Dynamic Research Based on the Width and Height of Prefabricated Concrete Anti-collision Wall

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Abstract—Aiming at the problem that there is no uniform requirement for the section height of the prefabricated concrete anti-collision wall, the critical height of the prefabricated concrete anti-collision wall during design and installation cannot be confirmed. The co-simulation method of LS-DYNA and Hypermesh is used based on the common anti-collision on the market. Five finite element models of concrete anti-collision walls with different heights and widths were established for the wall, and common cars were used to simulate their collisions. The three indicators of vehicle turning, seat position acceleration, and vehicle exit angle are selected to evaluate the anti-collision performance of the anti-collision wall. The research results show that increasing the height of the anti-collision wall can significantly increase the anti-collision performance of the anti-collision wall when the width of the anti-collision wall is constant and the position is fixed.

1. Introduction
With the rapid development of my country's economy and the continuous progress of science and technology, the process of urbanization is accelerating, and traffic congestion is serious. In order to solve the increasing traffic pressure, road and bridge construction projects have been carried out in various parts of the country. According to relevant national regulations, anti-collision guardrails should be installed on both sides of highway bridges and urban bridges. Reinforced concrete anti-collision walls are one of the main application forms of anti-collision guardrails. The prefabricated reinforced concrete anti-collision wall can greatly reduce the energy received by the car during a car collision under the premise of meeting the prefabricated construction, and it is an indispensable and important part of the roadside protection of roads and bridges.

Hu Yuwen and others carried out a comparative study on the anti-collision performance of the F-type concrete anti-collision wall and the single-slope concrete anti-collision wall, and proved that a reasonable cross-sectional form can help improve the anti-collision performance of the anti-collision wall[1]. Huang Hongwu carried out a numerical study on the collision between a car and a highway anti-collision wall, and found that not only external factors will significantly change the simulation situation, but also changes in internal factors will also have a significant impact on the collision resistance of the anti-collision wall[2]. Wang Weili also made an in-depth study on the critical height of the anti-collision barrier[3]. The above research results show that the height and width of the surface anti-collision wall are closely related to the performance of the anti-collision wall.

In this paper, the LS-DYNA and Hypermesh co-simulation method is used to establish a finite element model of the collision between the car and the anti-collision wall. The finite element simulation analysis method is used to analyze the collision process of the car and the anti-collision
wall, and the prefabricated concrete anti-collision is studied. The relationship between the height and width of the wall section and the anti-collision performance of the anti-collision wall.

2. Finite element model

2.1 Selection of height and width of anti-collision wall and finite element model
According to the requirements of "Code for Design of Highway Traffic Safety Facilities" (JTG D81-2006), based on the commonly used F-type concrete guardrail structure in my country with a height of 130mm, the guardrail height is reduced by 100mm as an experimental group, a total of 5 experimental groups. The protection level of the guardrail is selected according to the design speed of 120km/h on the expressway, and the accident level of the guardrail model is selected according to the highest grade SS. The HyperMesh module is used to establish the finite element model of the guardrail. The guardrail unit type is a hexahedral unit. The length of a single guardrail is 4m, and the model is established. In the process, the connection between the guardrail is ignored, and the guardrail is considered as a whole for analysis. The entire guardrail model contains a total of 1573 nodes and 904 units. The specific picture is shown in Fig.1.

![Fig.1 Guardrail model diagram.](image)

2.2 Car model
Combining "Code for Design of Highway Traffic Safety Facilities" (JTG D81-2006) and "Detailed Rules for Design of Highway Traffic Safety Facilities" (JTG/T D81-2017), 8t trucks are used as experimental simulation vehicles. The 8t truck model comes from the National Collision Analysis Center (NCAC). The 8t truck model has a length×width×height=8500mm×2400mm×3000mm, and the total number of units is 38758. The specific model is shown in Fig.2.

![Fig.2 8t truck model diagram.](image)
2.3 Parameter settings

2.3.1 Material setting. The concrete material of the guardrail adopts the built-in MAT_JOHNSON_HOLMQUOSIT_CONCRETE (Mat-111) in the LS-DYNA program, the concrete unit adopts an eight-node solid unit, and the concrete strength grade is C40. The specific parameters are shown in Table 1. In consideration of ensuring the strength of the reinforced concrete anti-collision wall, the longitudinal steel bars and stirrups in the anti-collision wall are established using the MAT_PLASTIC_KINEMATIC (Mat-003) model that comes with the LS-DYNA program. The type of steel bar is HRB400. The specific material parameters are shown in Table 2[4].

| Type | RO   | G    | A    | B    | C    | N    | FC  | T     | EPS0 | EFMIN |
|------|------|------|------|------|------|------|-----|-------|------|-------|
| Value | 2.5e-9 | 1.5e4 | 7.9e-1 | 1.6e0 | 7.0e-3 | 6.1e-1 | 4.2e1 | 4.0e0 | 1.00 | 1e-2  |
| Type | SFMAX | PC   | UC   | PL   | UL   | D1   | D2  | K1    | K2   | K3    |
| Value | 7e0   | 1.4e1 | 7e-4 | 8e2  | 1e-1 | 3.8e-2 | 1   | 8.5e4 | -1.72e5 | 2.1e5 |

Table 2 Rebar design parameters.

| Type | RO | E  | PR | SIGY |
|------|----|----|----|------|
| Value | 7.85e-9 | 2.0e5 | 3.0e-1 | 4.0e2 |
| Type | ETAN | BETA | SRC | SRP  |
| Value | 3.0e2 | 1.00 | 4.0e1 | 5.00 |

2.3.2 Collision point setting. According to the relevant requirements of the "Highway Guardrail Safety Performance Evaluation Standard" (JTG B05-01-2013), the collision point between the vehicle and the guardrail should be selected at 1/3 of the starting point of the guardrail along the driving direction, and the collision angle between the car and the guardrail is 20°, the collision speed of a large truck is 80km/h.

