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NUMERICAL SIMULATION OF MOVING VEHICLES UNDER CROSSWIND FOR LANDING OF A HELIAMBULANCE ON EXPRESSWAYS

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ABSTRACT : Emergency medical care is very effective to save the lives of injured people in traffic accidents. The heliambulance has been under operation since 1999 in Japan, and it is expected to contribute for the emergency medical care. However, the heliambulance is allowed to land on the expressway under only some restricted conditions in Japan, because the heliambulance generates strong wind, called downwash. It is afraid that the drivers in the other lane of the expressway may feel the difficulties in controlling their vehicles because of the strong wind generated by the heliambulance. In this study, the moving stability of vehicles under crosswind generated by a helicopter is investigated based on field experiments and numerical simulation. In the numerical simulation, a driver-vehicle model is employed to obtain the moving trajectories of vehicles subjected to crosswind. Based on these results, the possibility of landing of a heliambulance on expressways is discussed.

KEYWORDS: heliambulance, downwash, expressway, moving stability of vehicles

1 INTRODUCTION

Emergency medical care is very effective to save the lives of injured people in traffic accidents, people who suddenly get ill or are involved in a disaster. The operation of heliambulances is expected to contribute for the emergency medical care because medical actions can be performed continuously until arriving at a hospital. In addition that, the transit time to the hospital will shorten using a heliambulance. The heliambulance has been under operation since 1970 in Germany. The number of casualties in the traffic accidents on the autobahn was 20,000 at that time, and it was gradually reduced by half in 15 years. The heliambulance has been under operation since 1999 in Japan. The 11 hospitals are making use of heliambulances at present. The heliambulances had been sent out more than 3,300 times in 2004 [1].

It is expected that the operation of heliambulance helps to save the lives of injured people in traffic accidents on the expressway. Because the vehicles are moving at high speed on the expressway, the people involved in traffic accidents have the potential to be heavily injured. However, the heliambulance is allowed to land on the expressway under only some restricted conditions in Japan. It is anticipated that the vehicles moving on the opposite side lanes, where the traffic accident is not occurred, may cause further traffic accidents because of the strong crosswind generated by a heliambulance. When a helicopter lands, the crosswind called downwash is generated [2]. Its wind speed is sometimes larger than 20 m/s. If the wind speed (average for 10 minutes) larger than 20 m/s is

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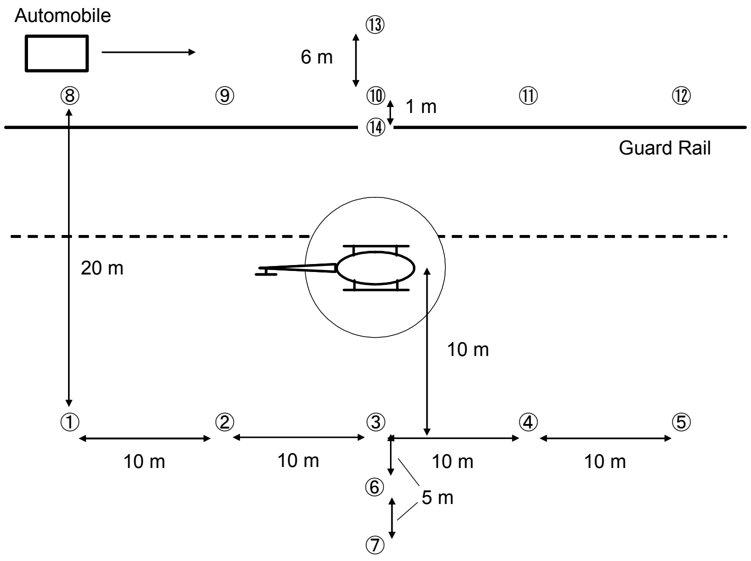


Figure 1. Locations of anemometers in the wind velocity observation

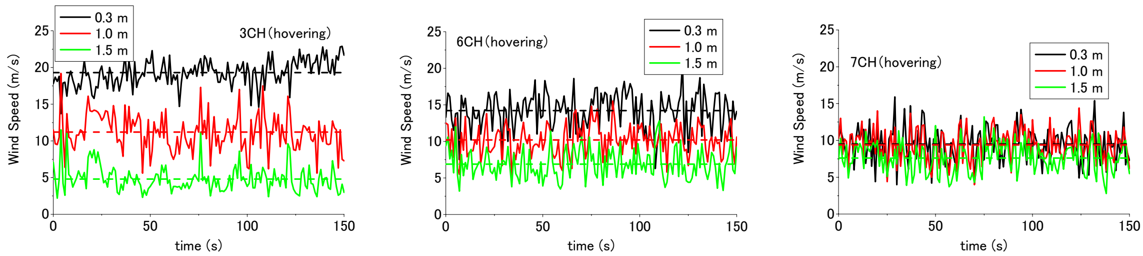


Figure 2. Wind velocities recorded at 3CH, 6CH and 7CH

observed in the expressway network, the expressway is closed by law to avoid traffic accidents due to strong wind. Therefore, the heliambulance is not allowed to land on the expressway in usual cases.

