Measurement of Road Surface Temperature using Thermal Mapping System

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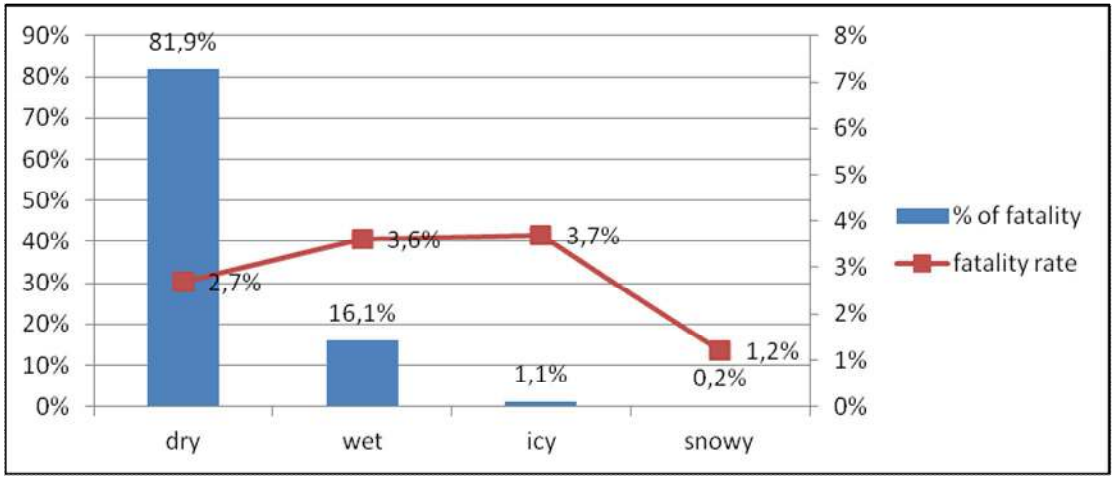
0. CONTENT

1. INTRODUCTION

- Road accidents statistics of Korea in 2006



- Temperature is important factor for road surface condition

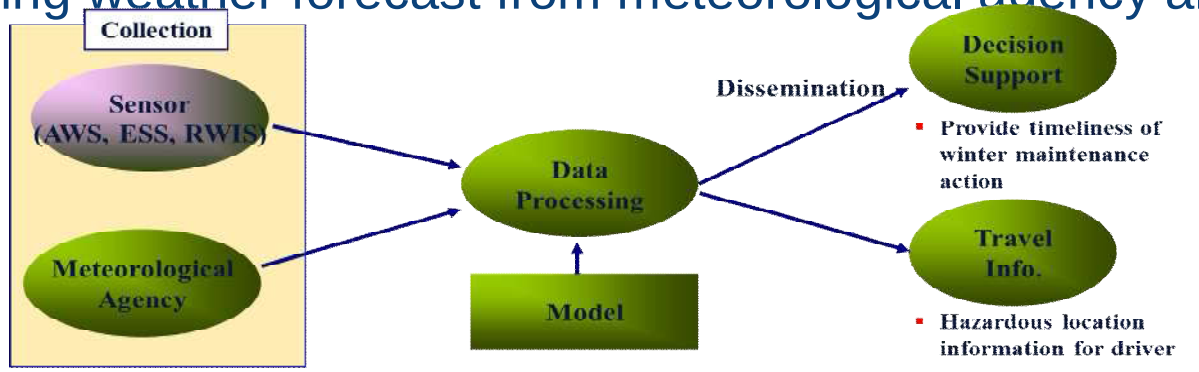
  - Road surface Temperature(RST) is more important than air temp.

- Although air temperature is same, RST would be different by road segmentations.

