Full-scale Collision Experiment of Various Guard Fences

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ABSTRACT

In this paper, the results of full-scale collision were firstly reviewed to compare with those of numerical collision analyses. The FEM analysis models of both guard fences and vehicles could usually simulate field experiments. The new code required that a truck with 25t should be used in the field collision experiment. The problem was that the capability of the existing equipment of field collision experiment was not enough. Experiments using trucks with 20t are still performed so that the velocity and angle are adjusted to meet the level of impact. In this study, it is clarified that differences in the condition of collision influence the performance of guard fences through numerical analysis. Then comparing the results of numerical analyses using two shapes of cars, it is found that their behaviors are different. These results show that the field experiment is not enough to confirm the performance of guard fences. For that reason, the new type of design flow confirming the performance of guard fences is finally proposed.

INTRODUCTION

A new code for guard fence designs based on the performance-based design concept was implemented and issued in April 1999 in Japan. The prescribed performances include: i) prevention of derail, ii) safety of occupant, iii) guiding vehicles to road, and iv) prevention of spreading out the broken pieces, and it is required to test the performance of full-scale guard fences in the field. If guard fences can satisfy these performances, any materials and types of guard fences are accepted in design.

Field experiments for checking the performance of guard fences need enormous cost, efforts and time. Accordingly, numerical analyses using the finite element method are expected to complement field experiment. Numerical analyses show to confirm some performances of guard fences accurately.

According to the manual of a full-scale field collision experiment, a field collision experiment is performed only one time. In this study, using numerical analyses, it is considered that the experimental method using the existing equipment is not applicable to prove the performance of the guard fence. Especially the guiding facility of the guard fence was not validated.

HISTORY AND OUTLINE OF A FULL-SCALED FIELD COLLISION EXPERIEMENT OF GUARD FENCES

A full-scale field collision experiment of guard fence in Japan was first performed using a truck in 1958. A lot of

similar experiments have been done so far to develop new types of guard fences. However,
there was no detailed manual how to perform experiments. The experimental method was determined by the classification of guard fences and the types of guard fences. In 2000, a manual of a full-scale field collision experiment was established. Conditions and methods of experiments were specified in the manual. The manual enabled to unify the experimental results.

According to the design code, the strength of guard fences is classified by the level of impact shown in Table 1. The level of impact means the index of vertical kinematic energy toward guard fences. It is calculated using Eq.(1).

$$Is = \frac{1}{2} \cdot m \cdot (\frac{V}{3.6} \cdot \sin\theta)^2 \qquad (1)$$

where, Is：impact index (kJ),

m：mass of vehicle(t),

V：collision speed(km/h), and

θ：collision angle(deg).

Table 1 Classification and impact indexes of guard fences

Classification	C	B	A	SC	SB	SA	SS
Impact index *Is*（kJ）	45	60	130	160	280	420	650

The design code prescribes that two kinds of experiments using a truck and a car should be performed meeting the classification of guard fences shown in Table 2 and Table 3. Now, almost all the experiments are performed at the institute in Tsukuba belonging to Ministry of Land, Infrastructure and Transport. Vehicles are winched to accelerate. Then the speed of a vehicle reaches to the target speed, the vehicle is cut off from wire automatically. Finally, the vehicle crashes into guard fences. The steering wheel is fixed by ropes not to change the vehicle's direction after cutting off from wire. The design code prescribes that a vehicle with 25t is used in the field experiment. However, there are no experiments using 25t vehicles in Japan because of the land of capability of the existing experimental equipment of field collision.

Table 2 the conditions of collision

<table>
<tr><th></th><th>The condition of collision</th></tr>
<tr><td>Condition 1
(Trucks)</td><td>The regulation of trucks is that mass of truck is 25t and the height from ground to the center of gravity is 1.4m.　The collision condition conforms to Table-3.</td></tr>
<tr><td>Condition 2
(Cars)</td><td>The regulation of car is that mass of car is 1.0t. The collision speed conforms to the table shown below, the collision angle is 20deg.
<table><tr><th>Classification</th><th>Speed</th></tr><tr><td>C，B</td><td>60 km/h</td></tr><tr><td>A，SC，SB，SA，SS</td><td>100 km/h</td></tr></table></td></tr>
</table>

As the speed and angle are adjusted to meet the level of impact, experiments have been performed so far. The condition of collision refers to NCHRP350(H.E.ROSS, 1993), which is the American design code of guard fences. Compared with that of Japan, more cautious and detailed experiments are performed in U.S.A. The American design code of guard fences refers to soil conditions, shapes of vehicles and so on. According to the American design code, numerical analyses are used to decide the position of vehicle's collision and the length of guard fences. EU has the similar design code as well, which is called CEN/TC226-WGI. The EU design code places a special emphasis on safety of crews compared with those of Japan and U.S.A. It has detailed regulation about performing experiments.

