AIR TEMPERATURE CFD SIMULATION OF OUTDOOR SPACE ACCORDING TO HEIGHT CHANGE OF MAIN BUILDING OF APARTMENT COMPLEX

Hyungi Song [1]

[1] Department of Urban Design and Studies, Chung-Ang University, Seoul

1. Introduction

1.1.Background and purpose of the study

The fact that abnormal temperatures and urban heat island phenomena are occurring all over the world has been revealed based on many existing studies. One of the causes of these abnormal temperatures and urban heat islands is human-induced urbanization. (Park Sang-wook, 2019) Nowadays, most cities in the world usually have temperatures between 1℃ and 4℃ higher than those in the surrounding rural areas, and the temperature increase in Korea is more than twice as fast as the average temperature in the world. In the past 100 years, global temperatures have risen by 0.74°C, the average temperature in the six major cities of the Republic of Korea has risen by 1.8°C, the precipitation has risen by 11.6m in the last 10 years, and the sea level by 10cm in 40 years Due to the recent realization of climate change, abnormal climates such as heatwaves, droughts, and cold waves are frequent and the damage is intensifying. The damage from the abnormal climate in Korea is concentrated in urban areas where more than 90% of the people live. (Ministry of Environment 2011)

The reality is that apartment complexes, which account for a high proportion of residential buildings in urban areas today, are designed and built with quantitative development as priority, so the design to respond to climate change is insufficient. To this end, the thermal environment of the outdoor space of the apartment complex was analyzed by applying various types of design element types to the CFD simulation.

Therefore, in this study, by simulating the microclimate environment of an apartment complex, the effect of temperature reduction in the complex according to the change in the height of the main building, a design element of the apartment complex, is to be analyzed in detail by using the CFD simulation program Envi-met.

1.2.Scope and method of study

In this study, a simulation scenario was established by setting the weather conditions on August 25, 2020 (the date of occurrence of a heatwave warning) targeting the Han Riverside apartment complex in Seocho-gu, Seoul, Korea. For the spatial range, the Banpo Acro River Park apartment complex located in the Banpo district of the Han River waterside in Seoul, Seocho-gu, South Korea, located in Asia, was selected. As for the content range, the atmospheric temperature of the outdoor space was analyzed according to the change in the height of the driving of the apartment complex using Envi-met, a CFD simulation program The air temperature of the space was analyzed. For the time range, statistical data from the Korea Meteorological Administration on August 25, 2020, when a heatwaves warning was issued, was used. The research method is as follows. First, Envi-met's definition, of a CFD simulation program and outdoor space within an apartment complex, is summarized through a literature review. Second, publicly measured data from the data portal (Seoul Meteorological Administration) is used. Third, based on the results of running the simulation using the CFD simulation program Envi-met, we find the appropriate height for reducing the atmospheric temperature of the outdoor space and suggest a pleasant outdoor space creation direction.

2. A Study on the Thermal Environment of Outdoor Space in Apartment Complex

2.1.Outdoor Space and Thermal Environment in Apartment Complex

1)Outdoor Space in Apartment Complex

An outdoor space generally refers to a space corresponding to the exterior of a house or building. The outdoor space of the multi-unit housing complex can be classified into an open space shared by all residents of the complex and a community space in the form of a building according to its function (Limited, 2011). As a building that directly affects the residential environment, it includes living convenience facilities such as medical facilities and social welfare facilities (Han Jeong et al., 2012).

The outdoor space can create a unique identity for the complex according to the landscape plan. visually Places can be connected, providing a walking and resting space for residents, and blocking from the outside. Moreover, as most of the complexes have recently removed ground parking as much as possible and converted them to underground, the importance of outdoor space is further emphasized and is emerging as a factor determining the value of complexes (Choi et al., 2009).

2)Walking Comfort and Thermal Environment

Comfort refers to the degree to which pedestrians can walk comfortably without being disturbed by pedestrian traffic in the pedestrian space. It is formed by topographical factors such as buildings. As such, comfort, which is a combination of thermal environment and microclimate factors, is an important factor that directly determines how long and pleasantly people can stay in a certain space.

In general, comfort in a thermal environment refers to the overall attractiveness of the environment, such as aesthetic value, comfort, convenience, and pleasure. Comfort is a very important characteristic that determines the quality of walking, but it is difficult to establish a universal standard because several factors act in a complex way. Also, depending on the recipient, contradictory reactions such as pleasantness and unpleasantness, preference, and dislike may appear (Seong-Hoon Oh et al., 2011).

