A Preliminary Study on the Protection and Performance of High-strength Steel Corrugated Beam Guardrail

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Abstract. Guardrail, as the last barrier to road safety, is an important part of road traffic safety facilities. Corrugated beam steel guardrail is the most widely used due to the advantages of simple replacement, easy construction, and good permeability. Currently, most of the corrugated beam steel guardrail is mainly used Q235 steel in our country. With further research and development of materials, the field of traffic safety facilities also gradually began to use new materials. High-strength steel is a new material with high tensile strength, when it is used for corrugated beam guardrail, using less material can achieve the same strength and stiffness as Q235 steel guardrail, thus making the guardrail lightweight. The reliability of the trial section with the new material guardrail needs to be evaluated before it is applied to the operational road on a large scale. To monitor the performance of the new material guardrail in the trial section, our research used numerical simulation analysis to verify the protective ability of high-strength steel guardrails car. Through the vehicle collision guardrail accident characteristics, the safety performance assessment index of high-strength corrugated beam steel guardrail is proposed, and the accident monitoring process, method, and data recording requirements are developed. In terms of durability, for high-strength corrugated beam steel guardrail corrosion treatment method, we summarized the technical points and requirements. For the trial section guardrail durability performance long-term monitoring, the specific process scheme, requirements and data recording, and other related requirements were developed. This study not only provides methods and guidance for the monitoring and evaluation of the use performance of high-strength steel guardrails but also provides support for the further development and application of new materials for corrugated beam guardrail.

Keywords: high-strength steel, corrugated beam guardrail, safety, durability

1 Introduction

In recent years, the construction of highways develops rapidly and the mileage of highway operations increases year by year. The development of material science provides more choices for traffic safety facilities. Common steel waveform beam

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guardrail material is mainly Q235 steel. Q235 steel in quite a long time are the main components of the highway guardrail. The highway guardrail is set in the roadside and the central divider, in order to ensure that the vehicle does not rush out off the road and can guide the direction of the vehicle driving. The emergence of new materials also triggered new thinking in the field of guardrail materials, in which, new materials of high-strength steel are well-known with lightweight and high-strength characteristics. The use of new materials constitutes the guardrail, its actual protection ability is still the focus of attention in the use process. The common evaluation methods of guardrail structure protection ability are mainly the vehicle collision test, numerical simulation, and the evaluation method of guardrail protection ability based on the accident.

In terms of car collision test, Liu studied the method of transforming the steel two-wave type guardrail on the roadside into a double-layer double-wave type guardrail to improve the protection performance[1], the study proposed the technical strategy of transformation and upgrading, and the car collision test was used to verify that the protection level of the transformed guardrail structure reached SB level. The protection capacity is improved by reinforcing and raising the old combination bridge, and its protection level can reach the SS level. This technical solution has been verified by vehicle collision test[2]. Li studied the safety performance of the new SA-level bridge guardrail using the vehicle collision test method[3], and analyzed the key indicators of the new SA-level guardrail on the vehicle blocking function, guiding function, and buffering function during the test. The results show that the guardrail protection capacity meets the SA-level guardrail protection capacity requirements.

In terms of numerical simulation, Jing studied the protection capacity of raised corrugated beam guardrail using LS-DYNA simulation software[4]. The study analyzed the related indexes of vehicle acceleration, velocity, and guardrail structure deformation, illustrated the protection capacity of guardrail structures for different vehicles, and verified the reliability of the raised modification program. For the new material guardrail, Xin performed a numerical simulation analysis on the new transition section structure of the A-level corrugated beam guardrail and bridge SB-level concrete guardrail and proposed an optimized combination scheme to guide similar projects[5]. Liu analyzed the allowable error value of guardrail height by numerical simulation method[6], provided the safety interval of guardrail height setting, and explained the impact of height change on the protection capacity.

In terms of combining accident data to assess guardrail protection capacity, Ma assessed the demand for guardrail protection capacity of different road sections by combining billion vehicle-kilometer mortality data[7], which provides a reference for highway guardrail design selection. Amirarsalan and colleagues collected accident data from 2007 to 2016 and conducted a study to analyze the impact of different guardrail types on accident severity degree[8], and found a pattern of accident severity of this vehicle collision with different guardrails. For the median guardrail, the analysis of vehicle collision guardrail accident data indicates that the guardrail type greatly affects the accident severity [9-10].