Table 3 Conditions of field collision experiments of guard fences

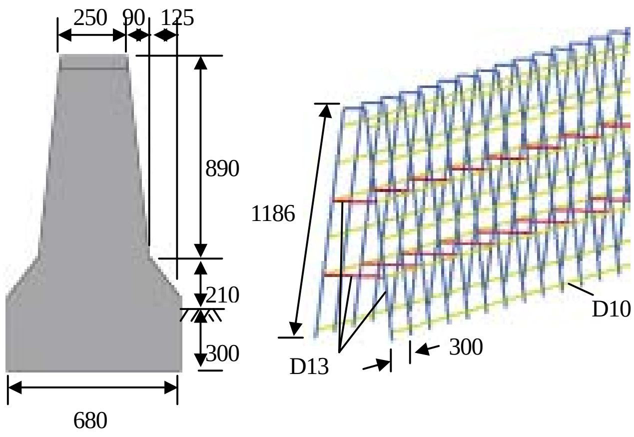
Classification For side of roadways	Mass of vehicle (t)	Speed (km/h)	Angle (deg)	Impact indx (kJ)
C		Over 26		Over 45
B		Over 30		Over 60
A		Over 45		Over 130
SC	25	Over 50	15	Over 160
SB		Over 65		Over 280
SA		Over 80		Over 420
SS		Over 100		Over 650

INFLUENCES BY DIFFERENCE OF THE CONDITIONS OF COLLISIONS

There are no experiments using 25t vehicles in Japan because of the land of the capability of the facility so far. Experiments with 20t trucks are performed so that the velocity and angle are adjusted to meet the level of impact. In this study, it is clarified that differences in the conditions of collision influence the performance of guard fences through numerical analysis.

Fig.1 shows the FEM model of the concrete guard fence, which was used in the field experiment in Ref.1). Two kinds of conditions shown in Table 4 are applied to this guard fence model. Condition A is the same as the field experiment using this type of guard fence, Condition B is the same as the indication in the design code shown in Table 3.

Fig.2 shows the response displacement of concrete guard fence. Comparing Condition A with Condition B, the simulated response displacement of Condition A is larger than that of Condition B at the first impact. At the second impact, the result of Condition B is about 1.5 times as large as the result of Condition A. Fig.3 shows the shearing force subjected to concrete guard fence. The maximum shearing



(a) Concrete body (b) Arrangement of reinforcing bar

Fig.1 The Florida type concrete guard fence（unit：mm） force is of little difference between the result of Conditions A and B. However, the duration of the impact in Condition B is longer than that of Condition A.

From these results, the field experiment with 20t truck has some problems. Though the maximum shearing force is of little difference between two conditions, the maximum response displacement is remarkably different. The condition of the field experiment using existing equipments is insufficient to check the prevention of derail.

Table 4 Condition of vehicle collision

	Mass of vehicle (t)	Speed (km/h)	Angle (deg)	Impact (kJ)
Condition A	20	100	17	660
Condition B	25	100	15	646