3)CFD Simulation and Envi-met Program

CFD is an abbreviation of 'Computational Fluid Dynamic', which means computational fluid dynamics. It refers to discretizing using methods such as the surface/incompressible fluid analysis method (MPS), converting it into an algebraic equation, and analyzing the fluid flow problem using a numerical algorithm. (Sanghyun Kim et al., 2020)

Envi-met, which is most commonly used in the urban environment field, was developed by Michael Bruse (1998) of Bochum University in Germany. The advantage of the Envi-met model is that it is a microscale model of the interaction of the ground, vegetation, buildings, and atmosphere in an urban area, and it can create distinct microscale weather patterns and soft models such as forests as well as rigid building walls that can also be created. In addition, it has the feature of numerically analyzing detailed microclimate changes, so it is possible to calculate microclimate changes (fluid flow field, airflow, temperature, and humidity distribution) in the surrounding area due to high-rise buildings in urban areas. It also has the advantage of being able to select various conditions such as buildings and vegetation, so that it is possible to analyze on a micro-scale considering the design topography according to the user's design plan (Eunah Ko, 2010).

2.2. Review of previous studies and differentiation

By analyzing the atmospheric temperature of the outdoor space according to the height of the main building of the apartment complex, the preceding research was divided into three keywords: the outdoor space of the apartment complex, the improvement of the thermal environment, and the building arrangement using Envi-met.

In a study related to the outdoor space of the apartment complex, Jeong Gwang-bae (2015) suggested a subdivision of the outdoor space of the apartment building by analyzing the preference survey for the outdoor space of the apartment building, analysis of the space, etc. Accordingly, a plan for activating each detailed space of an apartment house was suggested. Kim Young-hoon (2018) investigated the planning characteristics of the outer space of an apartment complex located in Seoul and analyzed the spatial planning and design characteristics of residents as a community facility. Yoo Soo-myung (2014) aimed to survey and analyze the facilities preferred by residents and experts in planning outdoor facilities based on some revisions to the Regulations on Housing Construction Standards, etc. and propose future plans for outdoor facilities based on the results.

Looking at research related to thermal environment improvement, Kim Hwan-Seong and two others (2020) compared the effects of three physical arrangements on thermal comfort in the Apgujeong Hyundai Apartment Complex in Seoul. suggested Park Sang-wook (2019) quantitatively verified the temperature reduction before and after landscaping construction and the improvement of the thermal environment felt by users of the external space for the external space of the apartment complex by using ECOTECT ANALYSIS and the micro-weather model Envi-met. Kim Myeong-seon and others (2017) simulated the thermal environment for each region in Songdo International City using the Envi-met model. The met model was presented and the improvement effect was comparatively analyzed.

Looking at the research related to building layout using Envi-met, Byung-ro Yoo et al. (2010) used the micro-weather program Envi-met to understand the thermal environment characteristics of each apartment complex by layout type of the apartment building, and the temperature by apartment layout type Changes and wind flow changes were examined, and the optimal arrangement of apartment complexes to reduce the thermal environment was suggested. Kim Jeong-ho et al. (2012) tried to predict changes in the external thermal environment and microclimate due to the new construction and green space arrangement of the building, and predicted that the construction of the building increased by 2.5℃ on average, The composition of the green area was analyzed to have a temperature reduction effect of about 1.8°C.

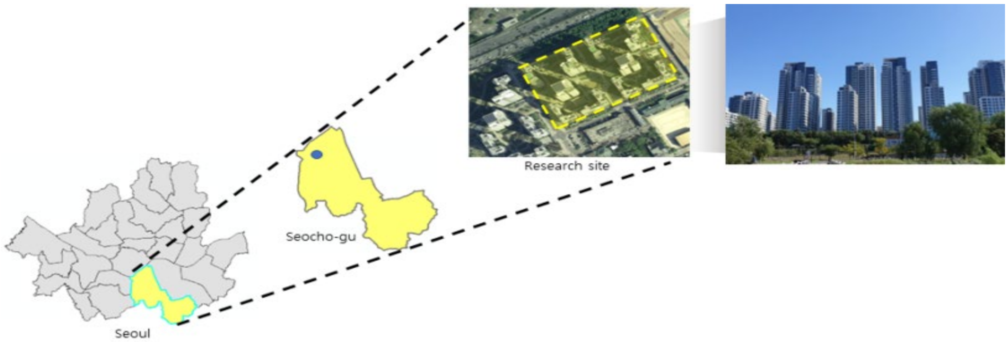
This study is differentiated from previous studies by using the CFD simulation program Envi-met to analyze the microclimate of the outdoor space formed according to the height change method for the outdoor space of the apartment complex in detail.

