ANALYSIS OF URBAN HEAT ISLAND EFFECTS OF ROADS IN SEOUL

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ABSTRACT

This study investigates the urban heat island effect in Seoul and examines the key factors causing this effect. This paper, in particular focuses on effects of roads and their environment on urban heat island effect. I analyzed what and the extent to which roads affect urban heat islands effects and find out any possible solution to reduce urban heat island effects.
Data was collected from the sites in Seoul downtown in 2009. Air temperature and pavement temperature, vegetation, as well as ground temperature were measured using infrared thermal tracer. Road characteristics such as road width, number of lanes, vegetation types, central barrier types and adjacent land use, as well as pavement types of roads and sidewalks are considered as main factors. The experiment results show that the types of road, types of pavement, vegetation characteristics affect urban heat island effects. Also traffic volumes and land use such as parks are important factors. Based on the results, this study will provide possible heat island reduction alternatives for road designs

Key Words: Heat Island Effect, Land use, Road Design, Temperature, Vegetation

INTRODUCTION

One of the main causes of HIE was reported to be the increased impervious surface of cities. In case of the capital, Seoul more than 73% of the surface were coved by impervious surface and 70% of these surface was occupied by road including sidewalks. These impervious surfaces caused various problems such as urban flooding increases, lower rivers and insufficient underground waters. One of the problem caused were the problem of urban heat island effects(HIE). This study investigates the urban heat island effect in Seoul and examines the key factors causing this effect. This paper, in particular, focuses on effects of roads and their environment on urban heat island effect. I analyzed what and the extent to which roads affect urban heat islands effects and find out any possible solution to reduce urban heat island effects.

LITERATURE REVIEW

There was a few researches about HIE. Most of literatures focused their research on effects of land use and roadside vegetation on air temperature distribution. Yoon(2001) found that temperature in roadside vegetation was lower than that in their surrounding towns. The temperature was higher in the paved surface and barren land than roadside trees. The impact of temperature reduction was affected by the wind velocity, i.e. the higher the wind velocity, the smaller the impact. In addition, temperature difference was greatest when wind velocity was lowest. The land cover ratio was also important factor. More wood and grassland land helped to reduce the temperature. It was reported that when wind velocity was low followed by when wind velocity was high, the temperature reduction was great. It was reduced the least when wind velocity was the lowest. Lee et al. (1996) found that surface temperature increase rates during the summer and spring season were the highest in grass, secondly high in barren land and thirdly high in interlocking block and the least in the concrete pavement. Air temperature depending on types of land use was also the same as above. Temperature difference between the highest and lowest in the natural land use such as barren land and grass was smaller than artificial pavement such as paved surface, implying that they are more relieved of the daily temperature range. Kim et al. (2003) found that high correlation between urban temperature and land use by estimating distribution curve of isothermal temperature in and outside of the city. According to their observation, temperature in the urban green zones was relatively lower than that in other parts of the urban zones, implying that land use types had strong impact on reducing air temperature.

EXPERIMENTAL DESIGN & DATA COLLECTIONS

In this study, the typical road sections considering road width, numbers of lanes, vegetation types, median types and so on were chosen from the downtown of Seoul. SP experimental design was applied. There were three variables were two or three levels of variables used for the experimental design. The factorial designs were applied and eighteen experimental compositions were chosen. According to the designs, the sites were chosen from the old downtown areas and also new downtown in Seoul. The air temperatures were measured using Infra Thermal Imager Equipment for the survey and Thermal Wizard were used to analyze temperature distribution. The temperatures were measured three times each day for a month in July. As well as the air temperatures, the characteristics of the road sections such as the pavement types, the width of roads, traffic conditions, and the median barriers, vegetation characteristics such as the types of vegetations, the areas of vegetations, heights and intervals of vegetations were also measured. The areas were measured in $500m^2$ and the air temperatures and pavement temperatures were measured. The photos of the sites were also taken as well as the thermal maps.

DESCRIPTIVE ANALYSIS RESULTS

The impervious surface areas were one of the main factors which caused HIE in the city. In particular, the impervious surface area occupied more than 73% in Seoul and 70% of them were covered by road paved surface. Therefore, the paved roads were very important cause of the HIE in Seoul. This was the first research which investigated the effects of road surface on HIE in Seoul. Therefore, in this paper, I explained the various factors considered to affect HIE such as vegetation, road surface, the road types and the median types.
There were only eighteen sites which were not enough number of observations for modelling, considering the number of variables and levels for the experiments. Therefore in this paper, the analysis was mainly based on the descriptive analysis about the air temperature. The average temperature and temperature difference distribution of highest were used for the analysis. At first, number of lanes, roadside vegetation effects, vegetation median types and surrounding types were considered and the number of lanes were not significantly effective on temperature reduction, therefore the other three effects were considered in this study.

