

Infrared Analysis on Heat Radiation of Urban Facilities

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ABSTRACT: Presently the urban heat island phenomenon highly draws attention of not only climatologists but also urban planners. Heat island phenomenon appears differently according to the urban structure and scale. Till now, many planners have fixed either on the various land use pattern or the energy consumption in order to solve the heat island phenomenon. These kinds of researches have limitations in closely inquiring its cause and characteristics.

This study tries to overcome these limitations and focus on grasping its cause through analyzing the thermal radiation of urban facilities in the street. The scope of study is three main streets and their facilities in Jeonju city. Along these routes the thermal radiation is captured by the PDIRC. In this process, it is possible to confirm the characteristics of thermal radiation in each facility and section visually. And finally, it can be known that there is a relationship between the heat island phenomenon and urban facilities.

Keywords: Heat Island Phenomenon, Thermal Radiation, DITI (Digital Infrared Thermal Imager), Land use, Urban Facility

NOMENCLATURE

1. INTRODUCTION

Urbanization and Industrialization have caused expansion of artificial urban facilities, increase of fossil fuel consumption and spread of paving surface. These are connected with increase in artificial heat radiation within urban areas, so that the purification power of air condition went on being weakened. Above all, it induces the urban heat island phenomenon that the temperature of urban areas becomes higher

than the one of rural areas. In terms of heat island phenomenon, a lot of researches are carried out. In the early period, most of researches had focused on the temperature differences between urban and rural areas under condition of topoclimate [1]. Recently, researches are extended in the scope of microclimate as follows: microclimate change on the basis of the impact of land use [2], real time interpretation of air temperature using vehicle observation system [3] and Satellite picture interpretation of heat island effect using

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ERDAS [4]. But most of researches have limitations, that their isotherm is just only drawn in one dimensional graph as a final result. On the contrary, this study tries to visualize thermal circumstance in the dimension of microclimate using a thermal imager, what of urban facilities are the main factors emitting the heat and to analyze heat island phenomenon on a principal road how different the thermal radiation in each section of the road is. Hereupon we can know the reason, from what the heat island phenomenon is affected in detail.

2. RESEARCH SCOPE AND METHOD

2.1 Research Scope

The spatial scope of this study is Baekjae principal road and its surrounding areas (e.g. Fig. 1). This road goes all the way across Jeonju city from the eastern outskirts via an urbanized area to the western suburban area. So, various land use patterns are made up. In the process of field survey, the thermal analysis is carried out in 9 sections. The reason of sectional division lies on the different characteristics of location, land use and urban facilities.

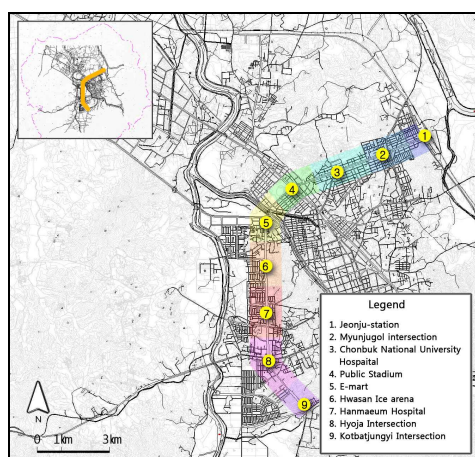


Figure 1: Survey area and its 9 sections.

In the process of field survey, the thermal analysis is carried out in 9 sections. The reason of sectional division lies on the different characteristics of location, land use and urban facilities.

The time period of this study is at 1 - 2 pm August 23rd 2007. Since it rained, 3 days have passed. And it was a sunny and hot day of high atmospheric pressure. This day is selected for preventing the effect on rain evaporation as much as possible [5].

2.2 Research Method and Process

For field survey, a Vehicle Digital Thermometer (VDT) and a Digital Infrared Thermal Imager (DITI) S280 are used. For air temperature survey, the VDT is covered with an aluminium box in order to prevent external effects like as direct rays of the sun, the affect of velocity and the heat of car surface (e.g. Fig. 2). As first step for the survey, the air temperature in each section is measured in real-time. The car is driven below 30km/h in order to avoid any effects of sudden mechanical shock.



Figure 2: VDT system.

The Digital Infrared Thermal Imager S280 (e.g. Fig. 3) is automatically focused for measurement distance and its temperature extent is from $-40^{\circ}\text{C} \sim +1500^{\circ}\text{C}$. Its accuracy is $\pm 2^{\circ}\text{C}$. In case of thermal image analysis, the heat resolution visually displays 0.08°C at 30°C .