3. Set frameworks and simulation boundary conditions for analysis

3.1.Selection criteria and selection of target sites

High-rise apartment complexes, which occupy a high frequency among the housing types supplied in the recent Seoul area, were selected. The complexes that are easy to apply CFD simulation and are standardized have been selected, and the waterfront area (Han Riverside) has a clear airflow and has the greatest impact on the urban microclimate, and that can be checked on-site, will be selected as the research subject. According to these criteria, the 'Banpo Acro River Park' apartment complex was selected in the vicinity of the Han River as a type 3 general residential area, with a standardized main building layout, and excellent site accessibility in the area of Banpo 2-dong, Seocho-gu. Seoul, Republic of Korea

Figure 1. Site Location



Sources: Write it by referring to NAVER's picture

3.2.A framework for analysis

This study was jointly conducted by referring to the type of water space 1-plan(Located in water space where wind speed is high in the complex), which was most effective in terms of temperature reduction in Kang Jeon-hoon and Bae Woong-gyu (2022), 'CFD simulation analysis study of temperature change according to green space and piloti arrangement in an apartment complex during a heat wave'. It is to simulate the effect of temperature reduction according to the change in the height of the main building in the housing complex.

First, it goes through the 'basic status analysis of the site ⇒ modeling of the site ⇒ establishment of simulation conditions ⇒ setting of simulation scenarios ⇒ analysis of simulation results by scenario type ⇒ presentation of implications for the creation of pleasant apartment complexes'.

3.3.Establishment of the basic status and simulation boundary conditions of the target site

Seocho-gu, to which the target site belongs, is an autonomous district located in the southeastern part of the Han River in Seoul, South Korea, and has been using high-density land centered on complex functions since 1975. The area of the target site is about 28,975 m2, and it is designated as three types of residential areas. The building consists of 15 buildings with 3 basement floors and 38 floors, with the highest height of 134 m and the lowest height of 45 m. The total number of households consists of 1,612 households, and the complex is arranged in a cluster of 2 districts with 5 main buildings combined. In addition, there are 2 central squares and 4 courtyards at the center of the complex, and the lower floors of the site were mostly made up of rest and leisure facilities, and community facilities were constructed inside through piloti arrangement.

The simulation boundary conditions of this study were set based on the data collected by the Seoul Meteorological Administration (http://data.kma.go.kr), and the boundary conditions were established based on the data on August 25, 2020, when the heat wave warning was issued to maximize the temperature reduction effect in the apartment complex. The single average wind speed was set at 1.69m/s, and the wind direction was set at 234.2°, the main wind direction on August 25. <Table 1>

Table1.Study Site Modeling and Boundary Conditions

Category	input value	Aerial photography of the target site	Targeted Site Modeling(Sketch-up)
Time	2020.08.25		
The speed of the wind	1.69 ㎧		
wind direction	234.2° (a southwestern wind)		
temperature	Min 31.9℃(at: 18:00), Max 36℃(at: 14:00)		
relative humidity	Min 48% (at: 14:00), Max 62% (at: 18:00)		
Surface roughness	0.1		

Sources: Kang, (2021), “A Study on the Simulation Analysis of CFD for Temperature Mitigation in Apartment Complex by Water Space and Piloti Arrangement and Using Naver Map as a Reference to Naver Map

3.4.Temperature Mitigation Scenario Setting by Change in Main Height and Pilots Placement

In this study, Jeon-Hoon Kang and Woong-Gyu Bae (2022), 'CFD simulation analysis study of temperature change according to green space and piloti arrangement of multi-unit housing complex during heat wave' The scenario was set up with a type A with the best temperature reduction effect and Type B with the lowest average temperature in the complex

To analyze the temperature relief of the outdoor space of an apartment complex according to the height of the main building and the arrangement of the piloties, the height of the main building and the arrangement of the piloties were divided as shown in <Table 2> below. As for the piloti type, it was divided into Area A, where all piloti were built in the north main building, and Type B, which was created by alternating one piloti per cluster. Roof greening was created on the roof part. Greenery was installed in each of the 8 places with a size of 27㎥ (the thickness of the songak is 0.3m). In the case of water space, the water space 1 plan, which had the best temperature reduction effect in the CFD simulation analysis (Kang Jeon-hoon, 2021), was set as the standard for the temperature relief of the external space of the apartment complex according to the water space and piloti arrangement, and the water space 1 plan was the area of one place. was set to 292.5㎥ and placed in a total of 4 places. In the case of main pillar height, it was divided into 4 floors (3rd floor, 7th floor, 14th floor, 20th floor) for each A and B piloti arrangement type. <Table 3>

