Building Simulation 2009

Eleventh International IBPSA Conference
Glasgow, Scotland
July 27-30, 2009

POSSIBLE IMPACT ON TEMPERATURE BY DIFFERENCES IN URBAN DISTRICT CONFIGURATIONS

N Umemiya[1*], S Sakurai[1], M Kawamoto[1] and R Okura[1]

[1]Department of Urban Engineering, Graduate School of Engineering, Osaka City University
3-3-138, Sugimoto, Sumiyoshi-ku, Osaka, Japan
*umemiya@arch.eng.osaka-cu.ac.jp

ABSTRACT

Effects of differences in a town's configuration and the building surface components on urban warming were investigated. One of the most traditional and now urbanized districts in Osaka was selected as the objective. The CFD model was developed for the present district and has verified by measurement in the former study. Surface temperatures were used as boundary conditions and the air temperature distributions were simulated. Surface temperatures of the wooden and soil walls were measured in another district those building materials were similar to those in 1917. Air temperature distribution simulated for various settings of surface temperatures for town's configuration in 1917 were compared.

INTRODUCTION

A simulation study of how an urban environment would differ in terms of the summer temperature by town's configuration and building surface components was made. Osaka is known as one of the most highly advanced urban warming city in Japan. It has been said that not only the geographical features of the Osaka Plain but also the lack of green tract of land and the high population density peculiar to the urban area cause the warming.

The traditional Senba district was selected as the objective in this study. The town's configuration in 1917 reappeared according to the literatures. Buildings were two or three stories and made of wood and mud at that time. The configurations of the blocks were similar to those of the present, but the streets were narrower than now. Inner gardens were planted with trees. Surface temperatures are expected to be lower.

A fundamental CFD model was set up for the present district and verified by the measurements. Air temperature distribution for old Senba district was simulated by the CFD model. Basic model was built so as to be close to the measured environment and the modelling method was verified. Results of the simulation are expected to show how the town area would change in terms of the temperature if we presumed that we restored the town shape and configuration to its conditions of 1917. The town area is the model we used to calculate the temperature distribution for this study.

SIMULATION

Modelling an urban district

To find the ratio of building area versus open spaces in that town district, a 1:1000 scale map of that area drawn in 1917 was used (as presented in Figure 1).

Imaginary streets and buildings were constructed on rectangular coordinates. A depiction of Osaka "Morisada Mankoh" (Asakura H., 1973) was referred to know building dispositions in every one of the premises that existed there. For large houses, "Konishi Family House" (Tani et al.,1998) was . Located near the district, it is authorized as an important cultural property of Japan. For information related to small houses, instructions from Akio Shintani, a vice-director of Museum of Living in Osaka were given (Figure 2-6).

To model that area, the height of small houses there was assumed to be 5 m on average. In addition, it was assumed that surface materials of the houses were wood from the ground level up to as high as 2.5 m above the ground, with mud walls at heights between 2.5 m and 5 m. Furthermore, the height of the medium to large houses there was assumed to be 10 m, being made of wood from the ground level to 2.5 m high, and of mud walls from 2.5 m to 10 m high.

The urban district examined was a place called Higashi-yokobori, which spanned 500 m wide along the east and west direction and 400 m along the north and south direction. More precisely, the actual area that was chosen as a model and analyzed was 6 m toward the place where the wind comes from, 100 m to which the wind is blown, 30 m from the side of the model toward the direction to which the wind is mainly blown, and 200 m upward in the vertical direction from the ground surface (See Figure 7).

Surface Temperature Measurement

Because the surface materials were found to be mainly wood and mud, surface temperatures on the wood, the mud, and also the rooftop tiles were assumed. Surface temperatures were measured between 1:00 pm and 3:00 pm on Sep. 6, 2008 in the currently existing town district, which is an area with row houses in Shimizugaoka, Shumiyoshi-ku, Osaka.