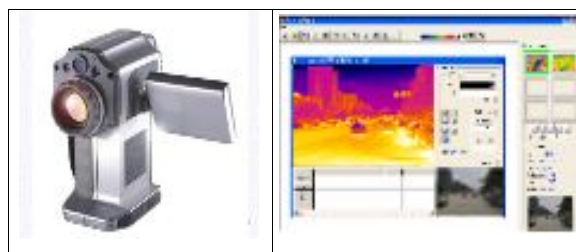


Figure 3: DITI S280 system and its display.

With use of this DITI, the heat emission from urban facilities is visually identified. Hence it is possible to grasp the characteristics of heat emission and the distribution of thermal facilities precisely. These visual data can be applied for drawing the isotherm in the survey areas. So this is the second step of the survey process for confirming the thermal condition of each area. Finally, all of these results are compared with the air temperature of the identical time, which is officially announced by the meteorological observatory of Jeonju City.

3. SPATIAL CHARACTERISTICS OF SURVEY AREAS

3.1 Spatial Characteristics

Each section of survey areas is distinguished by land use and its thermal facilities.

Section 1 is next to the western outskirts of the city. So, this area is mostly surrounded by natural landscape. Its land use is specified as commercial zone for a rail station and its real development density is relatively low. From section 2 to section 4, these areas come under an urbanized zone. Among them, section 2 consists of commercial zone and residential zone. Most of buildings are set back from the principal road. And it is mostly surrounded by low 3-4 story houses. Section 3 is a typical residential zone of high development density. Section 4 is a mixed area of commercial and residential use. It has also a

sports complex mostly with asphalt paving open space. Sections 5 and 6 are a buffer zone, which have relatively broad open space as like as river and hill. From section 7 a suburban begins. Section 7 is specified as commercial zone and residential zone. Section 8 is the highest development density among sections 7, 8 and 9.

3.2 Thermal Circumstance

The meteorological observatory of Jeonju City announced that the air temperature at the identical time of the surveyed day was 33 degrees Celsius. It was the highest temperature day in the week.

Urban facilities showed respectively various surface temperatures. These surface temperatures are measured by DITI S280.

Table II: Average Surface Temperature of Urban Facilities. (°C/ No.)

	Sign-boards	Street furniture	Wall	Asphalt	Street Trees	Street Garden
1	33	38	34.33	54	29	32
2	42	37	31.5	51	30	32
3	34	34	31	52	27	31
4	40	35.3	32.5	46	28	31
5	34	33	26	48	25	28
6	34	35.3	27.5	45	28	28
7	38	40	32.67	44	28	31
8	34	41.3	32.67	50	30	27
9	46	36	34.67	47	27	31

Besides the temperatures in Table II, the temperatures of building were different according to facing materials. For example, Glasses showed 29°C in average and their deviation was within $\pm 3^\circ\text{C}$. Bricks showed 32°C in average and their deviation was

Table I: Spatial Characteristics.

Section	Total Size	Length of Road	Traffic Sign-boards	Pavement (Asphalt)	Front Garden	Footpath
	m ²	(m)	(No.)	m ² (%)	m ² (%)	m ² (%)
1	8472	169	6	5641 (66.58)	425 (5.02)	2406 (28.40)
2	37014	734	13	24620 (66.52)	2001 (5.41)	10393 (28.08)
3	11929	222	7	7687 (64.44)	715 (5.99)	3527 (29.57)
4	11010	214	8	8097 (73.54)	89 (0.81)	2824 (25.65)
5	11488	229	4	9105 (79.26)	0 (0.00)	2383 (20.74)
6	16867	337	7	12960 (76.84)	0 (0.00)	3907 (23.16)
7	20383	396	12	15462 (75.86)	400 (1.96)	4521 (22.18)
8	12617	231	7	9460 (74.98)	140 (1.11)	3017 (23.91)
9	20121	397	8	12802 (62.48)	370 (1.81)	7319 (35.72)

within $\pm 1.5^{\circ}\text{C}$. Whereas, the walls with marble and cement showed relatively high surface temperatures: Marble showed 32.7°C in average and their deviation was within $\pm 8^{\circ}\text{C}$. And Cement showed 35°C in average and their deviation was from -4°C to $+7^{\circ}\text{C}$. The DTIT S280 made it possible to analyze the temperature at each point of urban facility from the highest to the lowest (e.g. Fig. 4).