Table2.Setting up a simulation scenario

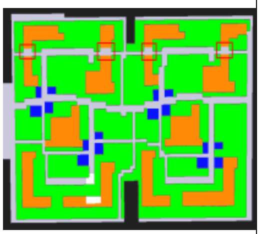
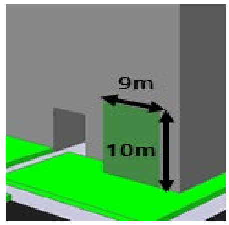
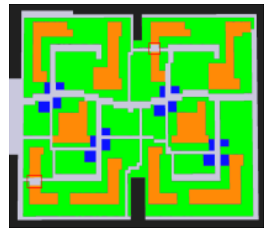
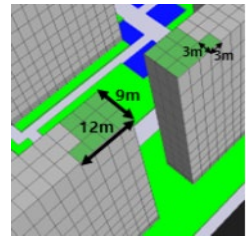
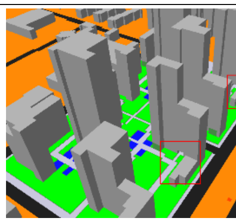
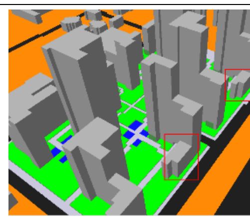
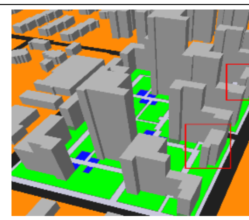
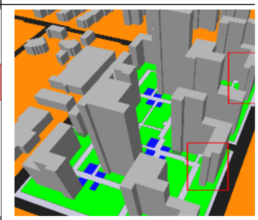
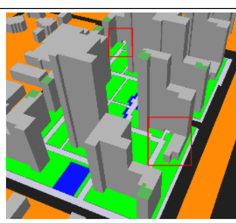
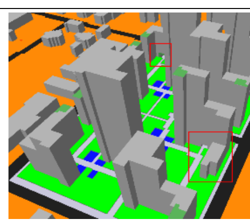
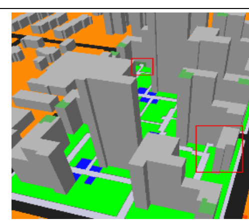
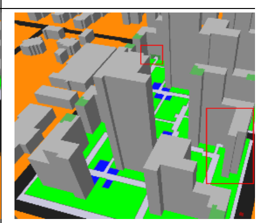
Filotypes	North East Piloti. all created/ wall recording(A)				Create two pilotis by crossing over/ Rooftop greening(B)			
layout drawing								
main cylinder height	3rd floor(a)	7th floor(b)	14th floor(c)	20th floor(d)	3rd floor(a)	7th floor(b)	14th floor(c)	20th floor(d)

Table3.Model Type A, B Destination(Envi-met)

main cylinder height	3rd floor(a)	7th floor(b)	14th floor(c)	20th floor(d)
Modeling (A)				
Modeling (B)				

4. Analysis of Temperature Changes according to Height Changes in Apartment Housing Complex

4.1. Mean Temperature Variation according to the Change of Main Drive Height

In order to extract the temperature of the part of the target area reflecting the simulation results of the Banpo 2-dong Acro River Park area in Seocho-gu, Seoul, the average temperature of 14 o'clock was extracted from the pedestrian level of 1.5 m for 8 scenarios bordering the study site Judong to 72 m, which is higher than the maximum height of the North Side. (1.5m, 7.6m, 14.6m, 32.33m, 56.4m, 72m)

Through the results of the extracted data values, the temperature increased as the height increased in all types, and it was confirmed that the temperature was different according to the piloti arrangement and the change in the height of the main body, and the temperature change was shown as a bar graph.

In addition, the atmospheric temperature of the outdoor space of the target site was analyzed by cutting type A and type B into cross section and longitudinal section based on the part where the temperature change of the outdoor space of the target site was good. First, the highest temperature among Type A was the highest at 31.61229 °C when cut in cross section with 14 stories high and had the lowest temperature at 31.6006 °C when cut in cross section with height of 20 stories. Type B was three stories high and had the highest temperature at 31.6113°C when cut in cross section and had the lowest temperature at 31.60134°C when cut in longitudinal section. <Table6>,<Table7>,<Table8>

