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Study on Safe and Anti-Collision Measures Towards Expressway of Underpass

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Abstract. With combining manage features of expressway and express railway, this paper analyzes safe and Anti-collision measures towards expressway of underpass. In order to ensure safety of the pier and prevent wrecked vehicles from crashing the piers of elevated express railway, Anti-collision of expressway and express railway will be researched. And this paper proposes that expressway of underpass should increase safety and anti-collision measures and Anti-collision measures and makes a checking calculation for intensity of Anti-collision of the piers. This research provides a practically analyzing thought for the related projects.

Keywords: Expressway, anti-collision wall, down the express railway bridge, anti-collision piers.

1. Introduction

With the rapid advancement of China's high-speed railway construction, there are more and more cross-over phenomena between expressways and high-speed railway bridges. At the same time, the economic development of the local area has also increased rapidly, the demand for transportation has been continuously increased, the traffic flow of the expressway has been increasing, the traffic accidents on the expressway have also increased. If a traffic accident occurs on a section of the expressway that runs through the high-speed rail bridge, it will pose a threat to the high-speed Railway Piers beside the expressway. The advantages of high-speed railway have fast speed and heavy traffic density. In order to ensure the safe operation of high-speed railway trains, the safety anti-collision measures and the collision prevention grade of high-speed railway bridge piers are particularly important.

Through the comprehensive analysis of domestic and foreign related literature, the main research includes: research on the structure of vehicle impact piers [1],[2], research on the structure of vehicles impacting piers and columns [3],[4], and the anti-side of reinforced concrete beam-column members research on impact performance [4],[5],[6],[7],[8] and anti-vehicle impact of piers [9],[10],[11],12]. Analysis and research show that the current research on anti-vehicle impact of piers is still in its infancy, and there are many key problems that have not been solved, such as the calculation method of vehicle impact force. In this paper, the anti-collision measures of the high-speed rail bridge under a new construction project are set up, the anti-collision measures of the expressway anti-collision wall and the high-speed rail bridge pier are combined for comprehensive research and analysis, and the self-compiled program is used for checking calculation to ensure the safe operation of the expressway and high-speed rail and the reliability of anti-collision measures.

2. Project Overview

An expressway new construction project was built from the pier of bridge no. 709 -710 of a high-speed railway bridge, and the pier of no. 710 -711 bridge. At the intersection of the two projects, (32+32) m simply supported beam is adopted for the high-speed rail bridge hole. The pier is 3.0 meters wide, the pier is 7.8 meters long, the bearing platform is 5.1 meters wide and 10.08 meters long, and the clearance under the bridge is more than 5.5 meters. The plane relationship diagram and elevation diagram of the two are shown in Fig. 1 and Fig. 2.

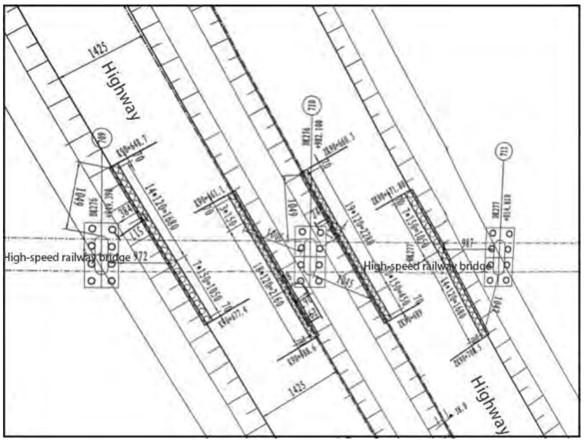

Fig. 1 Layout of relation between expressway and express highway

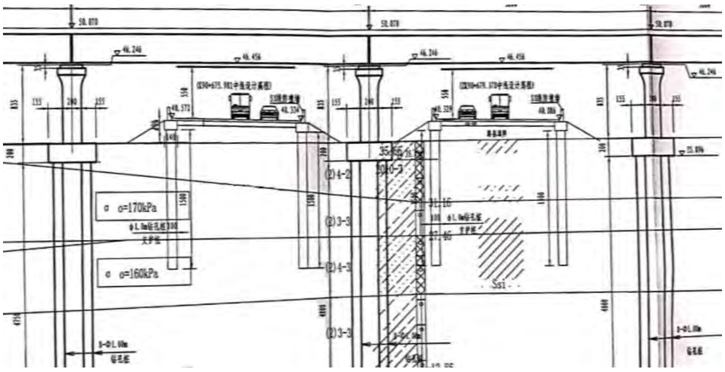

Fig. 2 Elevation of expressway and express railway

3. Anti-Collision Analysis of High-Speed Railway Piers

3.1 Vehicle Impact Force

When a new project of an expressway crosses the high-speed railway bridge, the pier of no. 709, no. 710 and no. 711 of the high-speed rail bridge pier has the possibility of being hit by the accident car. When it is hit by a car, a solid and reliable protection project should be set up according to the actual situation, such as adopting baffle, anti-impact frame, anti-collision guardrail and other measures to prevent the piers from being hit. When the protection project cannot be set, the impact force of the car on the pier must be considered. According to the calculation of article 4.4.7 of "the Basic Code for Design of Railway Bridges and Culverts", the impact force is 1000KN in the direction of driving, 500KN in the direction of transverse vehicle. It acts at 1.20m above the road surface.