From the view point of emergency medical care, it is surely expected that heliambulances can land on the expressway to save the lives of injured people. Based on these backgrounds, the moving stability of vehicles subjected to crosswind generated by heliambulance is investigated in this study. First, the field experiment is conducted to measure the wind speed of downwash. Then, the driving tests are also conducted using two types of automobiles to reveal the moving stability under downwash. In addition that, the numerical simulation is performed to reproduce the moving trajectories of automobiles obtained in the field experiments, and the possibility of landing of a heliambulance on expressways is discussed.

2 OBSERVATION OF WIND VELOCITY GENERATED BY HELIAMBULANCE

2.1 OUTLINE OF FIELD EXPERIMENT

The observation of wind velocity generated by a helicopter was conducted on May 28, 2005. The observation was carried out at the construction site of the Second Tomei (between Tokyo-to-Nagoya) Expressway. Figure 1 shows the locations of anemometers in the observation. The heights of measurement points of wind velocities are 0.3 m, 1.0 m and 1.5 m. Figure 1 illustrates the locations of anemometers at the site where the guard rail is installed. The wind velocity was also observed at the site where the guard rail is not installed. According to the records of anemoscopes, the downwash was generated in a radial pattern by a helicopter.

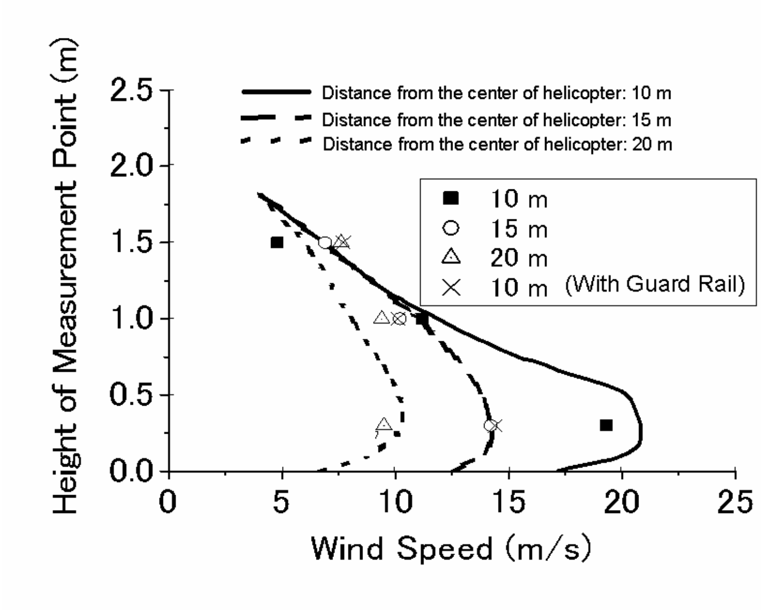


Figure 3. Comparison between the wind velocity obtained from in this study and that from numerical simulation

The actual driving tests were also conducted during the measurement of wind velocity as in Fig. 1. The moving trajectories of automobiles subjected to downwash generated by a helicopter were recorded. The details of the experiment will be described in the next chapter.

2.2 WIND VELOCITY OF DOWNWASH GENERATED BY A HELICOPTER

Figure 2 shows the wind velocities recorded at the site where the guard rail is not installed. The height of hovering of helicopter is 1.5 m. The wind velocities in Fig. 2 were recorded at 3CH, 6CH and 7CH, which are located 10 m, 15 m and 20 m away from the center of helicopter, respectively. The wind velocity of 3CH depends on the height of measurement points. The larger wind velocity is recorded at the lower observation point. This tendency is also observed in the wind velocity at 6CH, but it is not seen at 7CH. As the distance from the center of helicopter becomes larger, the recorded wind velocity becomes smaller.

Figure 3 shows the distribution of wind velocities with respect to the height from the ground. The symbols in Fig. 3 are obtained from the experiment conducted in this study. The curves are drawn through numerical simulation conducted by O'Bryan [3]. The result of this experiment coincides with that of numerical simulation. The average wind velocities at the site where the guard rail is installed are also shown in Fig. 3. The wind velocity becomes smaller due to the guard rail. The wind velocity with a guard rail recorded at the site where is 10 m away from the center of a helicopter shows a good agreement with that without a guard rail recorded at 15 m away site from the helicopter.