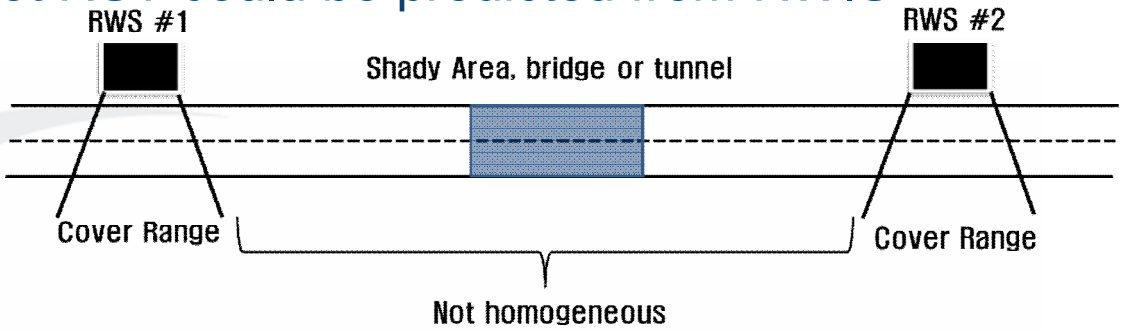
  - Road managers and drivers know only the air temperature

1. INTRODUCTION

- RWIS(Road Weather Information System) was developed to predict RST using weather forecast from meteorological agency and AWS.



- Only spot RST could be predicted from RWIS



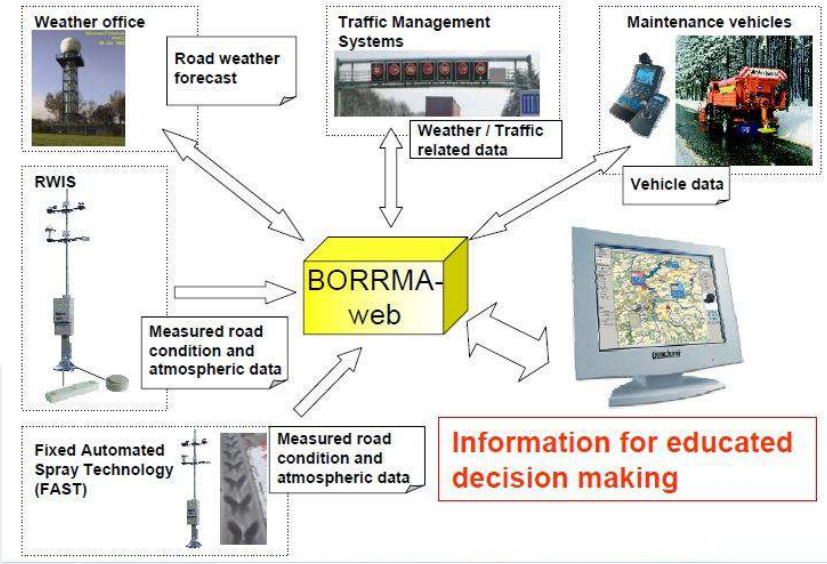
- Predicting the RST information of continuous road sections from spot RST of RWIS is necessary for road safety and maintenance.

1. INTRODUCTION

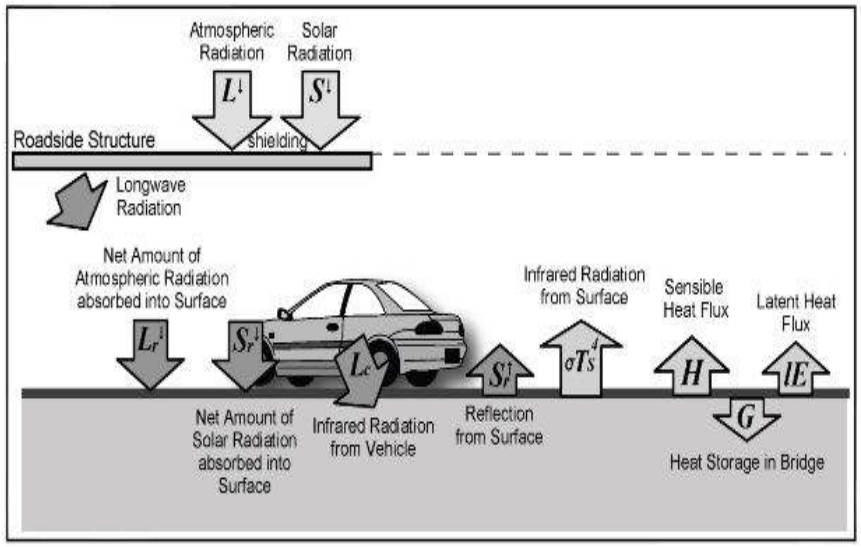
- Thermal mapping system using mobile mapping system was developed and the RST was compared with each road segmentation
- The road surface temperature and air temperature data were collected over 200km of expressway (motorway of Korea) during the night time using the developed system
- After collecting the RST, compared the RST to identify the characteristics of the normal, bridge, tunnel and cut slope road segmentations using ANOVA test.