3.2 Anti-Collision Analysis of Pier and Piers

The internal force F of the pier can be obtained when the pier is subjected to the collision force along the direction of 1000KN. According to the influence line loading principle, when the pier is subjected to the collision action of a vehicle with a size of P (KN), the internal force F' generated by the collision force at the pier is

$$F' = \frac{P}{1000} \times F \tag{1}$$

Then calculate the internal force of the pier according to the following formula.

$$\text{Bridge pier internal force} = \text{Combination } I \frac{P}{1000} \times F \tag{2}$$

(Combination I is the internal force value under the ultimate load capacity state obtained by the full bridge modeling.)

.1 According to the concrete strength damage calculation of pier.

According to Article 5.3.5 of "Design Specification for Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts" (JTG D62-2004), the calculation of the compressive bearing capacity of the normal section of the eccentric compression member with rectangular section shall be in accordance with the following provisions:

$$\gamma_0 N_d \le f_{cd} bx + f'_{sa} A'_s - \sigma_s A_s \tag{3}$$

$$\gamma_0 N_d e \le f_{cd} bx(h_0 - \frac{x}{2}) + f'_{cd} A'_s (h_0 - a'_s) \tag{4}$$

$$e = \eta e_0 + \frac{h}{2} - a \tag{5}$$

.2 Calculated according to the shear capacity of the pier.

When masonry components or concrete components are directly sheared, they shall be calculated according to the following formula:

$$\gamma_0 V_d \le f_{vd} A + \frac{1}{1.4} \mu_f N_k + \frac{\pi}{2} f_{yh} A_v D'/s \tag{6}$$

.3 Calculation of strength damage of pile foundation concrete.

According to Article 5.3.5 of "Design Specification for Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts" (JTG D62-2004), the calculation of the positive section compressive capacity of the eccentric compression member with circular section shall comply with the following provisions:

$$\gamma_0 N_d \le Ar^2 f_{cd} + C\rho r^2 f'_{sd} \tag{7}$$

$$\gamma_0 N_d e_0 \le Br^3 f_{cd} + D\rho g r^3 f'_{sd} \tag{8}$$

The load of the car is converted into the bottom load of the pier as shown in Table1.

According to the "Code for Design of Concrete for Bridges and Culverts and Masonry Structures" (TB10002.4-2005), the pier body should be checked for the eccentric compression stress of the concrete under the combined impact force of the pier body, and the eccentricity of the pier and the displacement of the pier top are checked. Vehicle impact force is a special load, and its load is only combined with the main force, and the corresponding increase coefficient is considered when the main force is combined with the special load.

In working condition 1: natural working condition, and working condition 2: considering the car impact caused by the heavy weight plus 20 years of heavy rain, the displacement of the pier top of the high-speed railway passenger bridge is shown in Table 2.

Table 3 represents the calculation results of the bottom section of the pier. According to the calculation of pier cross-section, the strength, eccentricity, longitudinal and transverse elastic displacement of pier pier cross-section are all within the allowable range of the specification when considering the impact force of automobile.

Table 1 Load of Piers for Intensity of Collision

Piers number	**Piers height (m)**	**High impact point (m)**	**Elevation of pier bottom (m)**	**Impact force distance from the bottom of the piers (m)**	**Section of pier bottom Fx (kN)**	**Section of pier bottom Fy (kN)**	**Section of pier bottom Mx (kN*m)**	**Section of pier bottom My (kN*m)**
709	8.0	41.746	37.896	3.85	866	499	-1921	3334
710	8.0	41.535	37.896	3.639	866	499	-1815	3151
711	8.0	41.276	37.896	3.38	866	499	-1686	2927

Table 2 Displacement of Top of 709-711 Great Piers Located at Zheng-Xu Passenger Transport Line

Piers number	Longitudinal displacement of pier top				Transverse displacement of pier top			
	Working condition 1	Working condition 2	Permissible value	Operation Influences	Working condition 1	Working condition 2	Permissible value	Operation Influences
	mm	mm	mm	mm	mm	mm	mm	mm
709	13.633	14.062	28.062	0.345	4.313	4.556	16.350	0.243
710	15.997	16.687	28.062	0.430	5.328	5.675	16.350	0.347
711	15.997	16.410	28.062	0.553	5.328	5.585	16.350	0.257

Table 3 Checked Results of Bottom Section of Piers

Piers number	Concrete compressive stress			Eccentricity of pier bottom section				Satisfied
	σmax	σmin	[σ]	e/s	[e/s]	Pier body stability coefficient minimum	Pier body stability coefficient allowable value	
	（MPa）	（MPa）	（MPa）					
709	3.314	0.000	11.800	0.488	0.700	16.620	2.000	Yes
710	2.725	0.144	11.800	0.202	0.600	16.620	2.000	Yes
711	2.725	0.144	11.800	0.202	0.600	16.620	2.000	Yes

3.3 Collision Prevention Analysis of Pier Foundation

The foundation of 409-711 of the High-speed Railway Bridge should be checked for the bearing capacity of the foundation when considering the impact force of the vehicle. The basic method also uses the above method to convert the impact force to the load behind the bottom of the pier, and this force is included as a special load. Experience shows that the pier foundation of no. 709-711 high-speed railway bridge has no special load (Automobile impact force) control in all design schemes. Therefore, under the action of car impact force, the pier foundation can meet the requirement of bearing capacity.

