Protection Capability Analysis of the Common A-grade Corrugated Beam Barrier for the Truck

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Abstract: In order to understand the protective capability of the common A-grade corrugated beam barrier for the truck, the method of the computer simulation and the full-scale impact test with real vehicles were used to research it. The results show that the ultimate protection energy of the common A-grade corrugated beam barrier for the truck is 125kJ, which can satisfy the requirements of the old standard, but can not satisfy the requirements of the new standard. The research results can provide basic data for the rational application of the common A-grade corrugated beam barrier.

1. Introduction

Highway barriers with the good safety performance can effectively reduce the accident death rate. The corrugated beam barrier which uses the deformation of the soil foundation, the column and the corrugated steel plate to absorb the collision energy, and compel the out-of-control vehicle to change the direction of driving, and prevent the vehicle from going out or entering the opposite lane. The corrugated beam barrier is widely used in Chinese expressways. In highway operation, the large and medium-sized truck is one of the mainstream vehicle models, and the wave-beam barriers play a certain role in the safety protection of the trucks.

This paper intends to conduct the real vehicle crash test and the simulation crash analysis on the common wave-beam barrier according to the standard crash conditions, and analyze the protection performance of the wave-beam barrier and verify the accuracy of the simulation models, and then determine the ultimate protection ability of the wave-beam barrier on the basis of the verified simulation models, and finally use the full-size crash test of the real vehicle to do further verification.

2. Commonly used corrugated beam barrier

2.1. Structure of corrugated beam barrier

The common corrugated beam barrier is a continuous beam-column structure composed of the corrugated steel plate and the column spliced with each other. The structural characteristics of the barrier are as follows:

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The size of the wave beam plate is 310mm×85mm×4mm, and the height of the beam plate center from the ground is 600mm. The size of the column is Φ140mm×4.5mm, and the spacing of the column is 4m. The hexagonal block is arranged between the wave beam plate and the column, the size of which is 196mm×178mm×200mm×4.5mm. The high strength bolts (M16) are used to connect each structure of the barrier [1-3]. The structure of the corrugated beam barrier is shown in Figure 1.

2.2. Requirements for barrier protection capability

The protection capability of the barrier is characterized by the collision energy of the barrier protected vehicles. The collision energy is mainly determined by the impact
angle, the impact velocity and the vehicle mass[4,5]. The design protection grade of the common corrugated beam barrier is Grade A, which follows The Evaluation Specification for Highway Safety Barriers (JTG/T F83-2004) promulgated and implemented on December 31, 2004 (hereinafter referred to as the "Old Standard"), while the Standard for Safety Performance Evaluation of Highway Barriers (JTG B05-01-2013) (hereinafter referred to as the "New Standard") compare with the Old Standard, the allowable error requirements of the three collision parameters are more stricter, which is promulgated and implemented on December 1, 2013.

Table 1 shows the comparison of the collision conditions and allowable errors of trucks with new and old standard Grade A barrier. It can be seen from Table 1 that the "Old Standard" has positive and negative provisions on collision parameters, while the "New Standard" eliminates the negative errors of the vehicle mass and the collision speed, and reduces the negative error range of the collision angle. The "New Standard" requires no negative error on the collision energy, which means that the collision energy of the A-grade barrier must be above 160kJ. While the "Old Standard" does not have clear requirements on this, and the lower limit of error is taken according to the three collision factors, and the "Old Standard" requires that the collision energy of the A-grade barrier must be above 122kJ.

Table 1. Comparison between the "New Standard" and the "Old Standard".

<table>
<thead>
<tr>
<th>Impact condition</th>
<th>Normal value and tolerance</th>
<th>&quot;Old Standard&quot;</th>
<th>&quot;New Standard&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle mass</td>
<td>Normal value(t) 10</td>
<td>-300~300</td>
<td>0~300</td>
</tr>
<tr>
<td></td>
<td>Tolerance(kg) -300~300</td>
<td>0~300</td>
<td>0~300</td>
</tr>
<tr>
<td>Impact velocity</td>
<td>Normal value(km/h) 60</td>
<td>-3~3</td>
<td>0~4</td>
</tr>
<tr>
<td></td>
<td>Tolerance(km/h) -3~3</td>
<td>0~4</td>
<td>0~4</td>
</tr>
<tr>
<td>Impact angle</td>
<td>Normal value(°) 20</td>
<td>-1.5~1.5</td>
<td>-1~1.5</td>
</tr>
<tr>
<td></td>
<td>Tolerance(°) -1.5~1.5</td>
<td>-1~1.5</td>
<td>-1~1.5</td>
</tr>
</tbody>
</table>

The protection of large trucks is mainly embodied in the containment and guided function in the evaluation criteria, which requires that vehicles crossing, climbing and riding over the barrier should be able to be blocked by it, and the barrier components and their escape parts shall not invade the vehicle occupant cabin. The vehicle shall not overturn after collision, and the wheel track after the vehicle drives out of the departure point shall not cross the straight line F when it passes through the guiding exit frame in Figure 2. Table 2 shows the values of A and B.