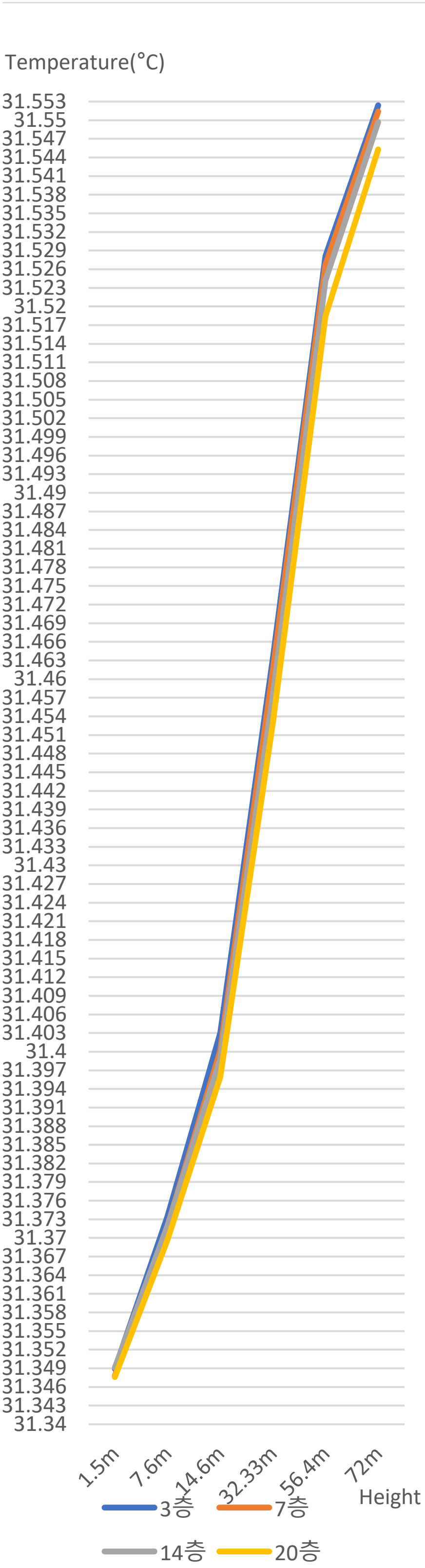


Figure2.
Type A Temperature change simulation results

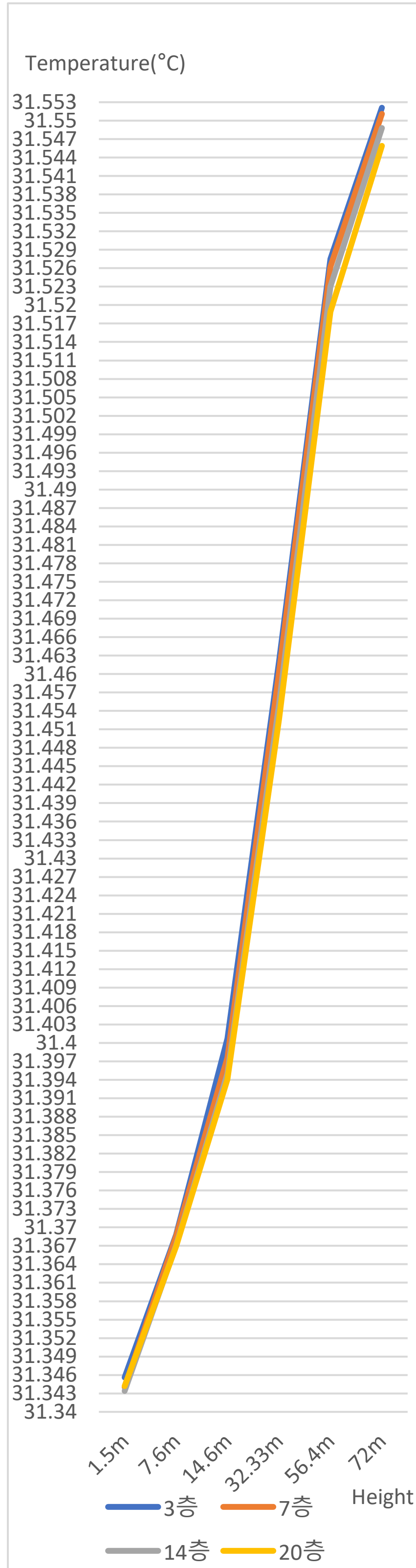
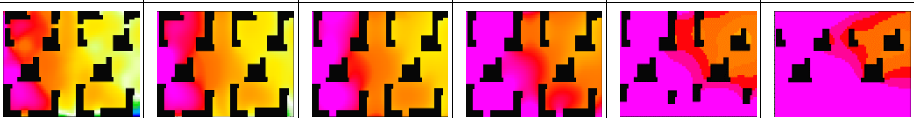
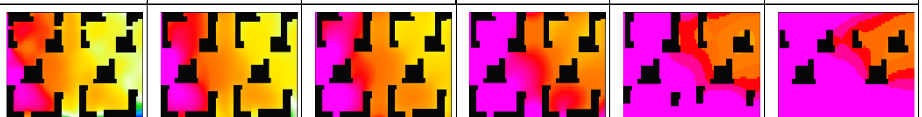
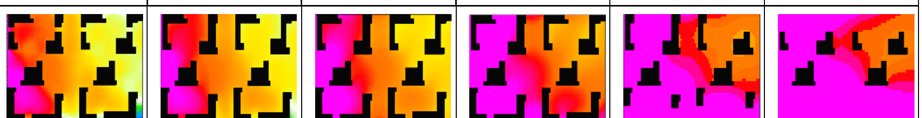
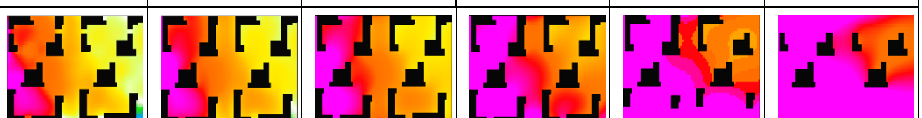