Some studies have used car collision test, numerical simulation, and accident data analysis methods to analyze the guardrail protection capacity, which illustrates the

weak position of guardrail protection capacity and the existence of structural problems. This provides a relevant basis for guardrail design and transformation. However, the actual performance of the new material guardrail still lacks the relevant accident and observation data support due to the actual road section to use them is usually short. Therefore, the method of long-term observation of new material guardrail performance needs to be further studied.

The long-term observation of the use performance of high-strength steel corrugated beam guardrail was studied. The study is based on vehicle collision guardrail accidents and long-term performance test content. This paper explains the accident and long-term performance observation record focus, provides the observation record process, and gives the data record format requirements. This provides a basis for the long-term observation of the performance of the new material guardrail use.

2 Numerical simulation of the protective capacity of high-strength steel guardrails

2.1 Numerical model establishment

Selecting a corrugated beam steel guardrail with a protection level of A as the research object, a high-strength steel guardrail model is established. Taking car as an example, LS-DYNA software is used to calculate the process of vehicle collision with the guardrail. This software can achieve simulation calculation of large deformation nonlinear dynamic impact problems. According to the material mechanical performance report, the yield strength of high-strength steel is 700MPa, and the steel is modeled using the MAT24 material model. Both the vehicle and guardrail are modeled based on actual dimensions. The established vehicle guardrail model is shown in Figure 1.

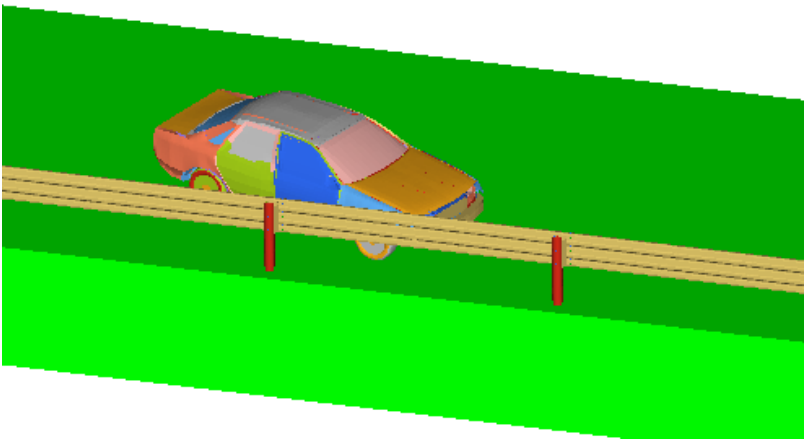

Fig. 1. Vehicle-guardrail model.

2.2 Analysis of collision results of high-strength steel guardrails

The vehicle wheel track during the collision of car with a guardrail is shown in Figure 2.

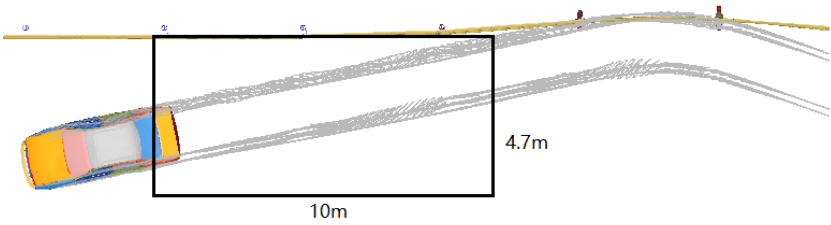

Fig. 2. The vehicle wheel track.

After the car collided with the high-strength steel guardrail, the vehicle did not cross the guardrail, which effectively blocked the vehicle. The vehicle's wheel tracks did not exceed the guiding exit frame, and the guardrail formed a guiding effect on the vehicle. The high-strength steel guardrail has a certain protective ability for small buses driving out of the road.

3 Key points of observation

Whether the guardrail structure design can reach the expected function, which depends on the actual results of the guardrail structure protection capacity and durability. The high-strength steel corrugated beam guardrail is a new material guardrail, its use time in the trial section is still relatively limited, therefore lack of sufficient traffic accident data. This makes it impossible to analyze in depth the real protective effect of the guardrail in practical application. The guardrail is a highway traffic safety facility that needs to be used for a long time, so its long-term performance also needs to be given significant attention. In order to evaluate the actual protection capacity and long-term use performance of the guardrail, this new high-strength lightweight steel waveform beam guardrail in the long-term use of the process of collision accidents and anticorrosion layer changes and structural integrity of the observation program needs to be developed. The relevant observation program can guide long-term monitoring during the use of the guardrail.

