CHANGES OF THE MICRO-CLIMATE AND BUILDING COOLING LOAD DUE TO THE GREEN EFFECT OF A RESTORED STREAM IN SEOUL, KOREA

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ABSTRACT

Cities all over the world have been warming up in the summer over the years. Seoul, Korea, is also an example of how a city was transformed into an urban heat island. Green areas produce social, economical and environmental benefits in highly populated urban areas. This study is to investigate the micro-climate changes and urban-scale cooling load reduction by the recently restored Cheonggye stream, also known as Cheonggyecheon, in Seoul, Korea. Under the urban development in 1950's, Cheonggye stream located in central Seoul had been covered with pavement and the overpass of concrete structures for 58 years. A lot of surrounding buildings, traffic and people caused Cheonggye stream area to be getting hotter than other districts. For the urban environmental renovation, 5.84km-long stream was restored on September 2004. Since the restoration, the ecosystem in the center of Seoul is reviving. This simulation study analyzes the micro-climate changes in restored Cheonggye stream and its surroundings by using Envi-Met, a microclimate model designed to simulate the surface-plant-air interactions in urban environment. We employed TRNSYS to estimate the urban scaled cooling load reduction by means of the output data of Envi-Met simulation. The results indicated the cooling benefits of the restored stream areas are promising at the surrounding built environments.

KEYWORDS

micro-climate, restored stream, Envi-Met, TRNSYS, cooling load

INTRODUCTION

Cheonggye stream situated in the middle of Seoul was covered with the concrete when the elevated road was built in 1991, beginning with the covering and pavement in 1958. Its surrounding area was crowded with buildings, cars and a lot of mobile population, but 5.84km of Cheonggye stream was restored in September 2004.

According to a report(Seoul Development Institute 2003), the effects from the restoration of Cheonggye stream include the maintenance & repair cost saving, better image of Seoul committed to the restoration of history and sustain ability, social benefit from the environmental improvement and so on. Among those effects, the social benefit from the improved environment is reported to include the relaxation of heat island in the city, higher availability of space to take a rest, better air quality, better health, restoration of ecosystem, cultivation of woods, etc. But, no quantitative studies have been conducted as to the expected building energy saving.

BACKGROUND

Cities which are covered with large heat capacity structure such as concrete and asphalt are easier to get heated by the sun than suburbs. As shown in Figure 1, temperature is about 2~5℃ higher in the city than its surrounding area because there are many factories, houses, cars, etc, in the city.

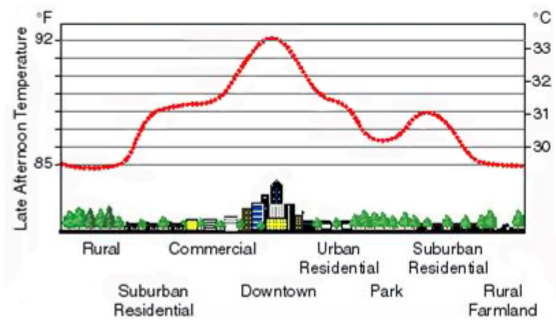


Figure 1 Heat island profile[1)]

Therefore, buildings located in the city have an increasing energy for cooling. According to the study(Meier 1997), 1℃ rise in the daily maximum temperature causes the peak electricity use to increase by 10%. Another study(Santamouris 2001) verified that 10℃ rise in the temperature causes the cooling energy to double. Therefore, cities are making efforts to reduce the heat flow of the earth

[1)] *http://employees.oneonta.edu/baumanpr/geosat2/Urban_Heat_Island/Urban_Heat_Island.htm*

Figure 3 Pre & post restoration of the stream

surface through the cooling roof, green surface, green roof, cooling asphalt or reduce the heat island through the wind path and shade effect by changing the urban form.

STUDY AREA

The study area to research the change in the micro climate and the reduction of the cooling load of building in the wake of the restoration of Cheonggye stream is located at Changsin 1-dong, Jongno-gu, Seoul, as shown in Figure 2. The study area is situated in the city and adjoins Cheonggye stream, a condition which led to a very poor environment with a noticeable high heat island intensity before its restoration.