Figure3.
Type B Temperature change simulation results

Table4.Temperature Variation of Type A Outdoor Space

Type	1.5m	7.6m	14.6m	32.33m	56.4m	72m
3rd floor (9.9m)						
	31.3489(℃)	31.3735(℃)	31.4030(℃)	31.4635(℃)	31.5281(℃)	31.5524(℃)
7th floor (23m)						
	31.3478(℃)	31.3720(℃)	31.4002(℃)	31.4616(℃)	31.5267(℃)	31.5514(℃)
14th floor (46m)						
	31.3491(℃)	31.3720(℃)	31.3989(℃)	31.4575(℃)	31.5242(℃)	31.5497(℃)
20th floor (66m)						
	31.3476(℃)	31.3697(℃)	31.3959(℃)	31.4531(℃)	31.5184(℃)	31.5453(℃)

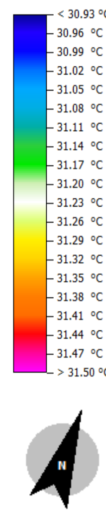
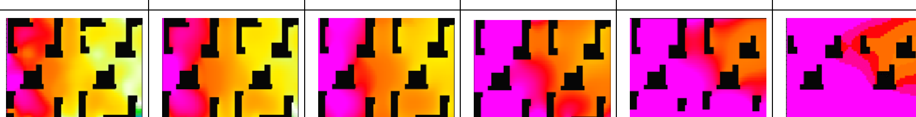
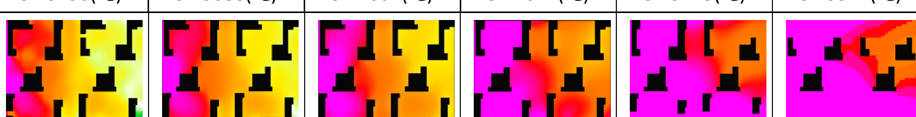
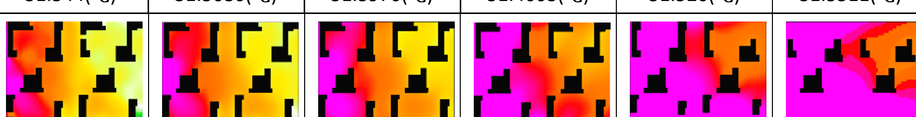
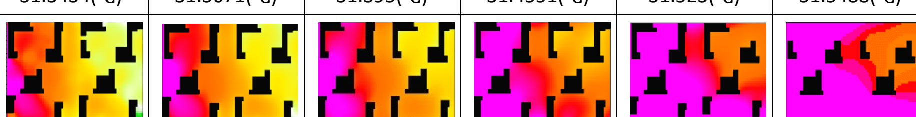


Table5.Temperature Variation of Type B Outdoor Space

Type	1.5m	7.6m	14.6m	32.33m	56.4m	72m
3rd floor (9.9m)						
	31.3456(℃)	31.3688(℃)	31.4007(℃)	31.4621(℃)	31.5275(℃)	31.5521(℃)
7th floor (23m)						
	31.344(℃)	31.3686(℃)	31.3976(℃)	31.4603(℃)	31.526(℃)	31.5511(℃)
14th floor (46m)						
	31.3434(℃)	31.3671(℃)	31.395(℃)	31.4551(℃)	31.523(℃)	31.5488(℃)
20th floor (66m)						
	31.3442(℃)	31.3669(℃)	31.3941(℃)	31.4527(℃)	31.5189(℃)	31.5459(℃)