2. Literature Review

- Many countries operate the RWIS or MDSS(Maintenance Decision Support System) to predict road surface conditions and obtain the information to select appropriate road maintenance work in winter.
- RST prediction model is the basic model of RWIS and MDSS.



(MDSS ASFINAG, Werner Seidl, Thorsten Cypra, ILC, 2010)

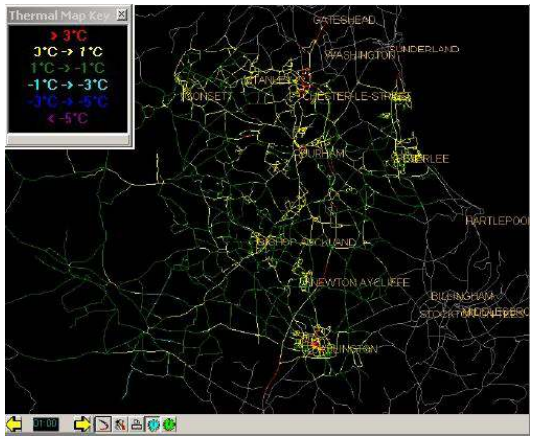


(Takahashi, 2008)

2. Literature Review

- The RWIS mobile temperature measurements, called thermal mapping system, has been used in applied road climatological studies since the mid-1970s(Torbjörn Gustavsson, 1999)
- Several Thermal Mapping Systems are operating
  - Vaisala, Boschung, Institute of Radar Meteorology(IRAM) Russia etc.

(http://www.iram.ru/iram/p32_mtras_en.php)



(Mobile Weather Data Collection, Paul Bridge, Vaisala, 2009.8)

3. Thermal Mapping System and Data Acquisition

- What is Thermal Mapping System ?
  - Thermal Mapping is the process of identifying the pattern of temperature variation across roads and runways under different weather conditions(Paul Bridge, Vaisala, 2009.8)
  - In order to collect the road surface data along the consecutively and promptly, survey vehicle is used to generate thermal map.
  - Spatial temperature map
- The road surface temperature, air temperature and air humidity were measured using mobile equipment with temperature and humidity sensors.
- The result was plotted on the GIS based map to generate Thermal Map.

3. Thermal Mapping System and Data Acquisition

- Thermal Mapping System

Road Surface Temperature

Air Temperature and Humidity

GPS

Survey Vehicle

1. Camera for sign, Road lane width information
2. Road surface temperature
3. GPS/INS for Road alignment (horizontal, vertical, cross section)
4. Laser for watering on road surface
5. Laser for Road width, guardrail, median info.
6. Camera for watering on road surface