Collision speed, collision angle, vehicle weight, and whether or not over the guardrail are effective indicators used to analyze the barrier function in a vehicle collision. The guiding function of the guardrail structure can be represented by the trajectory of the vehicle. The deformation length, the deformation value, and the damage severity of the guardrail and whether it can continue to function show the stiffness and strength characteristics of the guardrail structure. The injury level of the occupants and whether the existence of serious casualties reflects the buffer function of the guardrail. In the accident observation work the above information should be mainly recorded.

In terms of durability observation of the guardrail, the thickness of the anticorrosion layer of the guardrail components is closely related to its resistance to erosion, and the integrity determines whether it can implement the design expectations of its protective performance. The durability observation work of the above two indicators should be mainly recorded.

4 Collision Observation Program

4.1 Observation procedure

For the guardrail long-term use process of traffic accident observation, firstly, the road condition and traffic flow data of the guardrail installation section need to be identified, including road type, functional level, lane number, lane width, shoulder width, average daily traffic volume, truck ratio, and so on. Next, detailed data on roadside features should be collected, including the installation position of the guardrail and design information. Then the collision accident data will be recorded. The observation procedure is shown in Figure 3.

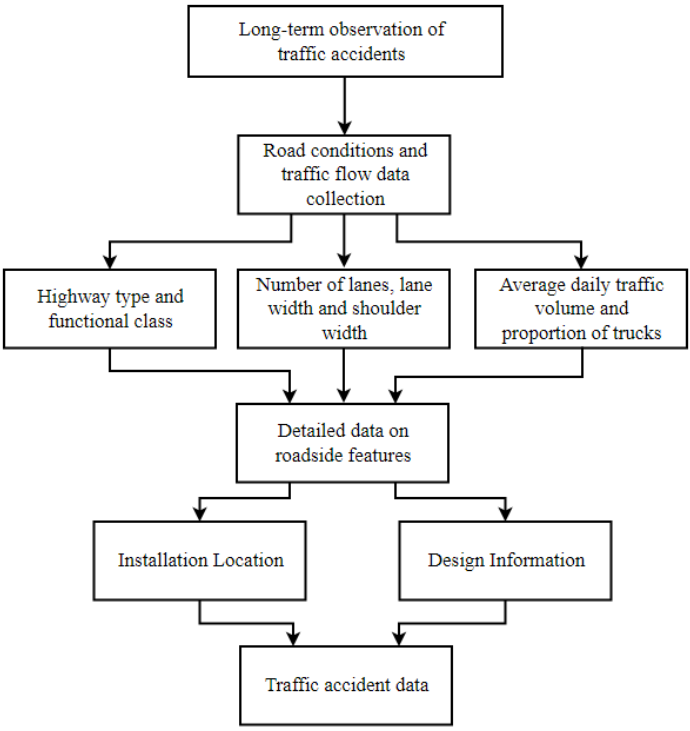

Fig. 3. Flow diagram of collision observation.

4.2 Observation contents and requirements

About recording data on the road conditions, the first step should be to define the class of the road, such as highway, primary road, secondary road, or tertiary road. The lane width measurement should be taken in meters, and the average daily traffic volume and truck ratio are obtained from statistical analysis based on the data of the last three years. Detailed roadside features require taking photographs of guardrail installation locations and collecting guardrail design information. It is required to record accident data, including accident cause, time and weather, collision speed, collision angle, vehicle weight, driving trajectory, whether over the guardrail, measuring the deformation length of guardrail with a meter scale, deformation value of guardrail, damage degree, occupant injury, whether the existence of serious casualties, whether the guardrail can continue to work, etc.

4.3 Accident data logging sheet

The accident data logging sheet is shown in Table 1.

Table 1. Accident Data Logging Sheet.

