CFD ANALYSIS OF DISTRIBUTION OF AIR TEMPERATURE ON PLATFORMS OF A LARGE RAILWAY STATION IN SUMMER SEASON

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ABSTRACT:

The purpose of this study is to analyze the principal causes of increases in air temperature on platforms of railway station. We analyzed the distribution of air temperature on Shinkansen platforms at Station 'A' using Computational Fluid Dynamics (CFD). We focused on the factors that influence the temperature dynamics associated with heat generated by trains and station buildings and their effect on the ambient temperature on platforms. In the case of heat generated by trains, air temperature on Shinkansen platforms increased by 4 to 7 degrees compared to when trains generated no heat. When a 50-m high station building was located on the windward side of the platforms, air temperature on Platform X was 2 degrees higher than when the station buildings were absent. Air temperature on platforms VII to IX increased progressively, and the maximum air temperature on platform VIII was 3 K higher than if station buildings were absent.

KEY WORDS: Platforms, Railway Station, Distribution of Air Temperature, Station Buildings, Heat Generated by Trains

1. INTRODUCTION

Despite functionality and comfort being considered the most important design criteria for railway stations in Japan, not all of the platforms at railway stations are comfortable. Recently, passengers made complaints of thermal environment of platforms recently. To improve comfort of platforms, the thermal environment on platforms is considered to be controlled by the air-conditioners. However, control of the thermal environment on platforms using air-conditioners on ground-type platforms is difficult.

The thermal environments of platforms at railway stations have been extensively studied (Izumi, 2002; Noguchi, 2003). Similarly, the characteristics of air temperature distribution on old railroad and Shinkansen platforms at a large railway station have also previously been reported (Iino, 2002; Iino 2005). However, the mechanism and the factors related to increased air temperature on each platform have not been clarified. If the factors of air temperature rise on platforms, we could take a method to resolve the problem. And design of ground-type platforms such as a large railway station will be able to apply. If the factors contributing to increased air temperature on platforms were known, then methods could be adopted to resolve the problem. This would also affect the design and layout of ground-type platforms such as a large railway station.

The purpose of this study is to clarify the factors that affect increased air temperature on platforms, and to acquire basic data for the design of optimal thermal environments on platforms. In this paper, we analyzed influence of heat generated by trains and the effect of station buildings on thermal environment of platform at station 'A' by numerical analysis.

2. OUTLINE OF ANALYSIS

2.1 Outline of basic concert

The factors affecting increased air temperature on platforms at railway station are considered to be:

1) Decrease of the air flow on platforms because of existence of the trains,
2) Heat generated by trains,
3) Heat generated by the ventilation fans of air-conditioners in kiosks,
4) The heat dissipation from a lot of passengers,
5) Decreased air flow due to the presence of high-rise buildings which surround the railway station enclosing it,
6) The rise of the surface temperature of the floor on platforms due to solar radiation.

Using these factors, we focused on the heat generated by trains. When the trains arrived at platforms, we postulated that they contribute to increased air temperature on platforms because of the heat they generate and which flows onto platforms.

We also focused on the influence of station buildings. The authors previously reported that air temperature of platforms located in areas surrounded by high-rise buildings increases (Iino, 2002). Stations in national capitals are often surrounded by high buildings on both sides of the platforms. Change of wind velocity, wind direction and distribution of wind velocity and air temperature need to be clarified by analyzing existence or absence of station buildings. If the platform is surrounded by station buildings, it would be possible to influence the distribution of air temperature on platforms because wind direction would be altered. Changes in wind velocity, wind direction and the distribution of wind velocity and air temperature therefore need to be clarified by analyzing presence or absence of high-rise buildings.

2.2 General features of Station 'A'

A plan and a section of station 'A' are shown in Figs. 1 and 2. On the east side of the station 'A' is Building 'D' which has 13 floors. To the west side of the station is Building 'S' with 3 floors. The distance between building 'D' and building 'S' is approximately 190 meters and 10 platforms between the two buildings. The floor levels of platforms II and V are almost at ground level and from VI to X the levels are approximately 3 meters above ground level and for platform I is approximately 9 meters above ground level.