3. Thermal Mapping System and Data Acquisition

- Composition of Thermal Mapping System Sensors

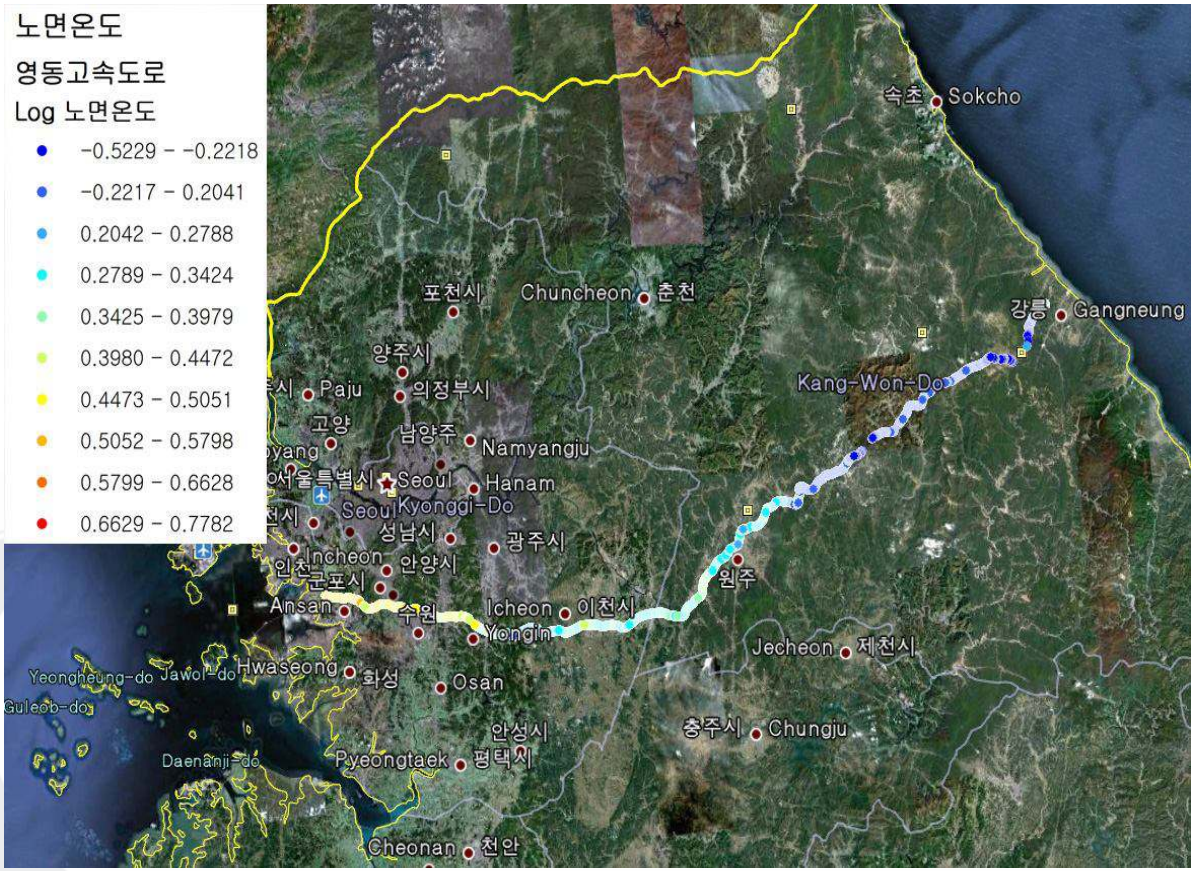
Sensor	Category	Range
Air humidity sensor	Measurement Range	0%~100% RH
	Measurement Accuracy	±3% RH
Air temperature sensor	Measurement Range	-20℃~+80℃
	Measurement Accuracy	±0.3℃
Power supply	Input	8VDC~30VDC
Communication device	Output	4~20mA
Road Surface Temperature Sensor	Measurement Range	-25℃~+100℃
	Measurement Accuracy	±0.5℃
	Maximum stable range	<0.5℃
	Measurement Position from surface	40mm~1000mm
	Input Voltage	10VDC~32VDC
	Communication	CAN
GPS Sensor	Positional Accuracy	- 1.8m(Single GPS) - 0.7m(DGPS)
	Frequency	Max. 20Hz (0.05s)
	Power Supply	9VDC~24VDC
	Communication	RS-422

3. Thermal Mapping System and Data Acquisition

- Aplied to approx. 220km of the expressway No. 50 (Young-dong expressway) of Korea
- The expressway No. 50 crosses the Korea peninsula from east to west and most of the road sections consist of mountainous area.
- Survey conducted around midnight from 10:00PM to 01:00AM, March, 2010 to minimize the impact of solar radiation and solar heat.
- The survey vehicle system collected the data of the air temperature, road surface temperature and air humidity every 0.5 seconds over every 14m at 100km/h travel speed
- Total 18,677 data were collected data for each sensor.