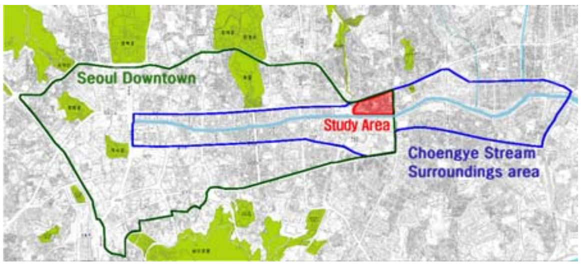


Figure 2 Study area

The study area is packed with approximately 1800 shops selling or manufacturing things because it is situated in a well-developed commercial zone. The area is famous for fashion shoe shops, always overflowing with cars and customers. However, the restoration of Cheonggye stream is considered to have improved the environmental conditions in this area a lot, such as the temperature, humidity, wind flow, air quality, noise. Figure 3 shows both pre-restoration and post-restoration of the stream.

Fig. 4 shows the cut section of Cheonggye stream which adjoins the study area, and water of 93,700m^3/day is flowing in the stream.

Figure 4 Cheonggye stream section[2)]

METHODOLOGY

To measure the heat island intensity in the study area, we measured the micro climate for 20 days, which was compared with the hourly mean weather data of Seoul for the same period. And temperature was measured by distance from Cheonggye stream to verify the cooling effect by the stream as shown in Figure 5. In addition, both measures were used as the initial value of simulation that will be conducted later.

Figure 5 Field measurement points

Envi-Met, micro climate forecasting program, was used to forecast the change in the micro climate before and after the restoration of the stream. Because field measured micro-climate data for the pre-restoration were not available, the results of Envi-Met simulation were verified by comparing

[2)] http://cheonggye.seoul.go.kr/

micro-climate data with measurement data in the study area after the restoration of the stream.

And then the reduction of cooling load was computed for each type of building using the TRNSYS 16 by classifying the buildings in the study area into different categories based on the building use, built era and gross area.

Figure 6 shows the flow chart in this study.

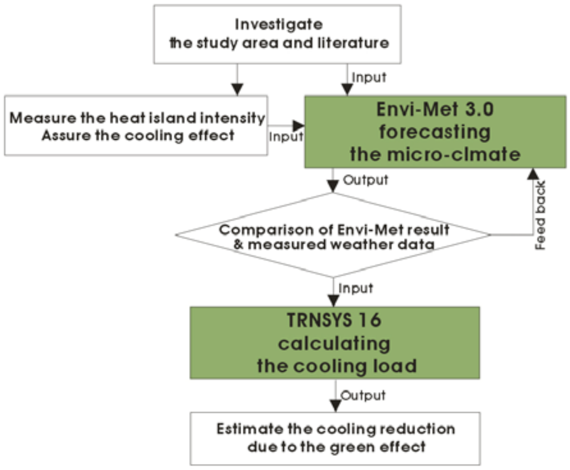


Figure 6 Flow chart

MICRO-CLIMATE ANALYSIS

By measuring the temperature, humidity, wind speed and radiation flux for the verification of the heat island intensity and the initial value of simulation, the micro climate was measured for a total of 20 days from Aug. 12, 2006 to Aug. 31, 2006, using the AWS (Automatic Weather Station). The location of measurement point was at 10m high on the ground.

Figure 7 shows the comparison between field monitored data and Seoul mean weather data for the same period.

In case of the temperature and humidity in the study area observed for 20 days, the temperature was always higher and the humidity was always lower than in Seoul. Except a few days, the wind speed and the total radiation were lower in most of the study area than in Seoul. Table 1 shows the summary.

Table 1 Summary of field data and Seoul data

	STUDY AREA	SEOUL AVERAGE	DIFFER-ENCE
Temperature (℃)	29.12	26.33	2.79
Humidity (%)	67.60	70.01	-2.40
Wind speed (m/s)	1.96	2.21	-0.25
Total radiation (MJ/m^2)	285.38	286.22	-0.84

As proposed by Landberg(1981), the fact that temperature increased though the total radiation, wind speed, humidity, etc, decreased implies that the study area is still suffered from the heat island effect even after the restoration of Cheonggye stream.