3 ACTUAL DRIVING TEST UNDER DOWNWASH AND NUMERICAL SIMULATION OF MOVING VEHICLES

3.1 ACTUAL DRIVING TEST UNDER DOWNWASH

The driving experiments using actual automobiles were also conducted while the wind velocities were observed. Table 1 shows the list of actual driving tests. Two types of vehicles are employed in the experiment. One is a compact car, and the other is a minivan. The moving speeds of vehicles are set to be 50 km/h and 80 km/h. The driving tests were conducted at the both sites where the guard rail is

Table 1. List of actual driving tests conducted in this study

Case	Type of Vehicles	Moving Speed (km/h)	Guard Rail
1	Compact car	50	Not installed
2	Minivan		
3	Compact car	50	Installed
4	Minivan		
5	Compact car	80	Installed
6	Minivan		

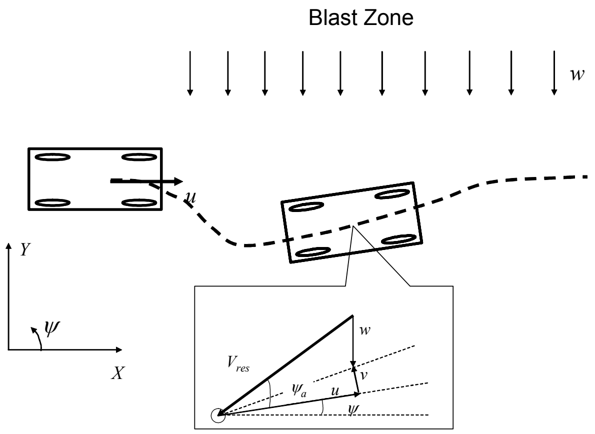


Figure 4. Vehicle model and crosswind disturbance

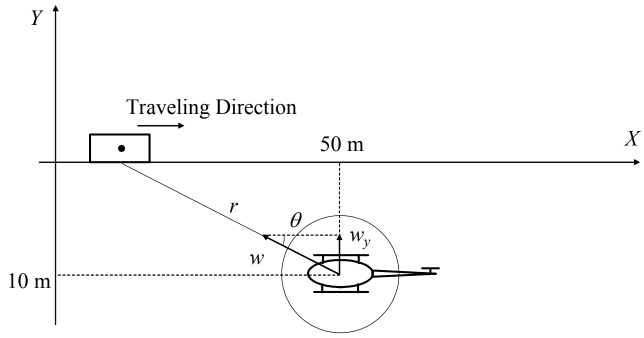


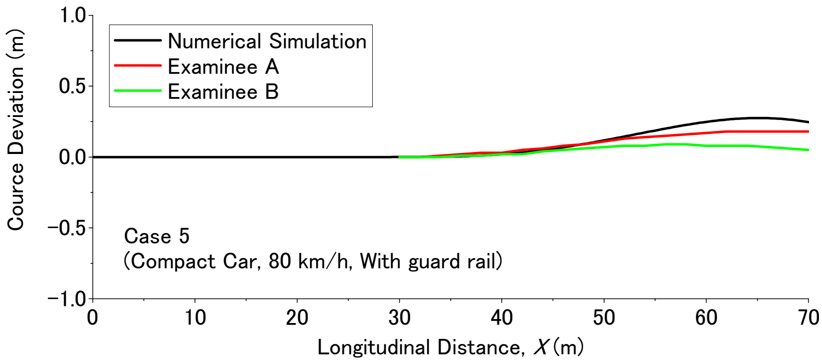
Figure 5. Locations of a vehicle and a helicopter assumed in the numerical simulation

installed and where it is not installed. The markers were attached to the vehicles to draw moving trajectories on the road surface. Then, the lateral displacements were recorded in the experiment.