Incident No.		Date		Location of occurrence		Highway type and functional class	
Lane width (m)		Average daily traffic volume		Percentage of trucks (%)		Cause of accident	
Time and Weather		Crash speed (km/h)		Collision angle (°)		Vehicle weight (tons)	
Whether over the guardrail		Guardrail deformation length (m)		Guardrail deformation value (m)		Occupant Injuries	
whether the existence of serious casualties		whether the guardrail can continue to work					
Photograph of the guardrail installation position							
Photographs of deformation and breakage of guardrail components							
Photographs of vehicle trajectories							

5 Durability Observation Program

5.1 Observation procedure

Guardrail anticorrosion layer changes and structural integrity of long-term observation work require regular monitoring of guardrail anticorrosion layer

thickness, regular inspection of guardrail components lost, and regular maintenance. The observation procedure is shown in Figure 4.

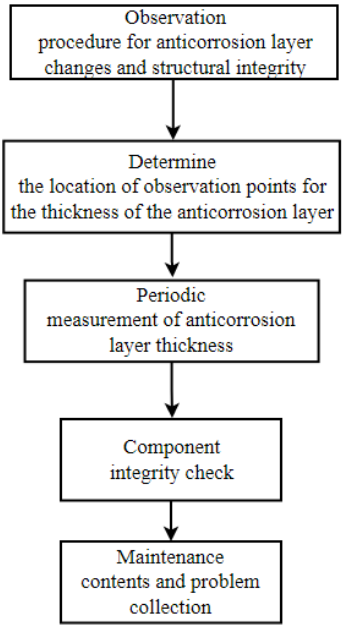

Fig. 4. Flow diagram of durability observation.

5.2 Data logging sheet

The logging sheet for the anticorrosion layer changes and structural integrity data are shown in Table 2.

Table 2. Data logging sheet for changes in anticorrosion layer and structural integrity.

Observation No.		Date		Observation Location		Thickness of the anticorrosion layer	
Observation Location		Thickness of the anticorrosion layer		Observation Location		Thickness of the anticorrosion layer	
Whether the structure is corroded		Whether the components are lost		Reasons for corrosion protection layer off		Whether the snowmelt affects the anticorrosion layer	
Whether the wind and sand		Whether the climate has an impact on		The main content of the repair			

affect the anti-corrosion layer		the guardrail structure					
Photographs of corrosion protection layer peeling and rust location							
Photographs of guardrail components lost location							
Photographs of guardrail structures affected by snowmelt and climate							

6 Conclusion

This paper researches the long-term observation method of the use performance of high-strength steel guardrail, analyzes the key points of vehicle protection capacity and guardrail structure durability observation, establishes the collision accident and durability observation program, identifies the observation process, observation content, and requirements, provides the data recording format and requirements, and the main conclusions as follows:

(1) Guardrail protection performance and durability is to evaluate whether the guardrail structure achieves the design expected to play an effective protective role against runaway vehicles. Guardrail protection capacity and durability can evaluate whether the guardrail structure achieves the design of the expectation that the runaway vehicle can play an effective protection function. New material guardrail analysis and evaluation focus on the guardrail structure of the actual protection effect and durability of the two perspectives in the trial section. Therefore, the trial section of the vehicle collision guardrail accident and durability need to be recorded, so as to provide support for the analysis actual protection effect of the guardrail structure and the use of performance.

(2) After the car collided with the high-strength steel guardrail, the vehicle did not cross the guardrail, which effectively blocked the vehicle. The vehicle's wheel tracks did not exceed the guiding exit frame, and the guardrail formed a guiding effect on the vehicle. The high-strength steel guardrail has a certain protective ability for small buses driving out of the road.

(3) Vehicle collision guardrail accident detection focuses on the indicators related to the guardrail blocking function, guidance function, and buffer function, such as vehicle collision speed, collision angle, vehicle weight, whether over the guardrail, occupant injury, and whether there are serious casualties. Meanwhile, the guardrail structure damage degree and whether it can continue to work and so on needs to be recorded.

(4) The observation of the durability of the guardrail focuses on the indicators related to corrosion resistance, including the thickness of the anticorrosion layer and the integrity of the components, because the corrosion situation is closely related to the use of the guardrail performance. In the long-term performance observation work should provide detailed observation records.

(5) This study on high-strength steel corrugated beam guardrails uses a performance observation program for a preliminary analysis. In the subsequent research process, vehicle collision guardrail accidents and durability performance observation data should be recorded according to the observation plan requirements, and the protection and use effects of new material guardrails should be evaluated from the perspectives of accident protection and durability.

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