The temperature was measured 8 times at 9 locations, depending on the distance from Cheonggye stream(Figure 8). As the temperature depends on the wind speed and direction, the measurement was conducted in time when no wind is available.

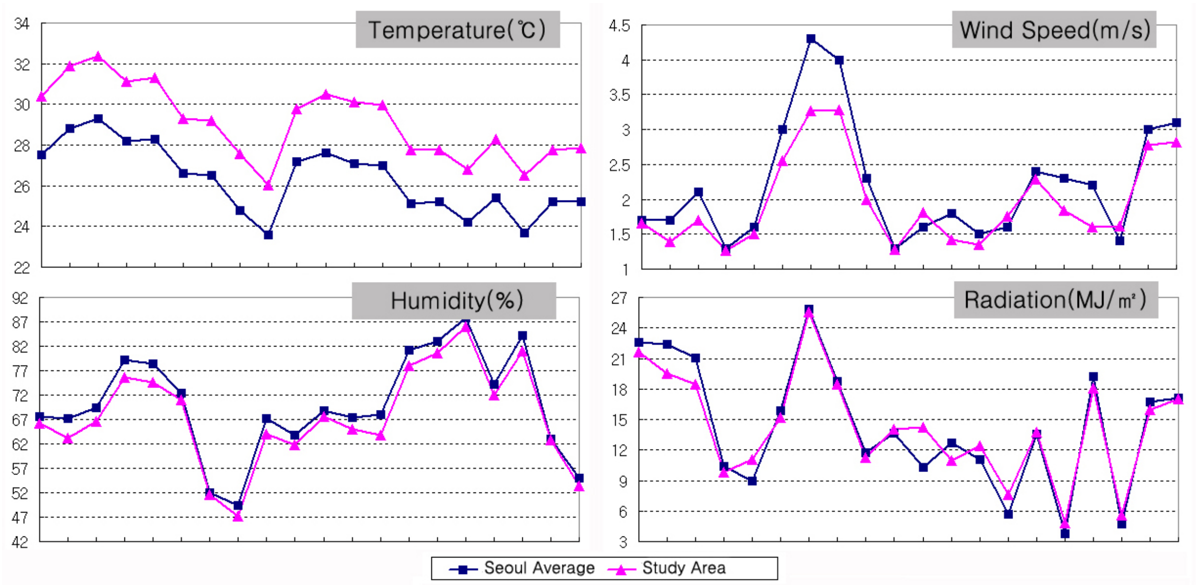


Figure 7 Comparison of field and Seoul average data

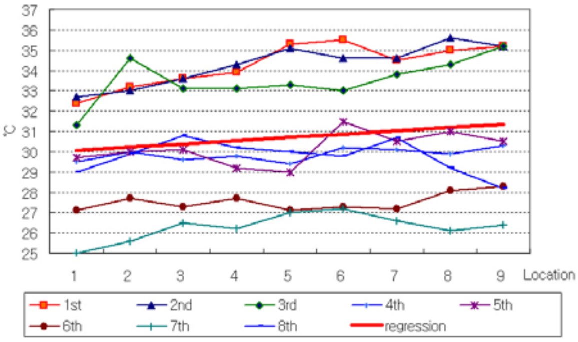


Figure 8 Field temperature measurement

The 1st, 2nd and 3rd measurements were conducted at 12:30 in a fine afternoon. The 4th measurement was carried out at 1:00 in a very cloudy afternoon. The 5th to 8th measurement was made out at 3:00 in a fine afternoon. The 1st to 3rd measurements were carried out when the sun was at the meridian altitude, and as a result, the entire area within Cheonggye stream except the green area showed a high temperature which exceeded 33℃ because all earth surfaces of the area were affected by the heat of sun. but it turned out that the temperature clearly rose in proportion to the distance from the stream.