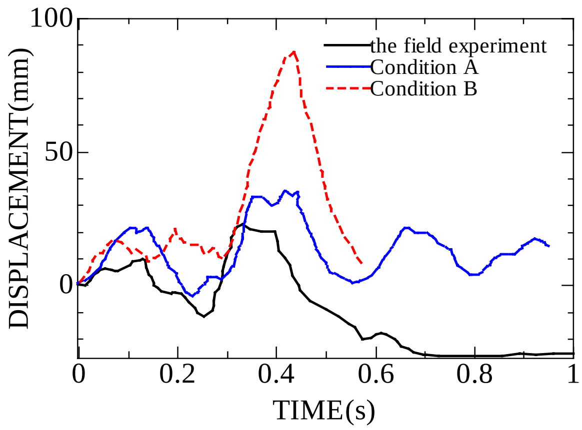


Fig.2 Comparison of the displacement

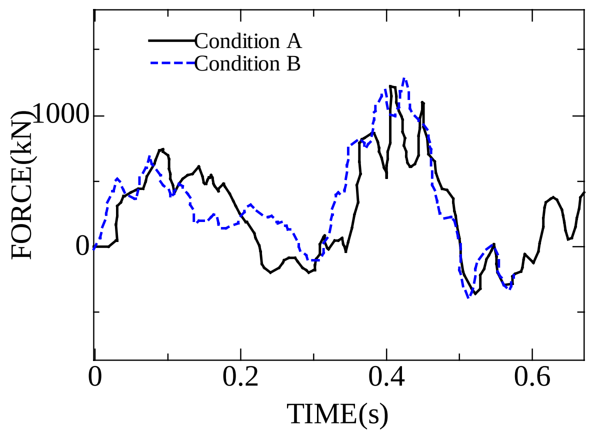


Fig.3 Shearing force subjected to concrete guard fence

INFLUENCES BY THE SHAPES OF THE VEHICLES

The design code prescribes that a car with 1.0t should be used to confirm the safety of crews. However, detailed regulations like the shape of cars are not specified. Only tolerances of cars shown in Table 5 are specified.

The numerical analyses are performed using two types of car models. The object of the collision is the Florida type concrete guard fence shown in Fig.1. Table 6 shows the detailed properties of two types of car models. Type A is the car model which was used in the field experiment on the steel bridge guard fence in Ref. 6). Type B is the car model which was used in the field experiment on the slope type concrete guard fence in Ref. 7). The collision conditions are speed of 80km/h and collision angle of 20deg. Fig.4 shows comparison of vehicle behaviors. The guard fence does not guide well the car of Type A because the back of the car moves to the opposite side of the guard fence after the second collision. The back of the car of Type B does not behave such a motion and the guard fence is capable of guiding the car of Type B. From these reasons, the present field experiment is not enough to confirm the performance of guard fences and the field experiment needs to be repeated by using some different types of cars.

Table 5 Tolerances of cars used in the field experiment

Items	From minimum to maximum	Average	Standard deviation	Permissive range
Length（mm）	3695 ~ 4860	4382	270	Average≦X≦4.7m
Width（mm）	1585 ~ 1775	1705	35	Minimum≦1.7m
Height（mm）	1235 ~ 1875	1390	112	Minimum≦X≦2.0m
Length of front shaft（mm）	1365 ~ 1520	1470	30	Minimum≦X≦Maximum
Length of back shaft（mm）	1325 ~ 1510	1460	34	Minimum≦X≦Maximum
Wheel base（mm）	2200 ~ 2805	2562	122	Minimum≦X≦Maximum
Minimum height from ground(mm)	130 ~ 205	153	10	130mm≦
Mass of vehicle (kg)	730 ~ 1570	1133	173	1t±200kg
Mass of front shaft（kg）	460 ~ 900	682	89	Front shaft：Back shaft 1.5：1
Mass of back shaft（kg）	260 ~ 790	451	107	
Gross mass of vehicle（kg）	1005 ~ 1990	1400	182	1t±200kg

Table 6 Properties of car models

Items	Type A	Type B
Length（mm）	4140	4120
Width（mm）	1615	1600
Height（mm）	1350	1343
Center of gravity*1（mm）	1070	730
Over hang*2（mm）	810	960
Mass of vehicle（t）	1.1	1.1

＊1 The distance from the front shaft

＊2 The distance from the front of car body to the front shaft

(a) Type A

(b) Type B

Fig.4 Vehicle behavior compared with two types of car models

THE NEW FLOW OF CONFIRMING THE PERFORMANCE OF GUARD FENCES

It is considered that the regulation of vehicles collision conditions in the manual of the field experiment is insufficient and the differences of collision conditions influence the performance of guard fences. The numerical analyses are proved to be valid in complement of the field experiment and are easy to be carried out. Therefore, the new design flow of confirming the performance of guard fences is suggested. First, a new type of guard fence is proposed and the static experiments are carried out to check the material and structural member strengths of guard fences. Then numerical analyses are performed to confirm the performance of guard fences before the field experiment. From the results of numerical analyses, if the successful probability of the field experiment is high, the field experiment is performed. After the field experiment, numerical analyses are performed to establish the FEM model meeting the field experiment. Using the established models, numerical analyses are performed again under other collision conditions. From the result of the field experiment and analyses, the performance of guard fences is confirmed.

