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NUMERICAL ANALYSIS OF DIFFUSION AROUND A SUSPENDED CROSSROAD BY A MULTI-SCALE CFD MODEL

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1. INTRODUCTION

The Ikegami-Shinmachi crossroad in Kawasaki City ranks at one of the top of locations with the worst concentration of NO_2 in Japan. The crossroad is the intersection of the metropolitan expressway between Tokyo and Yokohama. It is a suspended four-lane express road with a six-lane ground-level road under the expressway and another four-lane ground-level road intersecting the two roads. Two- or three-story residential houses and buildings line the roadside. At this site, the concentration of NO_2 exceeded the national standard (daily mean) for more than 10% of days in a year. Some mitigation techniques, one known as a "green wall," which makes use of plants that adsorb pollutants, and the other, which uses photo-catalysts in the pavement etc., have already been applied, however, those effects are not clear.

A green wall was established under the suspended expressway, which completely divides the lanes in each direction on the ground-level road. It is probable that the wall obstructs the crosswinds and diffusion near the roads. A multi-scale CFD model is used to investigate the complicated situation in the vicinity of the crossroads.

2. MODEL

The CFD model used in the present calculation is FUJI/RIC α-flow (Fuji Research Institute Corporation, 1992). The model consists of momentum equations, turbulent equations for k and ε, a temperature equation, a chemical transport equation without reaction, and an equation of continuity. The outline of the model is shown in Table 1. The model is three-times a two-way nested model (Fig. 1; Murakami et al., 2000). The largest domain is 500mX500mX300m, and only several big buildings are given as obstacles. The second domain is 340mX160mX100m, and blocks of houses that are surrounded by small roads are given as obstacles. The smallest domain is 100mX45mX30m, and the suspended expressway is the only obstacle. At this time, no attention has been given to the airflow and diffusion created by traffic.

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Table 1 Outline of the model

Turbulence model	k-ε model
Mesh	1st 26x26x21
	(500m x 500m x 300m)
	2nd 51x41x31
	(340m x 180m x 100m)
	3rd 41x31x61
	(108.8m x 45m x 30m)
Advection	Quick(momentum)
	Donor-cell(k-ε)
	PPM (Concemtration)
Time Integration	SIMPLE(momentum, k-ε)
	Euler(Concentration)
Boundary Condition (1st Domain)	Fixed
Stability	considerable

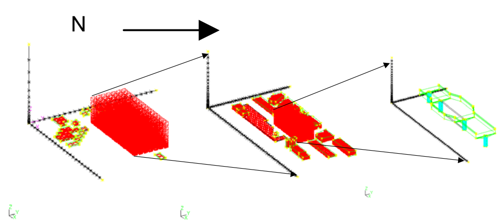


Fig.1 Three-times nesting for the domein.

NOx and CO emissions were constructed for automobiles and small stationary sources. Automobile emissions were estimated separately for major and local roads. The expressway and the ground-level road under the expressway were the major roads in the region being considered, and the emissions were produced from estimates of traffic, mean speed in respective types of automobiles, and road links and their emission factors. The emissions from small roads were estimated based on the volume of traffic and mean speeds in the area being studied with the same emission factors.

The emission from offices and houses are estimated as stationary sources. The total emission of approximately one square km was first estimated from the data regarding fuel consumption. The total amount was then distributed to each building according to their floor area. GIS data were used to calculate the floor area of each building.

3. RESULTS

Three cases were calculated for preliminary investigation. The wind perpendicular to the expressway (SE wind) of 3m/s at the inflow boundary was given in RUN 1. The same condition as RUN 1, except for the wind direction parallel to the expressway (SW), was given in RUN 2. These two RUNs were calculated in neutral stability. RUN 3 was the same as RUN 1 except for the consideration of exhaust heat from automobiles. Here, results for NOx are shown.

Figure 2 shows the cross section A-B in Fig.3. The wind velocity under the suspended expressway is very low, less than 0.1m/s both in the upstream side and downstream side of the green wall. This is not realistic because the flow driven by the traffic is usually more than 0.5m/s under heavy traffic with 20-30km/h. Under such low wind velocity, the maximum concentration of NOx is more than 5 ppm on the ground-level road. The concentration on the suspended road is relatively low due to the high wind speed there. The flow on the ground-level road goes up over a sidewalk on the downstream side and flows NW with pollutants on the level of the suspended road. Figure 3 shows the concentration of NOx at 11m above the ground (the level of the suspended road). The high concentration of NOx appears from the downstream side of the suspended road.