3.2 NUMERICAL SIMULATION OF MOVING VEHICLES INCLUDING DRIVER'S REACTIONS

The numerical simulation of moving vehicle subjected to crosswind generated by a helicopter was also performed in this study. When a vehicle is subjected to crosswind, the lateral force and yawing moment are generated as shown in Fig. 4. The lateral force and yawing moment are described as in Eq. (1) and (2).

$$Y_w = C_y \rho S \left\{ u^2 + (v + w)^2 \right\} / 2 \tag{1}$$



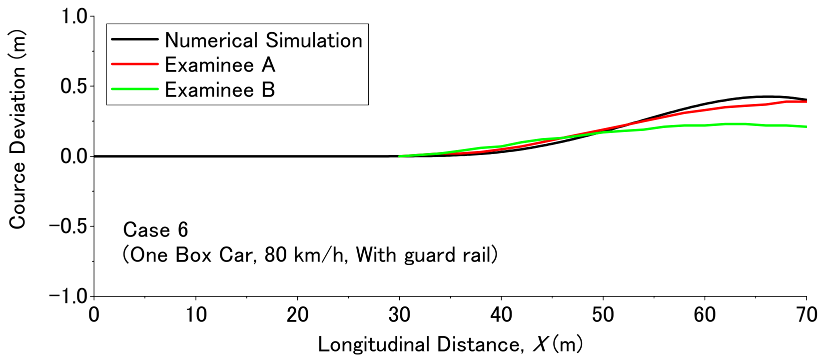


Figure 6. Moving trajectories of vehicles obtained from actual driving tests and numerical simulation

$$N_w = C_n \rho S(l_f + l_r)\left\{u^2 + (v + w)^2\right\}/2 \tag{2}$$

where S is the front area of the vehicle, and ρ is the density of air. w is the wind speed applied to the vehicle. C_y and C_n are the aerodynamic coefficients for the lateral force and yawing moment, respectively, which are the functions of the aerodynamic slip angle, ψ_a ($\approx \arctan\{(v + w)/u\}$). u and v are the longitudinal velocity and lateral velocity of a moving vehicle, respectively.

Maruyama and Yamazaki [4] determined the suitable values of parameters related to driver's reactions used in the second-order predictable correction model [5] based on the driving simulator experiment. Utilization of these parameters in the numerical simulation makes it possible to obtain the moving trajectories of a vehicle subjected to crosswind including driver's reactions.

In the numerical simulation, the locations of a moving vehicle and a helicopter are set as in Fig. 5. The helicopter is assumed to be at X = 50 m, and the vehicle is moving 10 m away from the helicopter at X = 50 m. Figure 6 compares the moving trajectories of vehicles obtained from actual driving tests and those drawn from numerical simulation. In the figure, the moving trajectories of Case 5 and Case 6 shown in Table 1 are illustrated. According to the figure, the lateral displacement of moving vehicles is smaller than 0.5 m. This means that the vehicles are in the moving lane under crosswind generated by a helicopter. It is also worthy mentioning that the moving trajectory obtained from numerical simulation shows a good agreement with that of actual driving test. Hence, it is possible to investigate the effects of downwash on moving vehicles under various conditions through numerical simulation.

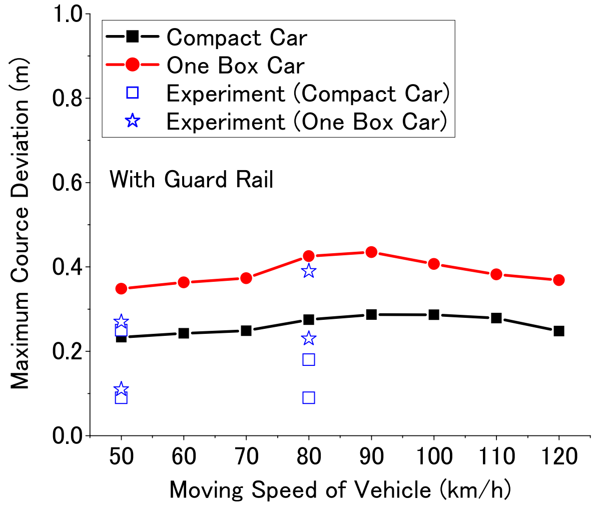


Figure 7. Relationship between the moving speed of vehicles and maximum lateral displacements obtained from numerical simulations

Figure 7 shows the relationship between the moving speed of vehicles and the maximum lateral displacement under downwash obtained from numerical simulation. In the figure, the results of actual driving tests are also shown as symbols. The maximum displacements of moving vehicles subjected to downwash are less than 0.5 m regardless of driving speed. Therefore, it is expected that the secondary traffic accidents because of crosswind generated by a heliambulance may not occur on the expressways under the current conditions.

4 CONCLUSIONS

In this study, the effects of crosswind generated by a heliambulance called downwash on the moving stability of vehicles are investigated based on field experiments and numerical simulations. The results of numerical simulations were verified by comparing with those of actual driving tests. Then, the maximum lateral displacements of vehicles subjected to crosswind for various driving speeds were obtained through numerical simulations. Based on the results, the secondary traffic accidents because of crosswind generated by a heliambulance may not occur on the expressways.

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