Station 'A' is a one of the largest railway stations in Japan and is located in the center of Tokyo. The station has 5 old railroad platforms and 5 Shinkansen platforms. Roof structures and the floors for each platform were different. Figure 3 shows thermal images of platforms IV and VI. Solar radiation came into platform IV because of the polycarbonate roof and the surface temperature was very high. With the exception of polycarbonate board over the stairs, the roof of platform VI was about 1m thick so the surface temperature of its ceiling was almost equal to the air temperature. The floors of platforms of II and III are made of asphalt and those of the other platforms are made of granite. Also, air temperature of each platform is different. Figure 4 shows the average air temperature for every 3 hours on Aug. 22, 2000. The air temperature on platform VII was 2 degrees higher than for platform III all though the day.

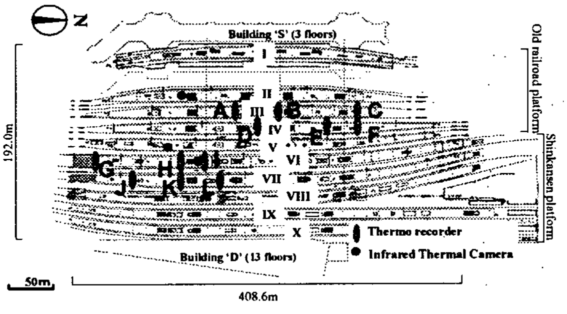


Fig.1 Plan of Station 'A'.

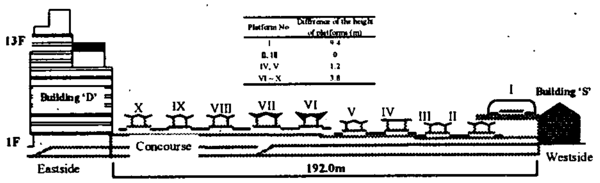
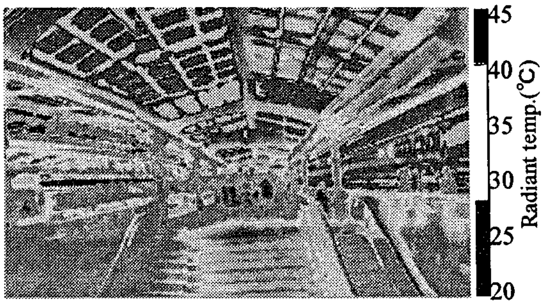
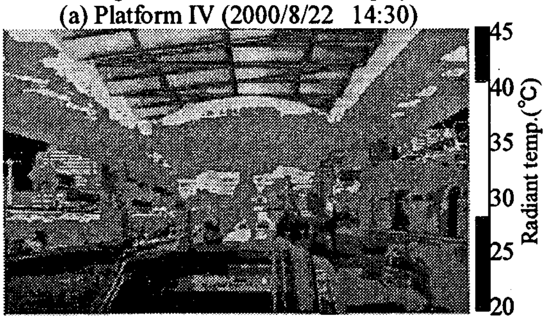


Fig.2 Section of Station 'A'.



Roof: single board made of slate and polycarbonate.

(a) Platform IV (2000/8/22 14:30)



Roof: double boards, and Toplight were made with Acrylics board.

(b) Platform VI (2000/8/23 13:00)

Fig.3 Example of thermal images.

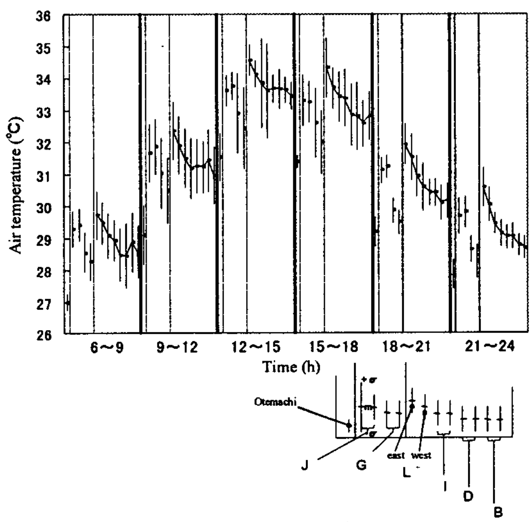


Fig.4 Air temperature

2.3 Method of analysis

2.3.1 Grid arrangement: The analysis considered the area around the station, extending 616m(x, north-south direction) × 623m(y, east-west direction) × 300m(z, vertical direction). The geometries of building blocks was represented using CAD and was generated using plans of the station and an electronic atlas. Figure 5 is an enlarged view of the computational grid. The whole computational domain was divided into 102(x) ×105(y) × 42(z) grids, respectively. The target platforms were surrounded by grids measuring 3 m(x) × 3 m(y) × 0.5 m(z). A standard k-ε model was used for the analysis.