3. Thermal Mapping System and Data Acquisition

- The blue dots represent lower temperatures whereas red dots do higher temperatures



4. Analysis Result

- In order to analyse the RST characteristics along each road section, the following analysis was conducted
  - Comparison of measured air temperature with Automated Weather Station(AWS) from Meteorological Agency
  - Comparison of RST for each road section
- Comparison of measured air temperature with AWS
  - The weather forecast data is a representative value for certain area not air temperatures above the road network
  - In order to compare the measured air temperature and the air temperature from AWS, nearest AWS air temperatures were collected
  - Comparison of RST for each road section
  - Dividing the road segmentations into a normal, bridge (overpass), tunnel and cut slope section to compare the RST for each road segmentation

4. Analysis Result

- The comparison result of measured air temperature from vehicle and AWS

No.	length of road(km)	Average Measured Air Temp. (A)	Observed Air Temp. of AWS (B)	(A)-(B)
1	8.4	2.6	0.7	1.9
2	7.9	2.7	1.6	1.1
4	10.3	2.7	1.4	1.3
5	10.3	2.7	0.6	2.1
6	10.8	2.0	-0.6	2.6
7	9.1	2.0	0.2	1.8
8	9.8	2.0	-0.1	2.1
9	3.1	1.9	0.5	1.4
10	10.3	2.1	0.5	1.6
11	2.9	1.8	1.5	0.3
12	4.9	1.7	-1.3	3.0
13	10.5	1.1	-0.6	1.7
14	9	1.2	-0.1	1.3

- Measured air temperatures from thermal mapping are higher than the observed air temperatures.

4. Analysis Result

- The comparison result of air temperature and RST for each road segmentation

Classification	length(km)	Ave. RST	Ave. Air Temp.	Ave. of RST-Air Tem.
Normal	135	1.94	1.87	0.08
Bridge	20	1.55	1.88	-0.33
Cut slope	43	1.45	1.82	-0.37
Tunnel	15	2.41	1.28	1.13
Total	213			

- The average air temperature for all road sections were almost similar except for the tunnel sections.
- However, the average RST in bridge and cut slope road segmentations were lower than in normal and tunnel segmentations.
- The RST of normal and tunnel sections were higher than air temperature, but the RST of bridge and cut slope road sections were lower than air temperature

4. Analysis Result

- The result of ANOVA test of RST for each road segmentation

	classification	N	significant error = 0.05			
			Normal	Bridge	Tunnel	Cut Slope
Tukey HSD	Cut slope	3560	1.446			
	Bridge	1678		1.552		
	Normal	11266			1.935	
	Tunnel	1283				2.412
	Significant Error		1.000	1.000	.151	1.000
Duncan	Cut slope	3560	1.446			
	Bridge	1678		1.552		
	Normal	11266			1.935	
	Tunnel	1283				2.412
	Significant Error		1.000	1.000	1.000	1.000
Scheffe	Cut slope	3560	1.446			
	Bridge	1678	1.552			
	Normal	11266		1.935		
	Tunnel	1283			2.412	
	Significant Error		.064	.268	1.000	

- From the ANOVA test, the RST for each road segmentation shows significant result among the normal, bridge, cut slope and tunnel segmentations

5. Conclusions and Further Study

- Thermal mapping system was developed and applied to the real-world roads to generate thermal map about the RST, air temperature and air humidity were acquired .
- Analyse the difference of RST for road sectional characteristics such as normal paved road, bridge, cut slope road section and The RST for each road section was compared.
- Even though the RST was usually higher than air temperature in normal paved road segmentations, the RST was lower than in bridge and cut slope segmentations due to insufficient geothermal on bridge and solar radiation on cut slope
- Similarly the RST in bridge and cut slope showed relatively lower values compared to the normal paved roads and tunnel segmentations
- Only one surveyed thermal mapping data was analysed
  - If several thermal mapping systems operate regularly for certain road segmentations and the acquired data accumulates, the RST for certain road segmentation without AWS can be predicted.

Thank you for your attention !