Table 2. The value of parameter A and parameter B.

<table>
<thead>
<tr>
<th>Impact vehicle type</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium and large truck</td>
<td>$4.4 + 0.16 V_w + V_e$</td>
<td>20</td>
</tr>
</tbody>
</table>

Note: $V_w$ is the total vehicle width (m); $V_e$ is the total vehicle length (m).

3. Collision analysis under standard conditions

The standard conditions for the collision of the truck with A-grade barrier are as follows: The 10-ton truck hits the barrier at the collision speed of 60km/h and the angle of 20°, and the collision energy is 160kJ. The finite element simulation models were established according to the standard collision conditions, and the full-size crash test was organized to analyze the protection capability of the corrugated beam barrier for the truck.

3.1. Simulation collision analysis

According to the parameters of the 10-ton truck specified in the "New Standard", the ls-dyna finite element simulation model was established by using the CAE pre-processing software hypermesh, and the simulation parameters were set by referring to the high-precision simulation model verified by the collision test[6-10]. Figure 3 shows the established computer simulation models.

In the simulation model, the boundary conditions of the model were set according to the standard collision conditions. Figure 4 shows the simulation results. It can be seen that after the truck head hits the barrier, and the truck body gradually turns, and then the rear starts to hit the barrier. The corrugated beam barrier in the collision area is crushed by the rolling vehicle.
3.2. Collision test analysis

The truck was purchased according to the parameters of the 10-ton heavy truck specified in the "New Standard", and the test section of the corrugated beam barrier was established, as shown in Figure 5. The front face of the purchased truck is different from the simulation model, but the main parameters affecting the evaluation results are consistent. The physical model of the corrugated beam barrier is strictly consistent with the simulation model.

According to the standard crash conditions, the full scale crash test of the real vehicle was organized, and the whole collision process was recorded by a high speed camera. Figure 6 shows the test results. It can be seen that the truck rolls during the rear collision, and the barrier in the collision area is squashed by the rolling truck.

4. Analysis of ultimate protection capability

Based on the simulation model verified by the crash test, the ultimate protection capability of the common A-grade corrugated beam barrier against the truck was explored, and the full-size crash test of the real vehicle was used to verify the exploration results.

4.1. Ultimate protection ability of the barrier

The ultimate protection capability of A-grade corrugated beam barrier was explored by the successive approximation method. The method is as follows: The collision energy starts from 160kJ, and the simulation calculation is carried out every 5kJ until the collision energy meeting the safety performance requirements is found, which can be used as the ultimate protection capability of the common A-grade corrugated beam barrier for the truck.

Through the simulation calculation, it can be seen that the truck overturns under the impact energy of 130kJ~160kJ, which does not meet the requirements of the evaluation standard. Figure 7 shows the simulation results at 130kJ collision energy.

Figure 8 shows the simulation results at 125kJ collision energy. According to the simulation results, it can be seen that the driving attitude of the truck after colliding with the barrier is good, and the driving trajectory meets the requirements of the guiding exit box, and the indexes meet the requirements of the evaluation standard.
Based on the above simulation results, it can be concluded that the ultimate protection capability of the common A-grade corrugated beam barrier for the truck is 125kJ.

4.2. Test verification

The real vehicle full-size crash test under the ultimate protection energy was organized and implemented to investigate the vehicle attitude, and judge the correctness of the ultimate protection ability analysis results obtained by simulation calculation. Figure 9 shows the test vehicle and the test barrier.

Figure 9. Ultimate protection capability verification test.

From the collision test results shown in Figure 10, it can be seen that the corrugated beam barrier effectively stops and guides the large truck under the ultimate collision energy, but the large truck is seriously rolled and close to overturning, which indicates that the 125kJ collision energy is the limit protection ability of the corrugated beam barrier for the truck. And the test results are consistent with the simulation results.

5. Conclusion

Based on the results of the computer simulation analysis and the full-scale crash tests, the following conclusions are obtained:

(1) The protection capability of the common A-grade corrugated beam barrier for the truck is 125kJ.

(2) Although the safety performance of the truck protected by the corrugated beam barrier can meet the requirements of the "Old Standard", the protection energy of 125kJ is slightly higher than 122kJ, which means that the safety reserve of the common A-grade corrugated beam barrier is small.

(3) The safety performance of the common A-grade corrugated beam barrier to protect the truck does not meet the requirements of the "New Standard", and it is necessary to apply the improved barrier structure in the new and renovation and expansion projects.

References


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