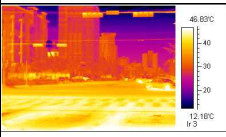
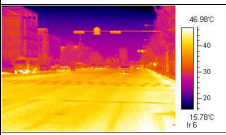
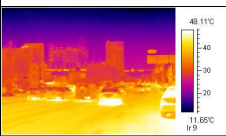
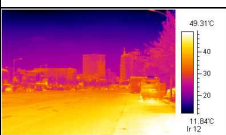
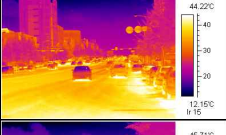
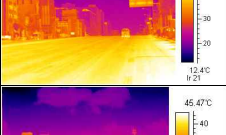
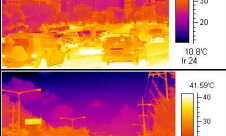
	Temperature Layers	Measured Section	Average Temperature
1			33.14°C
2			35.66°C
3			36.34°C
4			37.86°C
5			34.4°C
6			34.58°C
7			35.57°C
8			38.02°C
9			37.94°C

Figure 4: Thermal Radiation in each Section of Baekjae Road

4. SURVEY RESULT

4.1 Measurement of Air Temperature

The air temperature in each surveyed section was quite different. In comparison to the official temperature, all of sections showed higher temperature condition. The section 1, which is the outskirts of the city, was 0.14°C higher than the temperature of identical time at that day and the lowest temperature section. The highest temperature was sections 8 and 9, the western suburban area and their air temperatures were measured in 38.02°C and 37.94°C and the second highest one was the section 4, urbanized area. This kind of temperature trend showed that the nearer the urbanized areas were, the higher grew air temperature.

Table III: Air temperature in each section of Baekjae road.

Section	Temperature ($^{\circ}\text{C}$)	Humidity (%)	Velocity (m/s)
1	33.14	42.6	0.3
2	35.66	36.0	0.08
3	36.34	30.8	0.06
4	37.86	26.3	0.04
5	34.40	35.5	0.4
6	34.58	35.7	0.13
7	35.57	34.1	0.14
8	38.02	28.4	0.03
9	37.94	30.2	0.04

4.2 Effecting Factors on Thermal Radiation

We analyzed the effecting factors of all sections on air temperature through linear regression modelling. The possible variables are humidity, wind velocity, the ratio of front garden area over pavement area, and the ratio of footpath area over pavement area, as shown in Table IV. Those variables are chosen because they show the statistical significance. In Table IV, the significant effecting factor on air temperature of the

roadway is humidity. It is thought that humidity may absorb the heat in part.

Humidity, wind velocity and ratio of front garden over pavement have negative effects on air temperature. Increase of front garden area over pavement area results in decrease on air temperature, while increase of footpath area is negatively associated with it.

Table IV: Causal Analysis on Air Temperature^a

Variable	Parameter Estimate
Intercept	45.10 ^b
Humidity	-0.305 ^b
Velocity	-2.220 ^c
Front garden/Pavement	-4.620 ^d
Footpath/Pavement	3.657 ^c

^a $R^2 = 0.948$, $\text{Pr} > F = 0.0077$

^b significance at $p < 0.01$

^c Significance at $p < 0.05$

^d Significance at $p < 0.1$

5. CONCLUSION

5.1 Survey Result

In conclusion, it was possible to verify the clear difference of air temperature in city areas by use of DTIT S2880 visually and statistically. The air temperature in urban area was strongly influenced by various urban facilities. It means the difference of air temperature by section lies not merely on the location, but on its urban facilities, how intensive and artificial the location is developed. Namely, the heat island phenomenon is not only the problem between urban area and rural area, but the one even inside the urban area.

Moreover we could confirm the layer of air temperature in each section differently, even though in this study it was not possible to clearly differentiate the height and the width. Nevertheless, we could visually grasp the greenhouse effect as heat island phenomenon according to the urban facilities.

5.2 Necessity for following Researches

Except the presented results, this study has some limitations.

First, in the process of the measurement of air temperature the influence of wind and direct ray of sunlight was excluded as much as possible, because they are regarded as exterior effect. For that, an aluminium box was made and it was very effective to exclude this exterior effect in one hand. But in the other hand, the real air temperature, which human beings feel in daily life, was not enough reflected. So it is necessary to carry out various ways of study and compare their results.

Second, even though the air temperature of each point in all sections were measured and presented, the influence of factors such as size of shadow, energy consumption wasn't clearly reflected together. Accordingly, for more accurate causal analysis it is important to include not only physical urban facilities but also energy consumption or emission in following researches.

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