Figure 4 is the same as Fig. 2 except for the inflow wind direction. The inflow wind direction was SW, which was parallel to the expressway. Most of the cross section was covered by a weak upward wind (<0.1m/s). The axis of the concentration shifted slightly to the NW (right in the figure), where the wind velocity was weaker

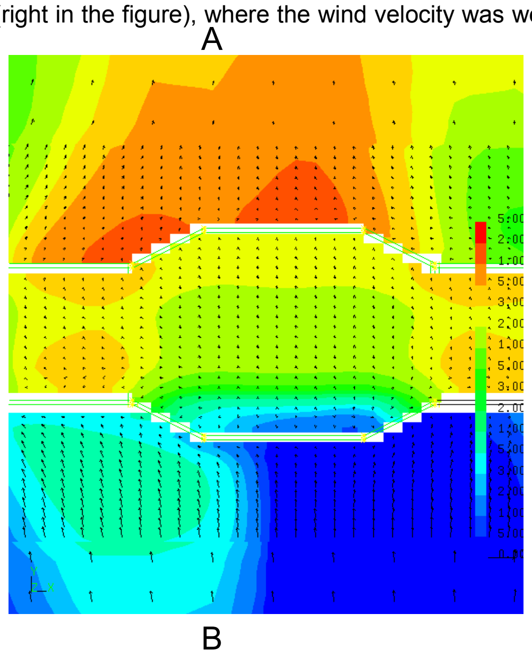


Fig.3 Wind velocity and concentration of NOx at 11m above the ground

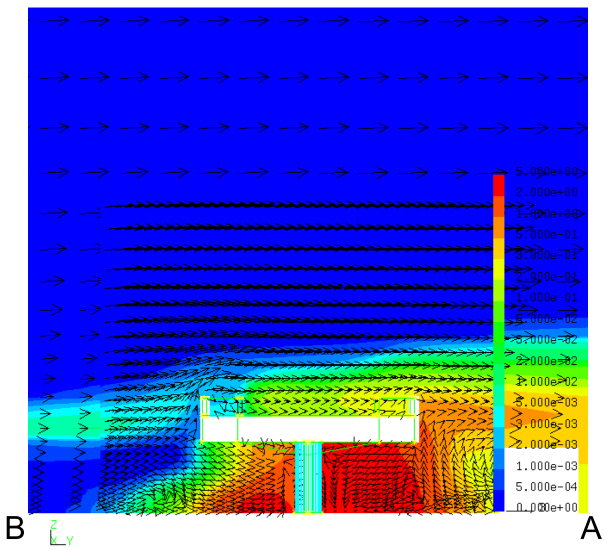
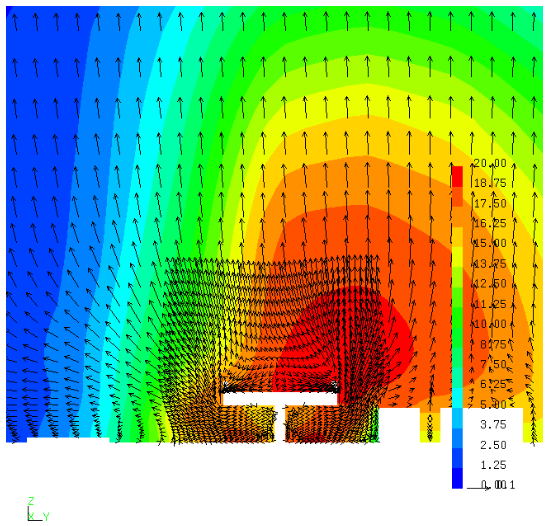


Fig.2 Wind velocity and concentration of NOx at the cross section A-B in Fig.3



than that on the SE side (left in the figure) of the expressway due to the drag force of the houses. In this case, the emissions from the expressway were highly concentrated.

Finally, the temperature increase due to the exhaust from automobiles is shown in Fig. 5. Other conditions, except for the introduction of the temperature calculation, were the same as those for RUN 1, and the basic temperature profile was neutral. The exhaust heat, which was calculated from the fuel consumption of each type of automobile, was 1.9kW/m for the expressway and 2.9kW/m for the ground-level road under the expressway. The contribution from other roads is not considered here. Figure 5 shows that the temperature increase due to automobiles is approximately 1°C on the sidewalk on the downstream side.

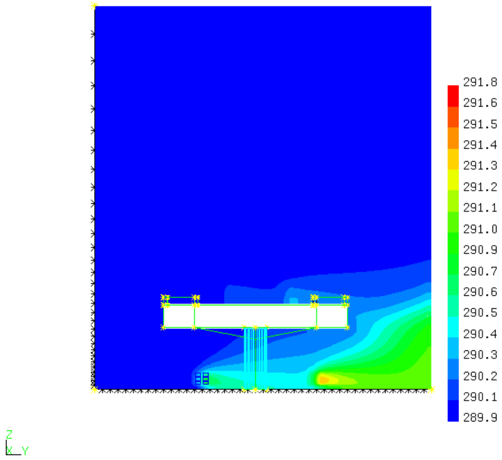


Fig.5 Temperature variation due to exhaust heat from automobiles

4. SUMMARY

The diffusion of NOx around the Ikegami-Shinmachi crossroad was investigated with a multi-scale CFD model. The emissions from the ground-level road resulted in a major concentration when the crosswinds were considered; however, those from the suspended road produced a high concentration in the case of parallel winds along the suspended road.

The model is insufficient since it does not account for the flow and turbulence resulting from the traffic itself or for the buoyancy turbulence in the atmosphere These deficiencies will be overcome in the near future..

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