Conversely, no regular difference in the temperature was found to arise from Cheonggye stream, considering that some of the measured points blocked by buildings were not affected from the solar radiation because the 5th to 8th measurements which were carried out around 3:00 PM were made when the solar altitude was lower compared to the 1st to 3rd measurement.

For the cloudy day(the 4th), that was found to be attributable to the little effect of reflected radiation and the relatively greater effect of diffused radiation on the earth surface because the heat radiation is little and the wind velocity is high over 2.5m/s.

The result of regression analysis indicates that the temperature rises generally in proportion to the distance from Cheonggye stream.

The micro climate of Cheonggye stream was forecasted, using Envi-Met 3.0 developed by professor Michael Bruce(1998) at Bochum University, Germany. The earth surface in the study area was structured using the mean of micro climate data which was measured in the study area based on the input value necessary for the program, and satellite photos. Although the study area was approximately 510 × 340m wide, a broader surrounding area must be considered because the temperature, humidity, wind speed and solar radiation are influenced by the interaction with the surrounding area. Therefore, an area which was 1080 ×540m wide was selected for the simulation. Figure 9 shows the map drawn on a scale of 1 to 15000 which was used for this study. Figure 10 demonstrates simulation results based on the input physical property value of components and data of initial micro climate(Table 2 and Table 3).

Figure 9 Study area map

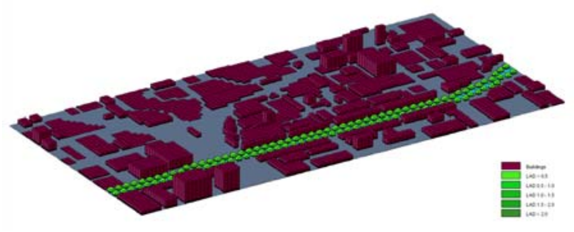


Figure 10 Field measurement result

Table 2 Physical property value of components

	ASPHALT	CEMENT	CLAY	WATER
Roughness	0.010	0.010	0.015	0.010
Albedo	0.2	0.4	0.0	0.0
Emissivity	0.90	0.90	0.98	0.96

Table 3 Data of initial micro climate

CONTENTS	INPUT VALUES
Simulation time	48h
Start time	06:00 AM
Wind speed	0.5m/s from ground
Wind direction	11.25 ° (NNE)
Surface roughness	0.1
Atmosphere	27.3℃
Relative humidity	77%
Absolute humidity at 2500m height	6g/kg
Longitude	127 E
Latitude	37.36 N

The simulation results indicated that the temperature difference between pre-restoration and post-restoration of the stream was distinct, however the cooling effect of the stream diminished as the distance goes further from the stream. The result of simulation indicated the greatest difference in temperature around noon between the pre-restoration and post-restoration of the stream (Figure 11). The temperature before the restoration of Cheonggye stream was 34.9℃, whereas it dropped to 33.6℃ after the restoration of Cheonggye stream, a decrease by about 1.3℃. The highest temperature in the area was 37.7℃, which is considered to be attributable to the heated surface of asphalt, as well as the fact that the area was not under any shade of surrounding buildings.

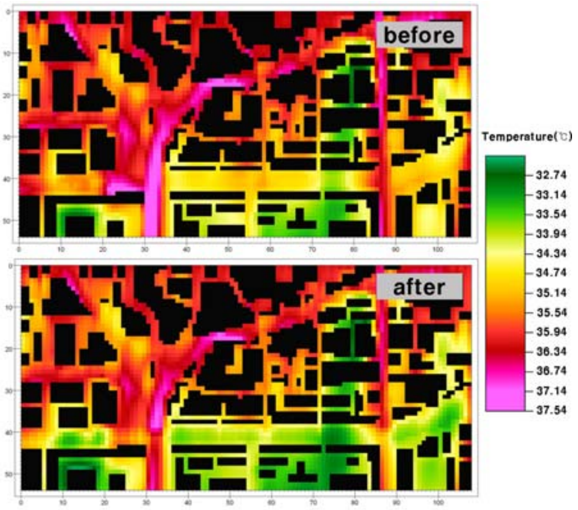


Figure 11 Envi-Met result at noon (temperature)

When it comes to hourly data comparison on a identical location of AWS installation as shown in Figure 12, we can realize that somewhat bigger difference between the measured data and the simulated results. Simulation predicted that the temperature was higher than most of the real measurement data.