4. Expressway Safety Protection Measures

4.1 Protective Design of Protective Wall

Through the above analysis on the anti-collision strength of bridge pier, the foundation of bridge pier can meet the requirement of bearing capacity under the action of vehicle impact force. However, for the sake of safety, the anti-collision wall is set on both sides of the lower section of high-speed rail bridge, which can effectively protect the high-speed rail pier from car impact

Table IV lists the anti-collision levels of bridge guardrails specified in the "Code for Design of Highway Traffic Safety Facilities" (JTG D81). Ø1.0m borehole protective piles are set on the shoulder of both sides of the roadbed adjacent to the railway bridge pier at the junction of the public railway. The piles are 1.2m or 1.5m apart, and the pile length is 15m. The pile body is made of C50 concrete. The crown of the pile is connected with crown and beam. The crown beam is 1.4m wide and 1.0m high. It is cast in C45 concrete. According to the "Code for Design of Highway Traffic Safety Facilities" (JTG D81), SS-level anti-collision guardrails are installed on the crown beam.

A highway is divided into two sections from the pier of no. 709~710 and no. 710~711 of the high-speed railway bridge. SS-level anti-collision wall is set on both sides of bridge pier no. 709~711, which can effectively prevent runaway vehicles from striking high-speed railway bridge pier outside the outlet road, as shown in Fig. 3 and Fig. 4.

Table 4 Checked Results of Bottom Section of Piers

Highway grade	Design spee （km/h）	The level of traffic accidents that may occur when a vehicle leaves the highway or enters the opposite lane	
		Major accident or main major accident	Second major accident or second main major accident
expressway	120	SB、SBm	SS
	100、80		SA、SAm
First highway	60	A、Am	SB、SBm
Secondary highway	80、60	A	SB
Third highway	40、30	B	A
Fourth highway	20		

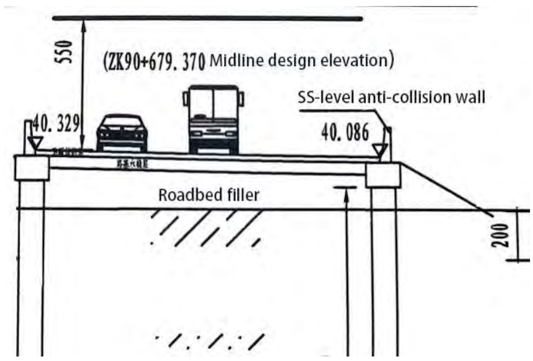

Fig. 3 Anti-collision wall of expressway

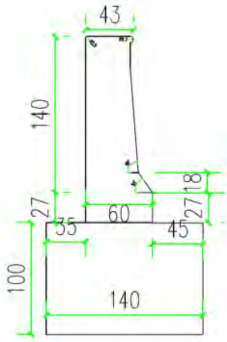

Fig. 4 Cross-section diagram of anti-collision

4.2 Other Protective Designs

.1 Necessary speed limit, height limit and lane separation signs shall be set for the lower railway bridge section, and the distance between vehicles shall be confirmed as the mark line and the color deceleration belt mark (as shown in Fig. 5). Meanwhile, reflective warning marks shall be set for both sides of bridge pier no. 709~711 and the side of beam.

.2 The expressway passes through the high-speed rail section of the expressway, and all vehicles are prohibited from crossing the high-speed railway section. It is forbidden for large vehicles to overtake in the high-speed railway section.

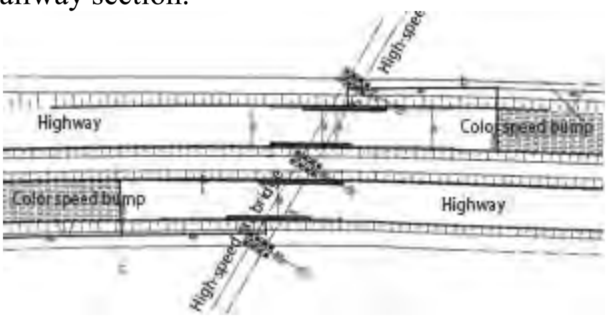

Fig. 5 The site of speed hump in Zheng-Xu passenger traffic section

5. Conclusion

1 Through theoretical analysis and calculation, the pier of no. 709-711 high-speed railway bridge can meet the safety requirements under the action of vehicle impact force.

2 The section of the high-speed rail bridge under the expressway is conducive to the safety of the bridge by setting SS level anti-collision wall (the direction of the incoming vehicle is not less than 30m), lane marking (the solid line of the lane line), speed limit signs, color speed reduction belts and other safety facilities.

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