FigureTable 1 - Average Temperature Difference Distribution between High and Low during Day

	Road	Sidewalks	Trees	Vegetation Median	Average
1	20.9	16.1	16.1	20.9	18.5
2	18.3	15.1	6.9	18.3	13.4
3	21.8	20.8	11.7	10.8	16.3
4	21.4	21.7	13.7	21.4	18.9
5	22.7	23.0	11.9	12.8	17.6
6	20.8	19.0	9.0	20.8	16.3
7	18.7	14.1	14.1	18.7	16.4
8	23.9	18.4	12.0	23.9	18.1
9	14.0	12.4	8.0	14.0	11.5
10	17.5	15.3	13.2	17.5	15.3
11	20.9	19.2	11.8	20.9	17.3
12	18.2	17.3	10.0	9.3	13.7
13	18.1	16.2	16.2	18.1	17.2
14	23.4	18.7	9.3	12.2	15.9
15	17.2	18.7	7.2	7.2	12.6
16	20.7	16.2	11.7	20.7	16.2
17	17.7	16.9	8.0	17.7	14.2
18	18.9	16.3	9.2	8.4	13.2

Roadside Vegetation Effects

As mentioned in the literature review, the vegetation was the one of the very important factors for the heat reductions. In particular the vegetation was related to the shadow, which was very important factor to reduce the temperature in summer. In Seoul, the old downtown had longer than six hundreds history and the street trees were also very old. Therefore, trees in old downtown were very old and high, which allowed very wide shadow effects on HIE. Four types of roadside vegetation were considered; no vegetation, individual small trees, individual tall trees, small trees with grassland, and tall trees with grassland. Average highest temperatures were compared depending on the types of roadside vegetations. The results were summarized in Table 1. The results showed that the roadside vegetation reduced the average temperature up to five to six ℃. The detailed types of vegetation didn't seem to affect the temperature reduction in terms of absolute temperature reduction. The average temperature difference between the highest temperature and lowest during the day showed slightly different results. The types of vegetation were likely to affect the temperature distribution across day. The individual tall tree types of vegetation were found to have great effects on temperature reduction, implying the tall trees keep the temperature steady relatively to the other vegetation types. As shown in Figure 1, the temperatures along the roadside trees were relatively lower than the road.

Table 1 Temperature Comparison by Roadside Vegetation Types

Median Types	Average Highest Temperature(℃)	Average Temperature Difference(High-Low(℃))
None	39.533	17.033
Individual small trees	33.404	16.004
Individual tall trees	33.338	13.588
Small trees with grassland	34.063	15.413
Tall trees with grassland	33.400	14.750

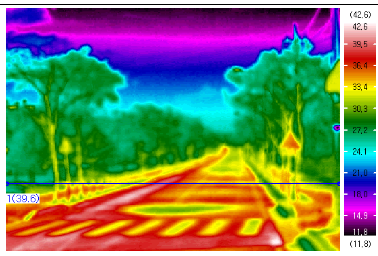
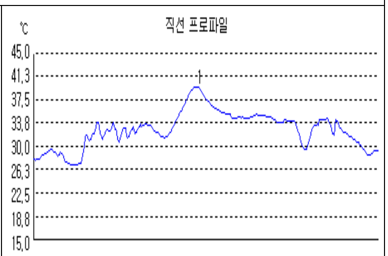
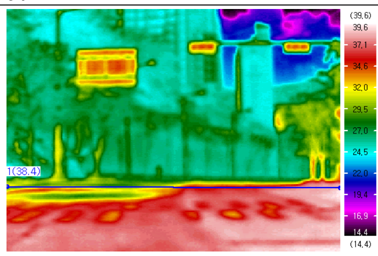
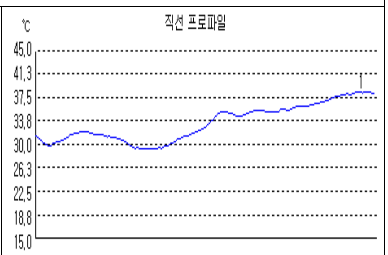
Photos	Thermal photos	Thermal Graph
Case 1 Typical road with tall trees with grassland		
		