This difference is considered to be attributable to the wind speed. It is considered that the high temperature of the surface of asphalt influenced the study area, resulting in a high temperature because the wind speed was assumed to be North North East (NNE) 0.5m/s when inputting the initial value for the simulation.

Though the outcome of simulation is an ordinary spatial and temporal result based on the numerical method using physical process, the actual measurement reflects the situation in which the measurement was carried out and is hard to be considered as a representative case. The error is considered to come from that difference.

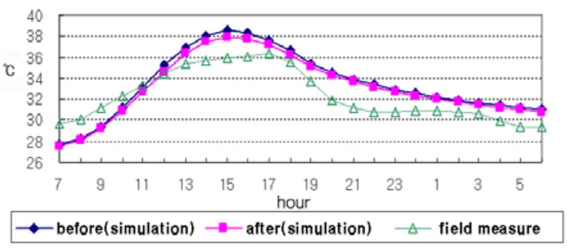


Figure 12 Temperature comparison of the real measurement and simulation

Figure 13 shows the absolute humidity at 12:00 in the afternoon. The absolute humidity was higher after the restoration than before the restoration, and the area located in the south of the stream saw the absolute humidity rose far more than the area located in the north of the stream did. Figure 14 represents the comparison with the actual measurement by converting the absolute humidity into the relative humidity.

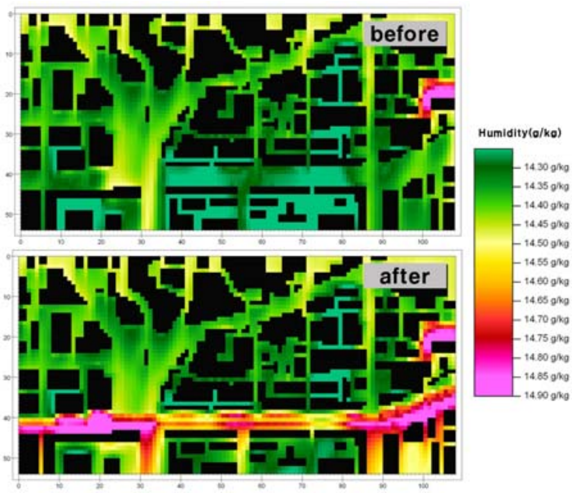


Figure 13 Envi-Met result at noon (absolute humidity)

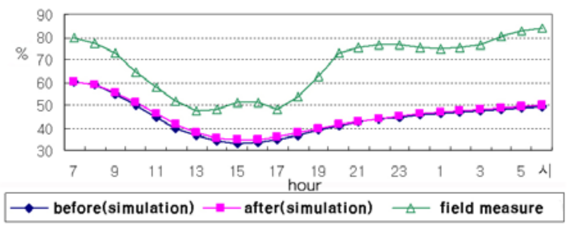


Figure 14 Relative humidity comparison of the field measurement and simulation

Wind speed and radiation were assumed as same in the simulation of both pre-restoration and post-restoration of Cheonggye stream. Even though they displayed a small difference at the point of the stream, there was no change in both wind speed and radiation considering the surrounding target area, not the restored stream itself.

ESTIMATE OF COOLING LOAD REDUCTION

To get the total cooling load reduction in the study area, the structures, use types and gross area of buildings were surveyed and modeled. And then the reduction of the load was computed using the micro climate change before and after the restoration of Cheonggye stream based on Envi-Met simulation.

The survey of the buildings area indicated that there were total 494 buildings in the study area. It was not easy to forecast the load of each building because so many buildings were scattered in this area. Therefore, the buildings were classified into different categories on the basis of the following assumptions and simplification of buildings.