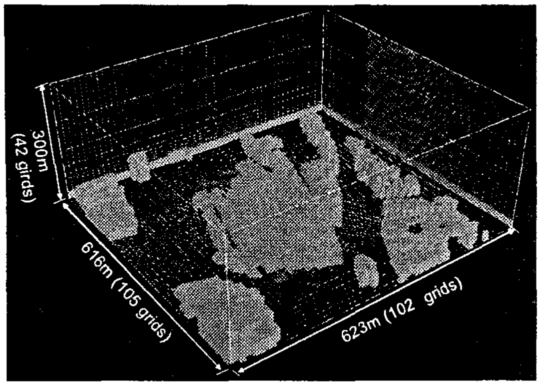


Fig.5 Grid arrangement.

2.3.2 Test cases: The different possible scenarios are listed in Table 1. Each scenario varies with respect to one of three different characteristics. For Case 1, heat generated by trains is not considered. Case 2 considers the heat generated by trains on each platform and presence of station buildings such as building 'D'. For case 3, building 'D' is absent. We analyzed the distribution of air temperature on Shinkansen platforms by CFD analysis using these 3 cases.

2.3.3 Specified conditions: Computational conditions are listed in Table 2. Inflow conditions were estimated using thermal environment measurements taken on August 22, 2000. Wind velocity and wind direction of the sea breeze were due to the influence of a general migratory High and the influence of air temperature distribution on platforms due to heat generated by trains and station buildings was considered (Iino, 2002).

2.3.4 Surface temperature of each part: Table 3 shows surface temperature of each part on platforms. Surface temperature of each part was estimated using thermal environment measurements taken on August 22, 2000 (Iino, 2002).

2.3.5 Arrangement and standing time of trains on platforms: The time trains spent waiting at each platform was based on the railroad timetable.

2.3.6 Heat generated by trains: Table 4 shows the heat generated by trains at each platform. We hypothesized that heat generated by trains came from the air-conditioners. Heat was calculated based on the time trains spent standing.

Table 1 All test cases.

Case	Heat generated by train	Station Buildings
Case1	×	O
Case2	O	O
Case3	O	×

※ O presence × absence

Table 2 Computational conditions.

Wind direction	east
Wind velocity	2.2m/s
Air temperature	31.5℃
Temperature of building surface	33.0℃
Temperature of ground surface	33.0℃

Table 3 Surface temperature of each part.

	I	II	III	IV	V
Floor (℃)	35.9	35.1	38.4	35.6	37.4
Top of the roof (℃)	43.0	38.0	45.5	43.5	48.0
Bottom of the roof (℃)	43.5	38.0	42.0	45.5	48.1
Rail (℃)	41.0				
	VI	**VII**	**VIII**	**IX**	**X**
Floor (℃)	34.2	34.5	35.9	35.9	35.9
Top of the roof (℃)	47.0	50.0	45.5	45.5	45.5
Bottom of the roof (℃)	37.7	35.2	43.5	43.5	43.5
Rail (℃)	41.0				

Table 4 Heat generated by trains of each platform.

Platform	I		II		III
Track No.	1	2	3	4	5
Heat generated (W)	17400	17400	5800	7300	7300
Platform	III	IV		V	
Track No.	6	7	8	9	10
Heat generated (W)	5800	30000	32900	0	13600
Platform	VI		VII		VIII
Track No.	20	21	22	23	14
Heat generated (W)	3900	59700	39300	45800	48400
Platform	VIII	IX		X	
Track No.	15	16	17	18	19
Heat generated (W)	36300	33000	42900	34100	44000

3. RESULTS AND DISCUSSION

3.1 Comparison of heat generated by trains

To compare Case 1 and Case 2, the influence of distribution of air temperature of Shinkansen platforms by heat generated by trains was considered.