Figure 1 Site map (1917)

Figure 2 Small house type

Figure 3 Medium house type

Figure 4 Large house type

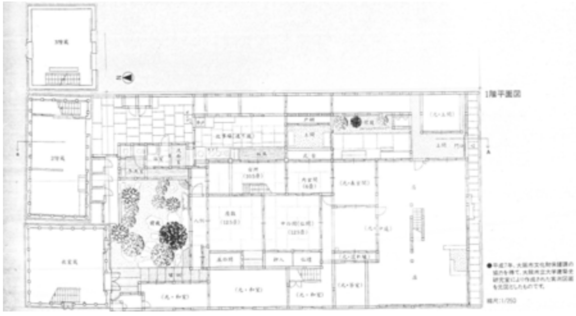

Figure 5 Ground plan of Konishi Family House

Figure 6 West elevation of Knishi Family House

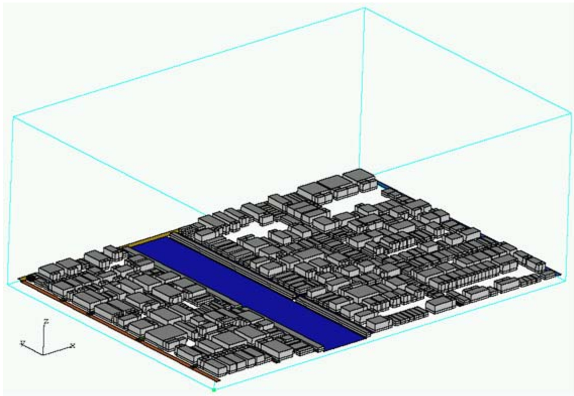

Figure 7 Model of Higashi-Yokobori District

The temperatures were measured using a radiation thermometer without touching the objects. The surface temperature of rooftop tiles was measured on the rooftop of one campus building using a thermocouple between 12:00 noon to 4:00 pm on Sep. 12, 2008.

Measurements of the surface temperature to make the basic model were carried out for five individual days in summer, July 6, July 26, August 8, August 30 and September 21, 2006 for Senba district.

Basic model

Standard k-ε model was used. Log low for the boundary condition of the force was applied to the wall surface and the ground surface. The free-slip condition for the boundary condition of the force was applied to the top end and the side of the analyzed space. The available surface temperatures were used for the thermal transfer boundary condition on the surfaces. Such input setup values as those of the surface temperatures were determined based on values obtained from actual measurements in Senba. A pre-calculation was made of the vertical distribution of U(z), T(z) and k(z) respectively signifying the wind velocity in the horizontal direction, the temperature, and the turbulent energy flow at the boundary for their entries into the area analyzed, while assuming that there existed more than one such area extending in the east and west direction.

The calculation size of the present district is 336 m x 699 m x height 200 m. West part of the district is used as a general urban district which exponential order is 0.38 accoding to the central area of Osaka. The inflow wind direction is assumed to be west according to the measurement. If five general parts and one modeled east district are connected for the assumed wind direction, the vertical distribution of horizontal wind velocity, air temperature and turbulent energy become constant. The inflow condition is decided after the pre-calculation. The free slip condition is used for side and top and log-law is used for walls and ground. Heat transfer coefficient is fixed at 23.3 (W/m2). Steady state simulation is applied for the typical peak summer under clear sky, July 26 14:00.

$$\varepsilon(z) = C_t^{0.5} k(z) \frac{U_s}{z_s} \alpha \left(\frac{z}{z_s} \right)^{(\alpha - 1)} \quad (1)$$

$$T(z) = T_0 - 10^{-3} \Gamma z \quad (2)$$

$$U(z) = U_s \left(\frac{z}{z_s} \right)^{\alpha} \quad (3)$$

$$k(z) = \left(I(z) U(z) \right)^2 \quad (4)$$

$$I(z) = 0.1 \left(\frac{z}{z_G} \right)^{(\alpha - 1)} \quad (5)$$

z_s : reference height$[m]$
U_s : air velocity at z_s[m/s]
α : exponential order$[-]$(= 0.38)
z : height$[m]$
T_0 : ground surface temp.[℃]
Γ : rate of temperature decrease$[℃/km]$
ε : turbulence dissipation ratio[-]

