosphere and the amount of saturated vapor.

When the experimental results are arranged, it is as shown in Table 5.

Table 5. Comparison amount of dew between theoretical and lab test

Theoretical amount of dew		Actual amount of dew		Error rate (%)
1 m^3 (g/m^3)	30cm X 30cm sample of road sign (g/m^2)	1 m^3 (g/m^3)	30cm X 30cm sample of road sign (g/m^2)	
16.24	1.46	15.44(16)	1.39(1.44)	4.8(1.4)

*Brackets denote the value with the outlier removed

In the case of insulated signs, an average of 1.23g of condensation occurs, resulting in an amount that is 0.17g less than normal signs. The amount of condensation that occurs on insulated signs being less than normal aluminum signs means that the surface temperature of insulators descended less than that of aluminum signs. By using the amount of condensation that occurred on insulated signs, the surface temperature of insulated signs can be inferred.

When the amount of condensation occurring on insulated signs are converted in units of g/m^3, such is as follows:

$$1.23g /(0.3m\times 0.3m\times 1m) = 13.7\ g/m^3$$

As shown in Figure 2., when the temperature is 25℃ the amount of saturated vapor is 23.04 g/m^3, resulting in

$$23.04\ g/m^3 - 13.7\ g/m^3 = 9.34\ g/m^3.$$

Thus, in the case of insulated road signs, the amount of saturated vapor is about 9.34 g/m^3, and 13.7 g/m^3 that exceeded 9.34 g/m^3 occurred as a condensation phenomenon on signs as a surplus amount of vapor.

The closest amount of saturated vapor to 9.34g/m^3 from Figure 2. is about 10℃, and when insulation is used on signs, the surface temperature can be inferred to about 10℃.

Compared to how the temperature descends to about 5℃ compared normal signs that have retro-reflective sheets directly attached, the temperature descends for signs that use 1mm of urethane insulators are less.

This research was conducted as an indoor experiment, and when urethane is used as insulation, it is evident that anti-dew road signs are more effective than normal signs.

4.7 Experimental result of measurement in reflectivity

In this experiment, the reflectivity of normal signs and insulated anti-dew signs were measured at 30 second intervals.
When the entrance angle of reflectivity were 2 degrees and 5 degrees, cd/lx· ㎡ of retro-reflectivity was measured. The experiment results showed that as time passed, insulated anti-dew signs showed an increase in retro-reflectivity when compared to normal signs. Due to this, condensation was eliminated faster.

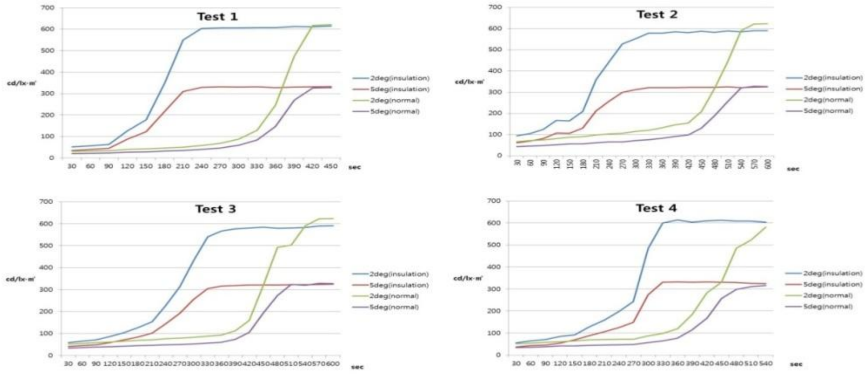


Figure 6. Comparison of retro-reflectivity between normal and anti-dew road sign

Figure 7. shows the improvement of reflectivity in aim of anti-dew with the use of insulation, which differs from general signs.

Table 6. Retro-reflectivity improvement rate for anti-dew road sign compared to normal road sign

(unit: %)

Sec	Test 1		Test 2		Test 3		Test 4	
	0.2deg	0.5deg	0.2deg	0.5deg	0.2deg	0.5deg	0.2deg	0.5deg
30	67.3	67.3	41.4	41.8	12.7	19.7	8.6	9.9
60	76.2	81.1	46.6	50.3	18.5	25.6	20.9	23.8
90	87.1	92.7	66	68.5	21.6	28.3	22.7	21.5
120	215.8	225.5	105.4	104.6	39.5	45.3	39.6	30.4
150	316.9	320.7	87.7	89.3	59.8	68.3	44.9	64.4
180	643.6	586.7	132.5	129.8	84.9	90	86.3	103.4
210	978.6	798.6	264.5	242.5	115.2	120.5	122.8	132.5
240	943.3	735	326	295.4	200	195.7	176.2	167.1
270	784.7	605.8	398.1	351.7	298.7	281	236.1	211.1
300	587.1	453.7	380.9	333.3	426.2	383	460.2	386.7
330	371.3	297.4	378.5	325.2	515	441.7	507.9	420.4
360	146.7	123.1	338.6	290.5	508.4	425.8	415.1	332.9
390	29.3	22.2	298	250.4	410.6	332.7	228.3	190.4
420	-1.1	1.5	274.8	228.9	262.5	205.7	115.5	98.8
450	-1.1	1.5	181.3	146.6	82.5	66.3	84.9	29.3