Case 2. Typical road with roadside individual tall trees		
		

Figure 1 Effects of Roadside Vegetation Types on Thermal Temperature Distribution

Vegetation Median Effects

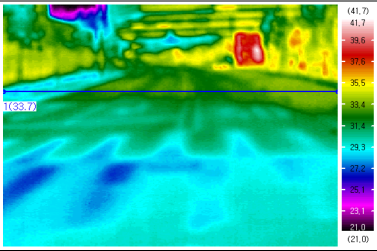
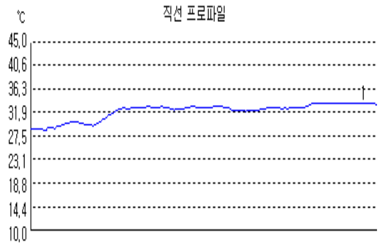
I investigated whether trees in the median reduced air temperature. Air temperatures were compared by the vegetation median types. There were three types were considered; no median, vegetation median with small trees and grassland, and vegetation median with tall trees and grassland. The average temperatures were summarized in the below table. As shown, the vegetation median seemed to have strong effects on temperature reduction. Average temperature on the road with no median, i.e. only asphalt pavements was 35.7 ℃. The average temperature with vegetation median was 32℃ and the height of tree didn't seem to be effective on temperature reduction. The differences of temperatures were about four ℃. The temperature reduction effects of vegetation might be caused by the shadow and the impervious surface. Fig 2 showed photos, thermal camera mapping and thermal graphs of two typical cases of the data collection sites, of which cases with vegetation median and the temperature distribution across its road. As shown in the Figure 2, the temperature profile clearly showed the reduction effects of vegetation medians. The average temperature difference between highest and lowest temperature was 2℃, implying the roads with median trees showed relatively low heat increases.

Table 2 Temperature Comparison by Median Types

Median Types	Average Highest Temperature(℃)	Average Temperature Difference(High-Low(℃))
None	35.7	16.3
Small Tree Median with grassland	31.9	14.2
Tall Tree Median with grassland	32.1	14.2

Photos | Thermal photos | Thermal Graph

Case 1 Typical road with no median

Case 2. Typical road with vegetation median

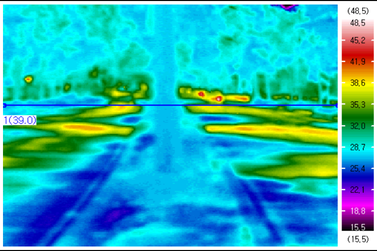
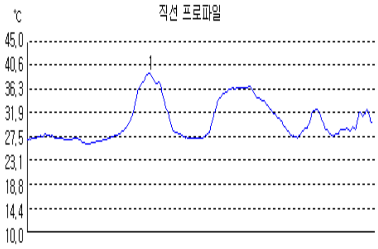




Figure 2 Effects of Median Types on Thermal Temperature Distribution

Surrounding Types

The interesting findings were that the temperatures along roads were very sensitive to the surrounding i.e. whether there were buildings or open spaces such as parks. The temperatures were also compared between surrounding along the roads. I classified into two groups; one for buildings and the other for open space such as parks. The results were summarized in Table 3 and shown in Figure 3. The surrounding types were also effective to the temperature reduction. The average temperature of roads surrounded with buildings was 35.8℃ and that of roads surrounded with open green spaces was 33.3℃. The average temperature difference didn't show great difference depending on surrounding types.

Table 3 Temperature Comparison by Surrounding Types

Surrounding Types	Average Highest Temperature(℃)	Average Temperature Difference(High-Low(℃))
Buildings	35.8	16.3
Parks, Open Space	33.3	15.6