Simulation Patterns

A Using such setup values as described in the section above, the simulation to assess cases B–F presented in Table 1 was used. Establishment of surface temperatures is shown in Table 2. Case A is of the basic model. Case B used the actual surface temperatures measured for the buildings at the Sumiyoshi district, and fed them into the calculation as a setup value. Cases C–F assumed that there existed some plants in the inner gardens. Measured leaf surface temperature was used for the ground surface temperatures of that area. The building surface temperatures of cases D and E took setup values from Umemiya et al., 2007 for case D, and from the actual measurement at Sumiyoshi for case E. All locations on the streets were assumed to be shaded. Building surface temperatures of cases F took setup values from Umemiya et al., 2007. The street surface temperature was 37.6°C in the shade and 51.3°C in the sun.

Table 1 Configuration and surface setting for simulations A-F

	Configuration	Building surface	Road surface	Ground surface inner garden
A	Present	Measurement in Senba	Measurement in Senba	shaded Senba
B	in 1917	Measurement in Sumiyoshi	Measurement in Sumiyoshi	shaded Senba
C	in 1917	Measurement in Sumiyoshi	Measurement in Sumiyoshi	leaf Senba
D	in 1917	Measurement in Senba	all shaded Senba	leaf Senba
E	in 1917	Measurement in Sumiyoshi	all shaded Senba	leaf Senba
F	in 1917	Measurement in Sumiyoshi	in shade and sun Senba	leaf Senba

Table 2 Setting of surface temperatures

Placement	Material		K settings		S settings		
South road	asphalt		53.3		53..5	46.9	56.5
North road	asphalt		52.4		50.9	51.9	54.3
West road	asphalt		51.1		45.3	43.2	46.4
East road	asphalt		49.4		38.3	39.0	38.0
South of building	W	S	41.7	39.4	39.4		
North of building	W	S	38.0	36.7	35.3		
East of building	W	S	36.5	38.0	35.2		
West of building	W	S	36.7	36.5	37.9		
Roof	Japanese tile		52.2		51.8		
River	water		28.0		28.0		
Ground			37.6		37.6		
Leaf			29.2		29.2		

W:wood S:mud

K settings refer the data from measurements in Senba. S settings refer data based on the measurements in Sumiyoshi.

RESULTS AND CONSIDERATIONS

Results showed that street temperatures at places indicated by arrows for every pattern depicted in the diagrams were 36.2–37.4°C for pattern A (Figure 8), 38.5–39.8°C for B (Figure 9), 40.8–41.5°C for C (Figure 10), 35.2–36.5°C for D (Figure 11), 36.3–37.1°C for E (Figure 12), and 36.4–37.3°C for F (Figure 13).

A surface temperature difference was apparent between those for the buildings, structures and streets of pattern A and pattern B: the temperatures of B (of 1917) were about 3 K higher. The reason is thought strictly to be attributable to the locations where measurements were made.

Between cases B and C, the air temperatures of C are about 2 K lower than those of B because the ground surface temperature setup values in that town area was changed.

Between cases D and E, the air temperatures are about 3 K lower than those of case C because the street width of 1917 was assumed to be narrower than that at present and that there were more shaded areas in 1917 than there are now.

Case F set up street surface temperatures depending on the place, whether in the shade or in the sun. However, little difference from temperatures for case E was found.