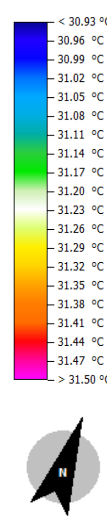


Table6. cross section & longitudinal section

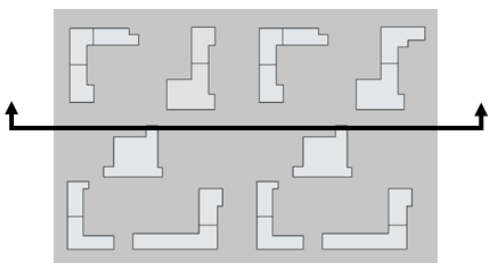
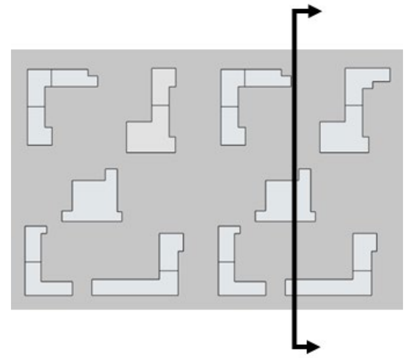
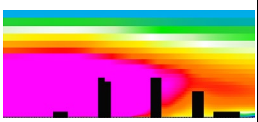
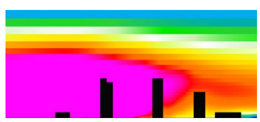
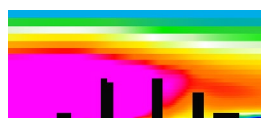
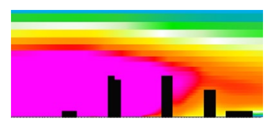
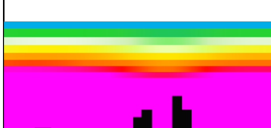
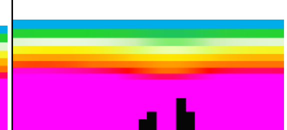
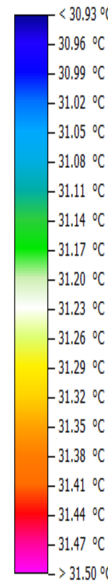
	
Type A cross section	Type B longitudinal section

Table7. TypeA average temperature

	3rd floor (9.9m)	7th floor (23m)	14th floor (46m)	20th floor (66m)
CROSS SECTION				
Temperature (°C)	31.6119	31.6117	31.61229	31.61034
Longitudinal section				
Temperature (°C)	31.60153	31.60163	31.60283	31.6006



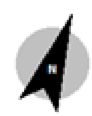
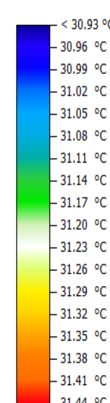
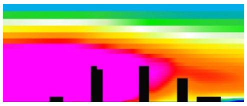
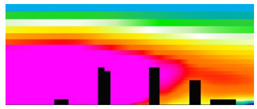
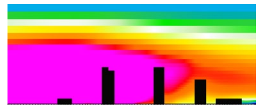
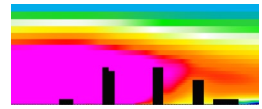


Table8. TypeB average temperature

	3rd floor (9.9m)	7th floor (23m)	14th floor (46m)	20th floor (66m)



CROSS SECTION				
Temperature (°C)	31.61173	31.61139	31.61103	31.61074
Longitudinal section				
Temperature (°C)	31.60134	31.60148	31.60157	31.60156