• Classifying by building use(retail, restaurant, residential, hotel, office), built era(before 1970s, from 1970s to 1980s, after 1980)

• The classification by structure was ruled out from the study, considering that the difference in the structure of buildings come from the only structure which supports buildings, and the wall which has effect on the thermal load tend to show ordinary characteristics depending on the built era.

• Buildings were classified by gross area, regardless of the building floor area and number of floors of building.

• A constant setpoint temperature is maintained for the space cooling.

• Floors for manufacturing purpose and underground floors were excluded from the study as they are mostly non-conditioned area.

The classification of buildings in the study area is to be made as shown in Table 4 below. Majority of buildings, 76%, were built before 1970s, and buildings for sales purpose were accounted for 71%.

Table 4 Classification of buildings in study area

BUILT ERA	USE	NO.	NO.
Before 1970	retail	254	379
	restaurant	35	
	residential	57	
	hotel	28	
	office	5	
1970~1980	retail	67	79
	restaurant	5	
	hotel	4	
	office	3	
After 1980	retail	29	36
	restaurant	3	
	office	4	
Total buildings in study area : 494 buildings			

The cooling load of buildings which were categorized in the above was computed using TRNSYS 16, a program for interpreting the energy of building. Type54c was used for meteorological data. This component is capable of changing the monthly averaged meteorological data into a meteorological data by time, using the statistical data obtained by the long-term analysis of climate.

As shown in the Table 5 and Table 6, the physical property and internal heat gains were used to simulation input values by the survey of the study area and related literatures were input, depending on the type of building that were classified accordingly.

Table 5 Simulation input values by built era

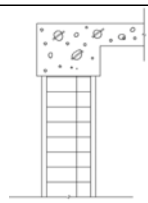
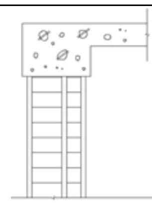
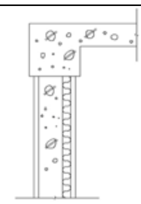
BUILT ERA	BEFORE 1970	1970~1980	AFTER 1980
Wall section			
Layer	cement mortar(0.01) brick(0.19) brick(0.09) cement mortar(0.01)	cement mortar(0.01) brick(0.19) air(0.03) brick(0.09) cement mortar(0.01)	cement mortar(0.01) concrete(0.15) insulation(0.05) gyps board(0.01)
U-value	1.340W/m^{2}K	1.147W/m^{2}K	0.535W/m^{2}K

Table 6 Simulation input by building use

INPUT DATA	RETAIL	RESTAURANT	RESIDENTIAL	HOTEL	OFFICE
Occupancy Density (㎡/person)	27.87	9.29	23.23	23.23	25.55
People (W/person)	90	75	65	65	65
Equipment (W/㎡)	2.691	1.076	8.073	2.691	8.073
Lighting (W/㎡)	17	17	17	17	17
Set point temperature (℃)	24	24	26	24	24
Schedule (hour)	06-20	05-20	0-24	0-24	06-20

Figure 15, 16 point to the pre-restoration load, depending on the building of each different type, based on the result of simulation. The difference of cooling load per unit area was as follows, depending on the occupant of building : hotel > residential > restaurant > office > retail building.

In addition, the comparison of the thermal load depending on the construction year implicates that old building with poor insulation causes an demands more energy.