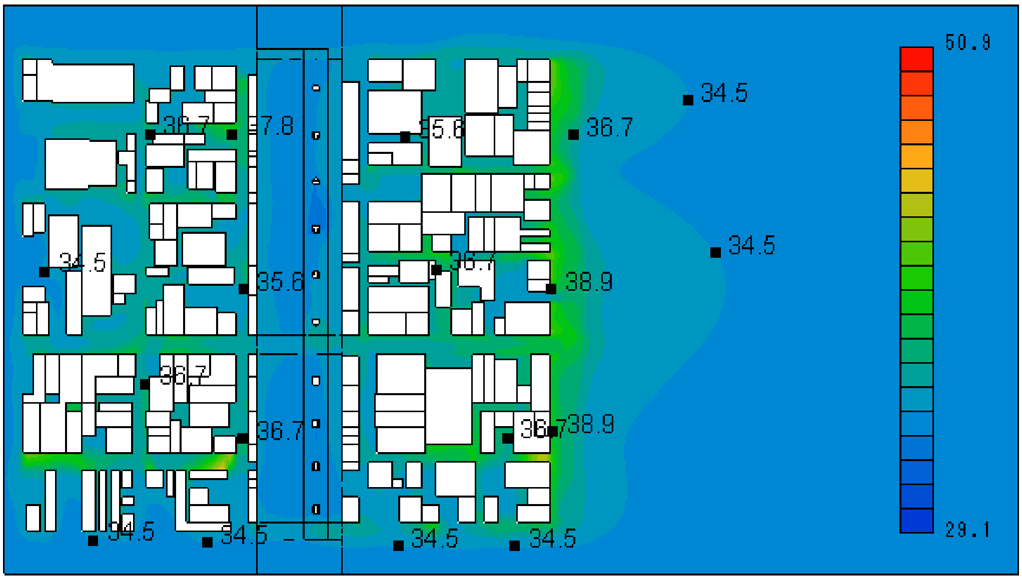

Figure 8 Air temperature distribution for Pattern A
(Present town's configuration)