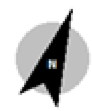


Table 9. Cross-section temperature comparison

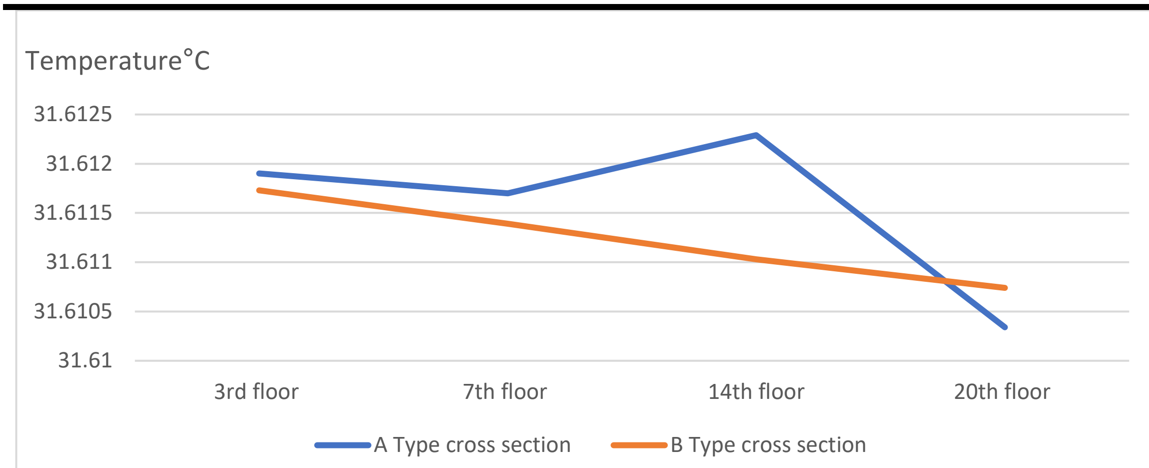
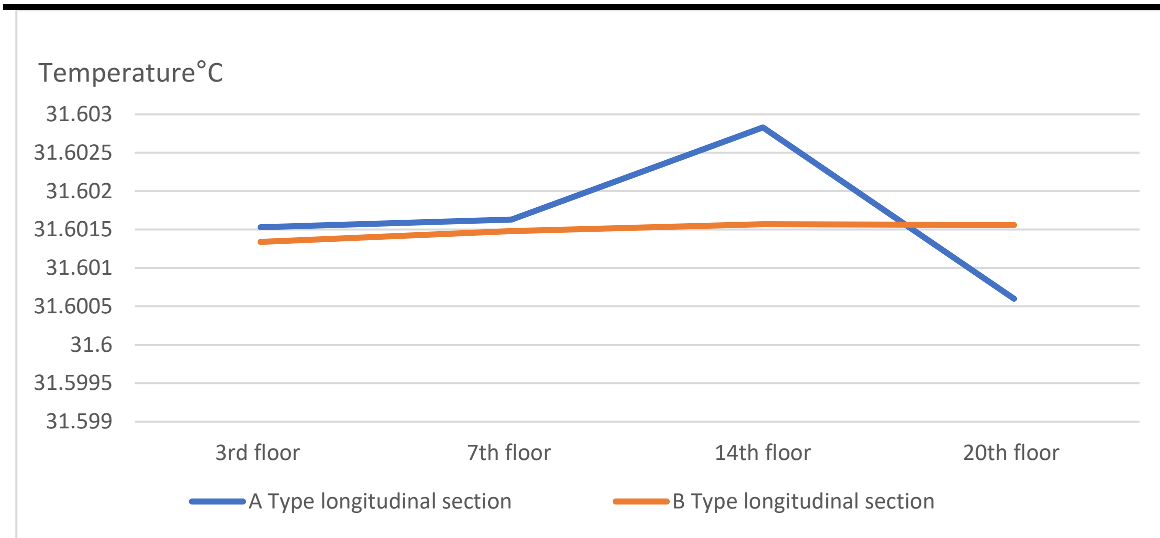


Table 10. Longitudinal-section temperature comparison



4.3.Sintering

In this study, the temperature change of the outdoor space of the apartment complex was analyzed through Envi-met simulation by classifying it into 8 types according to the change in the height of the apartment complex and the piloti arrangement. First, both types A and B showed that the temperature increased as the height increased, and it was confirmed that the temperature increased as the wind speed decreased.

According to the A-type analysis, the number of main floors in the north was 20 floors and the lowest was 31.34376°C from 1.5m height of pedestrian standard height, and the B-type analysis showed that the number of main floors in the north was 14 floors and the lowest temperature was 31.34°C from 1.5m height of pedestrian standard height. Conversely, as for the type with the highest temperature, the highest was 31.5524℃ when the number of floors in the northern main building was 3 stories and the height was 72m in type A, As a result of Type B analysis, the temperature of outdoor space in the apartment complex was the highest at 31.5521℃ when the number of floors in the north main building was three stories and the height was 72m. In the case of type A, on average, it was 0.003℃ higher than that of type B. In addition, looking at the temperature difference between the two types when cut in cross-section, type A was 0.0003℃ higher on average, and type A was 0.0002℃ higher when cut in longitudinal section.

5. Conclusion

In this study, in order to find out the atmospheric temperature of the outdoor space according to the change in the height of the main building of the apartment complex along the Han River in Seocho-gu, Seoul, the weather conditions were set on August 25, 2020 (the date of the heatwave warning), and a simulation scenario was conducted. was set. The results of this study are as follows.

First of all, the temperature of the outdoor space was different for both Type A and Type B, and the higher the height of the northern main building, the higher the temperature of the outdoor space. This seems to be the result of the inflow of hot air from outside the site, and the higher the height in the north, the stronger the hot air could escape. Second, The temperature change according to the height of the main building of the apartment housing complex was different not only depending on the height of the main building but also the location of the piloti in the complex. Third, as a result of identifying the effect of temperature change in the complex as piloti, green type, and floor height of the main building, it was confirmed that there was a difference according to wind speed.

In view of these results, it is meaningful that the degree of temperature change according to the piloti arrangement and the change in the height of the main building could be confirmed and the temperature change for the outdoor space of the apartment complex could be simulated. As a limitation of this study, there was a limitation in reflecting the weather conditions of various types of apartment complexes and weather conditions as it reflected the weather conditions on a specific day on August 25, 2020, when a heatwave warning was issued for specific apartment complexes.

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