It should be considered that regulation of vehicles used in the field experiments meets the different types of cars

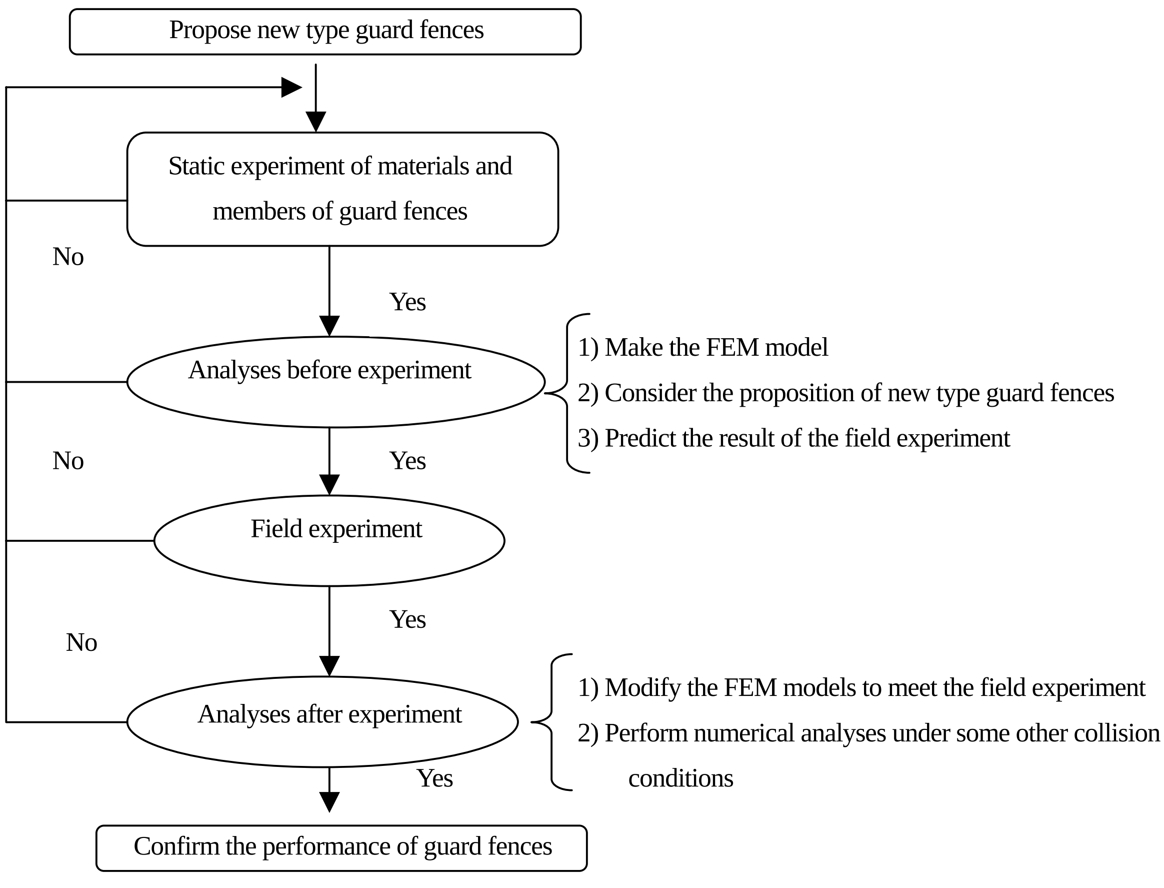


Fig.5 New flow of confirming the performance of guard fences

CONCLUSION

1) Because the capability of the existing experimental equipment of field collision is not enough, field experiments with 20t trucks are still performed in Japan. Comparing the result of numerical analysis under

the condition of prescribed in design code with the condition of the field experiment, the field experiment will be insufficient to confirm the prevention of derail.

2) Comparing the results of numerical analyses using two shapes of cars, it is found that their behaviors are different. These results show that the field experiment is not enough to confirm the performance of guard fences.

3) The new type of the design flow to confirm the performance of guard fences is suggested.

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