Figure 6 shows the horizontal distribution of air temperature of platforms. Air temperature of platforms from VIII to X for Case 1 was approximately 40 degrees. Air temperature on the platforms for Case 2 was approximately 3 to 7 degrees higher than those of Case 1 because of the heat generated by trains. The heat capacity generated by trains deferred between platforms, however, the air temperature of platforms increased toward the east. Figure 7 shows the distribution of air temperature in north-south directions on Shinkansen platforms. Air temperature from the center of the platforms to a 100 m of the southern side on platform X increased to 48 degrees because of the present of building 'D' and heat generated by trains.

Figure 8 shows difference in air temperature of platforms between Case 2 and Case 1. Air temperature of platform VI in Case 2 was 2 to 3 degrees higher than that observed for Case 1. Also, the air temperature of platforms from VII to X for Case 2 was 4 to 7 degrees higher than that observed for Case 1. The difference in the air temperature for each platform was greatest 20 to 80 m on the southern side.

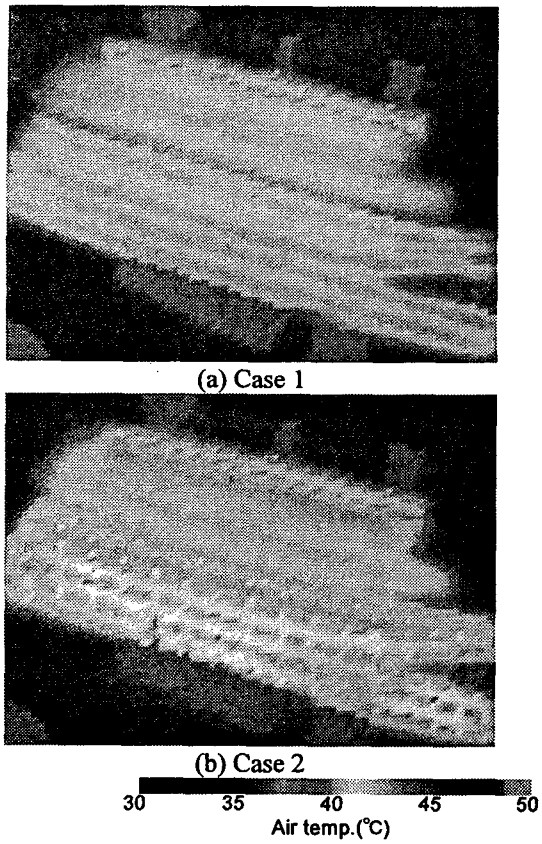


Fig.6 Horizontal distribution of air temperature.

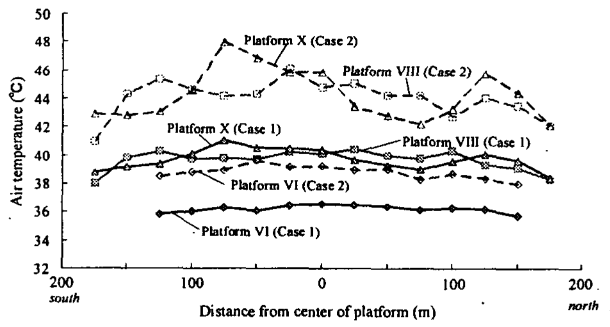


Fig.7 Air temperature distribution of Shinkansen platform.

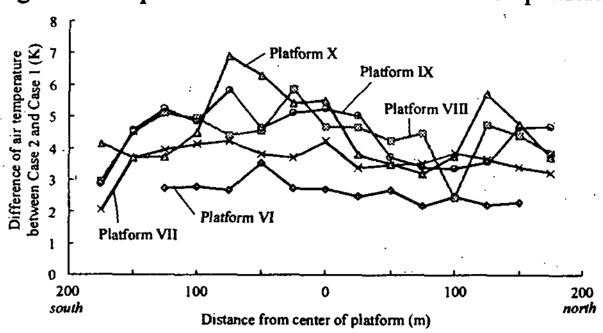


Fig.8 Difference of air temperature of each platform between Case 2 and Case 1.

3.2 Comparison of presence of building stations.

To compare Case 2 and Case 3, the influence of station buildings such as building 'D' on the distribution of air temperature on Shinkansen platforms was considered.

The horizontal distribution of air temperature in response to the presence or absence of building 'A' is shown in Figure 9. Air temperature on platforms IX and X for case 3 was lower than that observed in Case 2.