According to the test experiment results, the time consumed in securing 80% of retro-reflectivity standard before the occurrence of condensation was 20% faster for insulated signs as compared to normal signs. In the case of road signs where insulation was used to prevent condensation, the elimination of condensation progresses faster than that of normal road signs, leading to more prompt securement in its reflective functions.

5. CONCLUSIONS

In this study, anti-dew signs were made as prototypes in order to eliminate condensation from occurring on road signs. In the case of checking the performance of anti-dew signs, it is best when installed outdoors and observed the occurrence of insulation. However, condensation does not occur each time, and such requires much time and expenses.

In order to verify the effects of anti-dew road signs, this research suggests a method of implementing this experiment in a thermo-hygrostat so that the environment within the experimental lab becomes similar to that of the outdoors. In addition, in the case of condensation that already occurred, as a matter of efficiency, a method was suggested as the amount of condensation and amount of time consumed in eliminating condensation can be measured through the measurement of retro-reflectivity on sign.

The experiment results showed that errors that took place between the amounts of condensation and theoretically calculated the amount of condensation were within 5%, and if the outlier is eliminated, the error rate drops to within 2%. In addition, the amount of time taken for eliminating condensation was based on the retro-reflectivity that drivers can actually sense and were calculated by set times. In the end, it was evident that insulated anti-dew signs were more effective.

It is expected that any type of anti-dew signs can inspect anti-dew effects if the experiment methods as suggested in this research are applied.

However, since the experiment was conducted indoors, there is a need to conduct outdoor experiments so that differences can be examined.

Also, in the case of anti-dew signs with insulated materials, meteorological resources were used in this experiment to suggest a construction value. Still, additional experiments are needed regarding the construction method of anti-dew signs where the types and width of insulation such as thermal conductivity and heat transfer coefficient are taken into consideration.

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REFERENCES

Jensen, J. J., Sorensen, K., Pederson, H. (1993) Dew on Road Signs, Testing of anti dew film from May 11 -. June 17, 1993, *The information Service of Light & Optics*.

Kang,I.K., Kim,T.H. (2010) Experimental Research regarding the Condensation Performance of Windows following changes in external winds, *Korean Eco-friendly Construction Conference Proceeding 4th No.1*, 9-25.

Kidron, G., J.(2000) Analysis of dew precipitation in three habitats within a small arid

drainage basin, Negev Highlands, Israel, *Atmospheric resarch 55*, 257-270.
Kidron, G.J.(2005) Angle and aspect dependent dew and fog precipitation in the Negev desert, *Journal of Hydrology 301*.
Kidron, G.,J.(2010) The effect of substrate properties, size, position, sheltering and shading on dew: An experiment approach in the Negev Desert, *Atmospheric Research 98*, 378-386.
KICT (2012), *Development of Anti Dew Technologies-Phase 1*, Korea Institute of Construction Technology, Korea
Lee, C.Y. (2010) Research on characteristics of materials required for establishing qualitiy standards for films that prevent condensation on road signs, *Prodeeding of Korean Road Society Conference*, 489-192.
Lee, J.H., Cho, G. H.(2004) Examination of lighting facilities with highway information sign that applied an electrodeless system, *Proceeding of Korean Lighting and Electric Equipment Conference*, 184-188.
MLTM (2010) *Regulations for Road Signs*, Ministry of Land Transport and Maritime Affairs, Korea
MLTM (2010) *Installation of Road Safety Facility and Maintenance Guidelines*, Ministry of Land Transport and Maritime Affairs, Korea.
Waard, D., Brookhuis, K., Mesken, J. (2005) Evaluaion of legibility of improper reflecting signs, *International Journal of Industrial Ergonmics 35*, 645-651.
Xu, N. (2002) Laboratory Observation of Dew Formation at an Early Stage of Atmospheric Corrosion of Metals, *Corrosion Science 44*, 163-170.