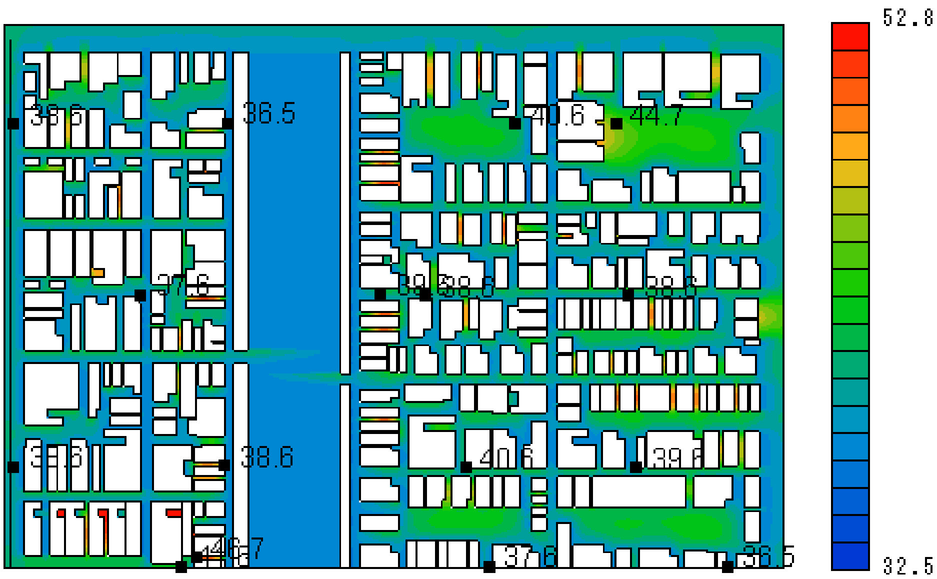

Figure 9 Air temperature distribution for Pattern B

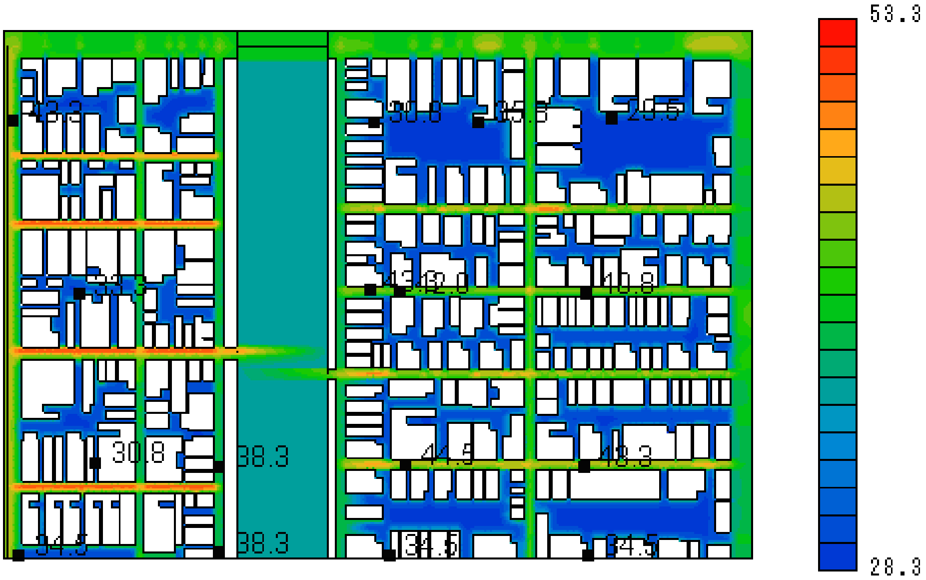

Figure 10 Air temperature distribution for Pattern C

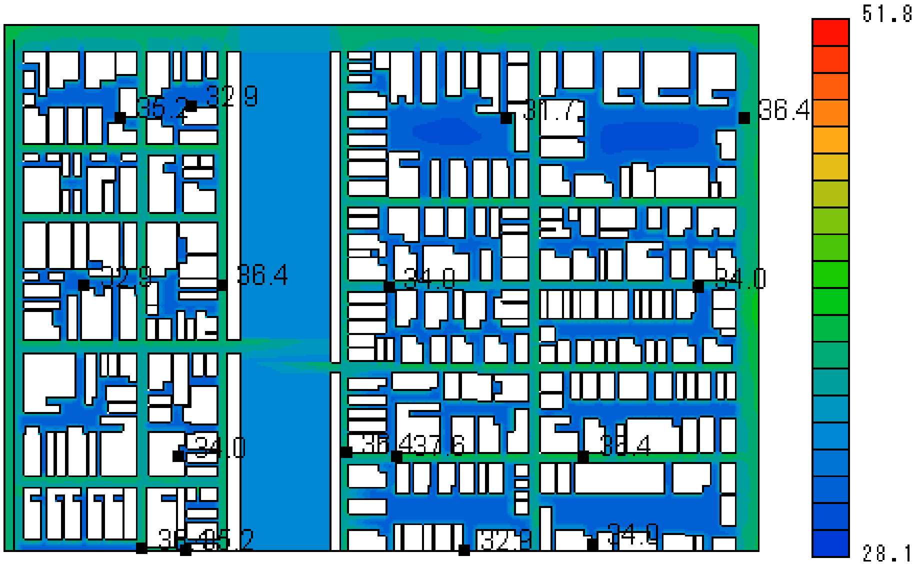

Figure 11 Air temperature distribution for Pattern D

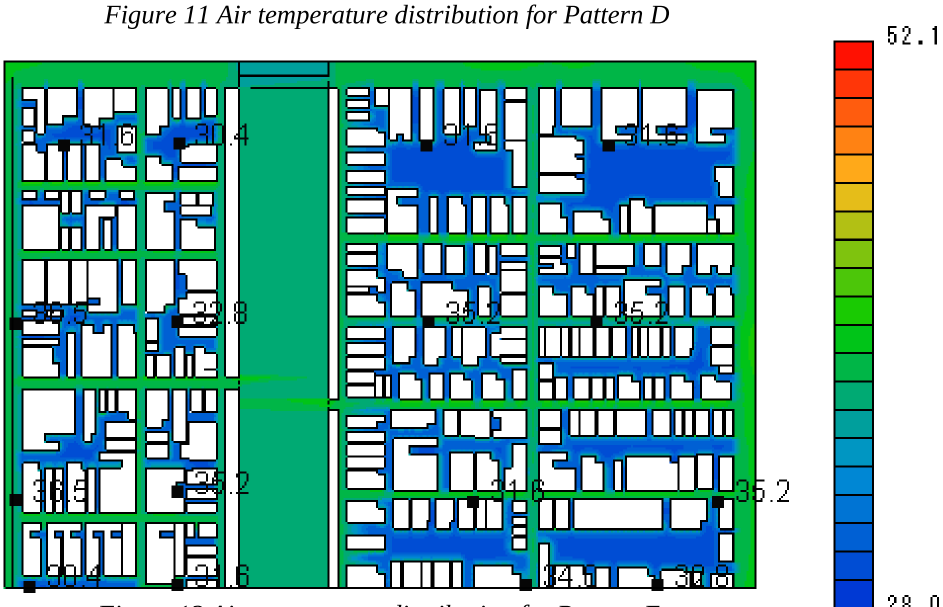

Figure 12 Air temperature distribution for Pattern E

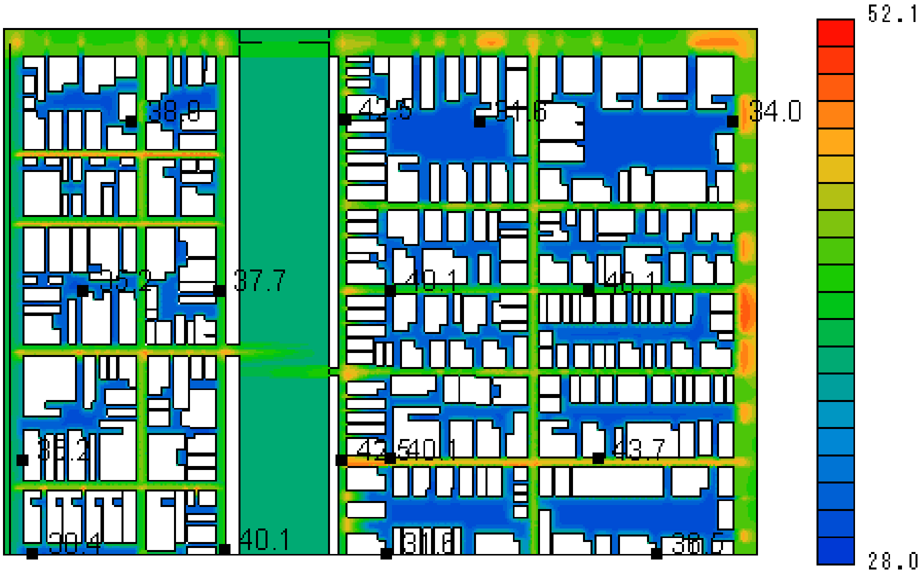

Figure 13 Air temperature distribution for Pattern F

CONCLUSION

As a result of the simulation, the air temperature distribution when the town district of Senba of Osaka were simulated presuming the building structures, and other environment restored back to its state of 1917. Results show that 1) the street air temperatures were lower about 2.0 K with the plants placed in the study area, and 2) they became lower about 3.0 K with the narrower street width in 1917, creating more shaded areas in the study area.

ACKNOWLEDGEMENT

This study is supported by Foundation of Urban Study Organization in Graduate school of engineering, Osaka city university.

REFERENCES

Asakura H. 1973. Morisada Mankoh: Tokyodo Press. (in Japanese).

Ito S., Yoshida H., Aotake N. and Takahashi K. 2005. “Measurement of the thermal environment in urban canyons and prediction by CFD simulation,” Proceedings of the Ninth International IBPSA Conference, Montreal: Building Simulation 2005, pp.475-482.

Majima M., Yoshida H., Umemiya N. and Rijal HB. 2006. “Prediction and improvement of the thermal environment in different configrations of the street in summer,” Summaries of Technical Papers of Annual meeting Architectural Institute of Japan, D1, pp.609-610. (in Japanese).

Takahashi K., Yoshida H., Tanaka Y., Aotake N. and Wang F. 2004. “Measurement of thermal environment in Kyoto city and its prediction by CFD simulation,” Energy and Buildings, 36, pp.771-779.

Tani N. and Yamagata M. 1998. Konishi Family House: Konishi Corporation. (in Japanese).

Umemiya N, Kawamoto M, Okura R and Tanaka T. 2007. “Cooling effects of waterway on thermal comfort in urban districts in summer” Proceedings of the Tenth International IBPSA Conference, Beijing: Building Simulation 2007, pp.475-482.