The distribution of air temperature in north-south directions on platforms VI, VIII and X is shown in Figure 10. When the building 'D' was absent, air temperature from the center of the platform to a point 100 m from the southern side on platform X was lower than that observed when building 'D' was present. However, air temperature along transect 100 m north to 100 m south on platforms VIII and IX was higher than when building 'D' was present. Air temperatures on platform VI were independent of the presence or absence of building 'D'.

Figure 11 shows difference in the air temperature of platforms between Case 2 and Case 3. When building 'D' was absent, air temperature from the center of the platforms to a point 100 m to the southern side of platform X was approximately 2 K lower than that observed when building 'D' was present. However, air temperature on platforms VII to IX increased and maximum air temperature on platform VIII was 3 K.

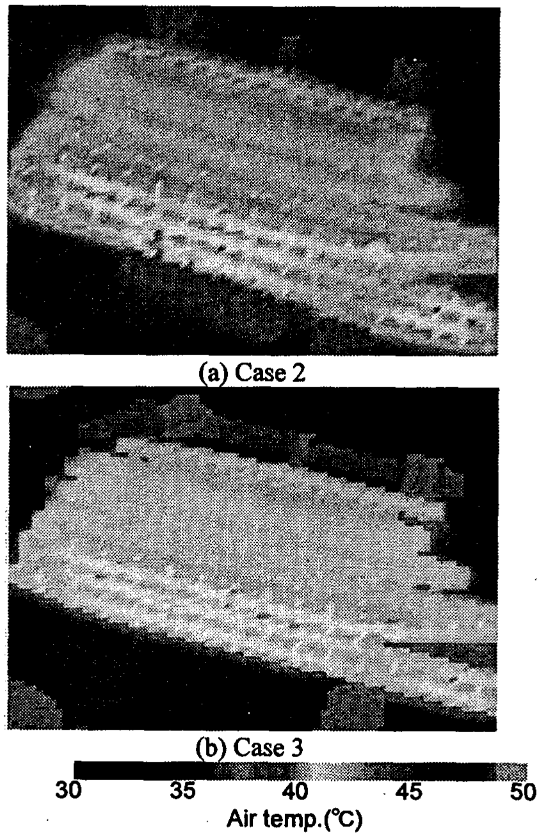


Fig.9 Horizontal distribution of air temperature.

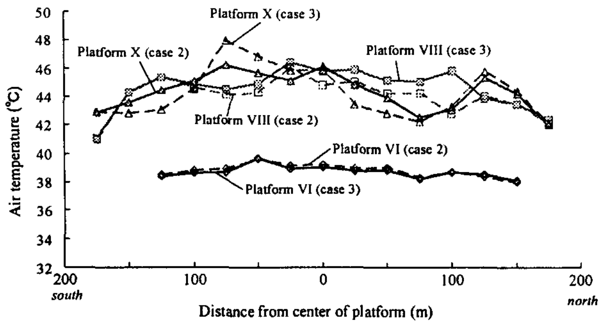


Fig.10 Air temperature distribution of Shinkansen platforms.

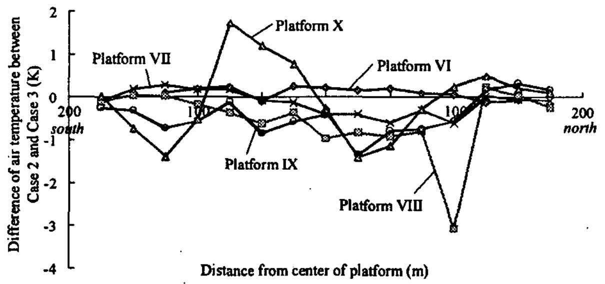


Fig.11 Difference of air temperature of each platform between Case 2 and Case 3.

4. CONCLUSION

In this report, we analyzed the distribution of air temperature on Shinkansen platforms at Station 'A' by numerical analysis. Results revealed that, when heat generated by trains was considered, air temperature on Shinkansen platforms was 4 to 7 degrees higher than when heat generated of trains was not considered.

When the effect of a 50-m tall building to the windward side of the station was considered, air temperature on platform X was 2 degrees higher than that observed when the station buildings were not present. Air temperature from platforms VII to IX increases progressively and the maximum air temperature on platform VIII was 3 K higher than that when station buildings were absent.

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