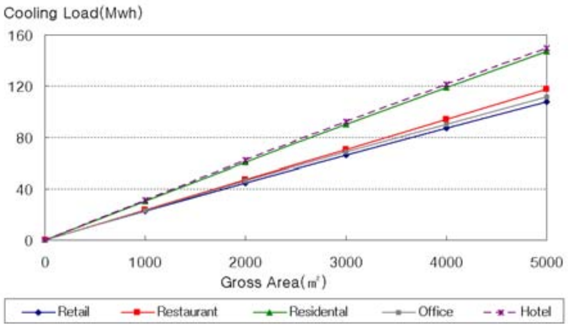


Figure 15 Simulation result by building use

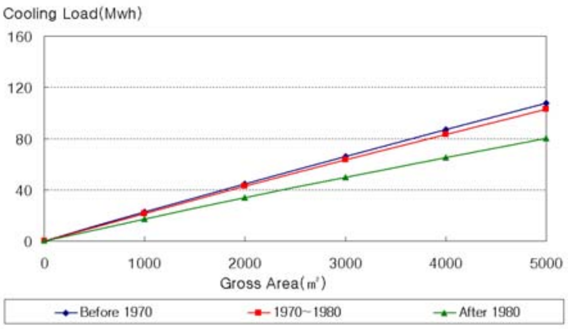


Figure 16 Simulation result by built era

Table 7 shows the load reduction rate by type of building, based on the simulation, before and after the restoration of Cheonggye stream. Mainly because of poor wall insulation the older the building, the bigger the reduction was.

Table 7 Load reduction rate by building use(%)

	BEFORE 1970	1970~1980	AFTER 1980	AVERAGE
Retail	2.20	2.20	2.05	2.15
Restaurant	2.24	2.23	1.34	1.94
Residental	2.20	-	-	2.20
Hotel	2.13	2.12	-	2.13
Office	2.03	2.01	1.84	1.96
Average	2.16	2.14	1.74	2.14

Fig. 17 shows the total cooling load reduction in August in the study area which was calculated by multiplying the gross area of all buildings by the cooling load reduction by type of building. The total cooling load required for a month of August was found to be 4167Mwh before the restoration. Total loads were recorded 4078Mwh after the restoration of Choenggye Stream.

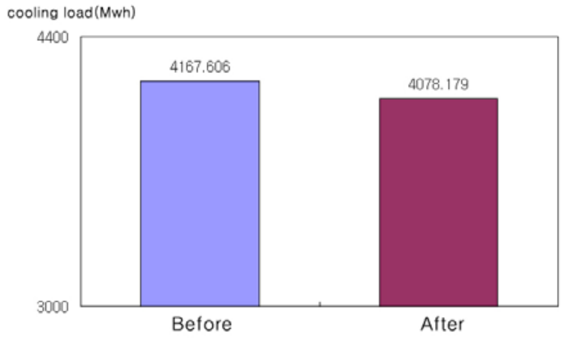


Figure 17 Total cooling loads before and after restoration of the stream in August

As a result, the cooling load reduction was approximately 89Mwh (2.14%). Because most of buildings in the area of this investigation were constructed before 1970s and have been mainly used for retail shops. Result has greater reduction effect of the cooling load than each type of buildings.

CONCLUSION

The green tract of land inside city reduces the heat island intensity and helps to save the cost of cooling the buildings around the green tract.

This study proposed the method to forecast the change in the micro climate arising from the greenization of urban surface and to quantatively analyze the reduction of energy load of buildings subsequently. As a part of that, this study analyzed the micro climate change in the center of Seoul arising from the restoration of Cheonggye stream and also analyzed the reduction of the cooling load of buildings in the surrounding area

Through field measurements, this study investigated the intensity of heat island in the study area and verified the cooling effect of Cheonggye stream on its surrounding area. This study figured out the change in the micro climate arising from Cheonggye stream and looked into the total reduction of the cooling load of buildings in August using two simulations. Though Cheonggye stream is narrow, it pulled down the daily mean temperature by 0.31℃ and pushed up the daily mean relative humidity by 0.89% in its surrounding area. And the total load of cooling in the study area lowered by 89Mwh during a month of August.

Though the reduction of the cooling load of buildings was 2.14% at best, a very insignificant figure, a tremendous reduction of the cooling load is expected in consideration of the whole surrounding area as a result of the restoration of Cheonggye stream. That suggests electricity cost in summer of cooling may be remarkably saved.

Advanced countries are struggling to overcome the urban heat island intensity in various ways, but not in a verifiable way. Therefore, this study was conducted as a part of basic research which aims to propose a method for forecasting the reduction of the energy of building, one of positive effects of greenization, by forecasting the effect of micro climate arising from the urban greenization.

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