2.3.3 Contact and restraint settings. The contact between the car and itself uses CONTACT_AUTOMATIC_SINGLE_SURFACE, and the static and dynamic friction coefficients of the self-contact are both set to 0.2. The contact between the car tire and the ground is indirectly realized by setting the RIGIDWALL_PLANER to achieve the friction between the tire and the ground, and the friction coefficient is 0.7. The contact between the car and the guardrail adopts CONTACT_AUTOMATIC_SURFACE_TO_SURFACE, both the static friction coefficient and the dynamic friction coefficient are 0.3. The internal longitudinal reinforcement and stirrup are related to the external concrete through CONSTRAINED_LAGRANGE_IN_SOLID[5].

3. Experimental program

Based on the standard F-shaped concrete guardrail with a height of 130mm, an experimental group is set for every 100mm reduction in the height of the guardrail, a total of 5 experimental groups. According to the requirements of the "Highway Guardrail Safety Performance Evaluation Standard", trucks were used to collide with the anti-collision walls of different experimental groups.

4. Simulation result analysis

According to the "Highway Guardrail Safety Performance Evaluation Standard" (JTG B05-01-2013) (hereinafter referred to as the "Standard"), this paper selects the vehicle turning situation, the acceleration of the vehicle's center of gravity and the vehicle exit angle after collision as the indicators for analyzing and evaluating the safety performance of the guardrail[6].
4.1 Turnover of the vehicle

4.1.1 Turnover situation of truck. A truck with a speed of 80km/h collides with the concrete guardrail at an angle of 20°. Take the collision process of a standard height concrete guardrail as an example. At 0.026s, the vehicle starts to touch the guardrail, as shown in Fig.3(a); at 0.057s, the truck begins to deform significantly under the collision, as shown in Fig.3(b); at 0.15s, under the action of the concrete guardrail, the truck began to turn significantly, as shown in Fig.3(c); at 0.22s, the truck and the guardrail began to be completely parallel and turned outward to leave the guardrail, as shown in Fig.3(d).

During the collision between the standard height concrete guardrail and the passenger car, the front insurance of the vehicle first contacts the anti-collision guardrail and turns under the lateral force of the guardrail, leaving the guardrail at a certain angle and speed. However, as the height of the anti-collision barrier decreases, the collision contact position between the truck and the anti-collision barrier begins to move down; when the height of the anti-collision barrier is reduced by 200mm, the collision contact position between the truck and the anti-collision barrier is transferred from the front fuse to the tires, and the vehicle starts to side. The overturning phenomenon is presumably due to the fact that the lateral force point of the anti-collision barrier on the vehicle has dropped too much.

4.2 The acceleration of the vehicle's center of gravity

The safety evaluation index related to the cushioning performance of the anti-collision wall is the acceleration of the occupant. The "Standard" uses the acceleration after the collision of the occupant to evaluate the cushioning function of the anti-collision barrier. The "Standard" stipulates that the vehicle can be used without a dummy. The acceleration of the center of gravity is a reference index. The truck...
model was used to collide the anti-collision wall models of five different experimental groups. Through LSDYNA finite element analysis, the maximum acceleration of the five different experimental groups was obtained. Comparing the peak accelerations of different experimental groups, it can be seen that as the height of the crash barrier decreases, the peak acceleration of the car's center of gravity shows an upward trend.

4.3 Vehicle exit angle
The "Standard" stipulates that the exit angle of the vehicle should be less than 60% of the collision angle. At a collision angle of 20°, the exit angle of the vehicle should be less than 12°. After analyzing and simulating each experimental group, a table of the relationship between the exit angle of the vehicle and the height of the guardrail is obtained. See Table 3 for details. As the height of the guardrail decreases, the exit angle of the truck begins to increase. When the anti-collision barrier is lowered by 200mm, the exit angle of the vehicle reaches a critical value.

| Height (mm) | Angle (°) |
|------------|-----------|
| 1300       | 5°        |
| 1200       | 7°        |
| 1100       | 10°       |
| 1000       | 13°       |
| 900        | 14°       |

5. Conclusion
Through the finite element analysis of the impact of the height of the anti-collision guardrail on the protection capability, it is found that when the height of the anti-collision guardrail is lower than the standard anti-collision guardrail height of 200mm, the truck starts to roll over, and the blocking function of the anti-collision guardrail fails to meet the requirements of the "standard". The height of the anti-collision barrier is obviously negatively correlated with the acceleration of the vehicle's center of gravity and the vehicle exit angle. As the height of the anti-collision barrier decreases, the buffering and guiding functions of the anti-collision barrier significantly decrease. The research on the height of the anti-collision barrier will help analyze the safety performance of the roadside anti-collision barrier.

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