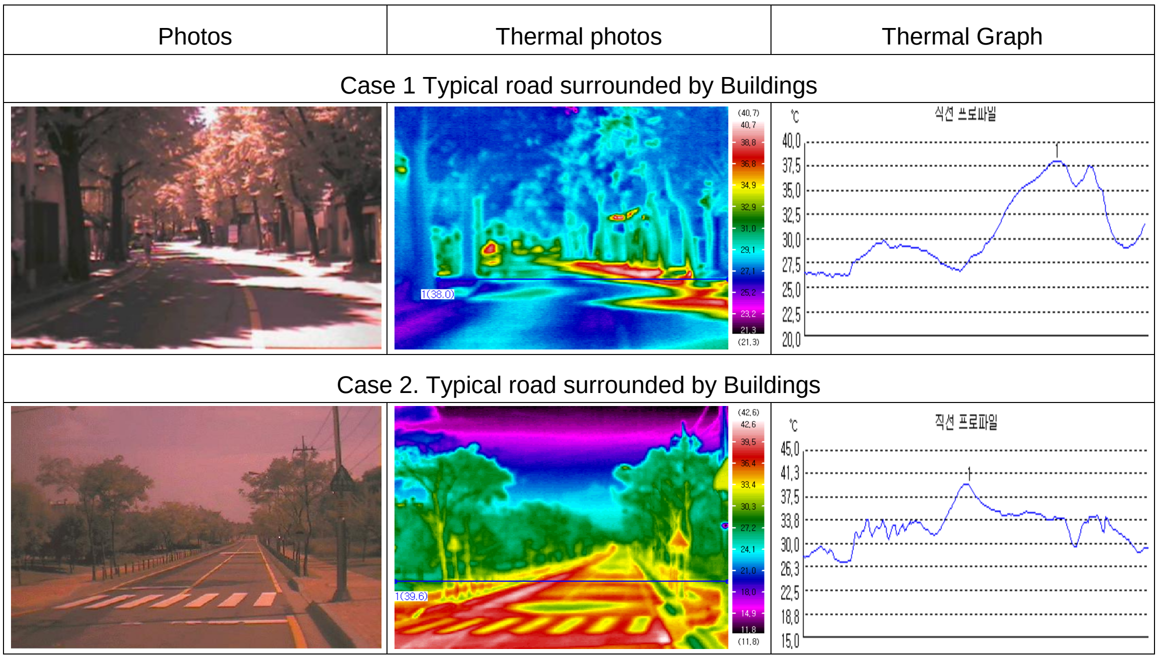


Figure 3 Effects of Surrounding Types on Thermal Temperature Distribution

DISCUSSION AND FURTHER STUDY

This study investigates the urban heat island effect in Seoul and examines the key factors causing this effect. This paper, in particular focuses on effects of roads and their environment on urban heat island effect. I analyzed what and the extent to which roads affect urban heat islands effects. Data was collected from the sites in Seoul downtown in 2009. Air temperature and pavement temperature, vegetation, as well as ground temperature were measured using infrared thermal tracer. Road characteristics such as road width, number of lanes, vegetation types, central barrier types and adjacent land use, as well as pavement types of roads and sidewalks are considered as main factors. The experiment results showed that the types of road, types of pavement, vegetation characteristics affected urban heat island effects.

At the planning stages I expected that the traffic and road related characteristics were more effective to the temperature increases such as number of lanes and traffic volumes. It, however, was found that the vegetation along roads were the most important factors, which I never accounted. The vegetation was not important factor in terms of transportation. So it was usually neglected from the main concern. The vegetation along roads was considered only for visual effects and landscape related factors. But the results showed that even the narrow vegetation strips such as vegetation median had great effect to cool down the road temperature.

According to the results, the possible solution for urban heat island effects were to provide more green space including vegetation along roads, vegetation median as well as allowing more green open space along roads. These green vegetation integrated into road systems would be expected to reduce the temperature of road, leading the total temperature reduction. So I have looked the related literature review and found that the tree canopy was very important in terms of heat reduction, air pollution reduction as well as road runoff reduction. Like Washington D.C. and Atlanta, there had tree canopy target to achieve in the city government. Based on these results, this year I started to collect data more focused on green related variables along roads. The data collection was conducted and was analyzing the results.

This study only looked at the factors which affected the temperature around roads. Therefore, it is necessary to investigate the way these factors affect urban heat island effects. Unfortunately, in this it was beyond the research scope even though the title of this study was related. According to the results of this study, the micro-climate analysis and simulation were prepared and the field experiments which allow the vegetation types into road systems will start in mid of July this year. In this study, I only looked at the effects of vegetation types of factors on heat reduction. These field experiments and micro-climate simulation are expected to show whether and the extent to which applying these vegetation to the existing roads reduce the road temperature and city temperature and ultimately, the way these affect the urban heat island effects.

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