

Study on Safety Distance between Expressway Tunnel and Interchange under Multi Tunnel

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Abstract: The net distance between the Xuatangwan interchange and the Huangshi tunnel exit of the Kaiyun expressway (Jiangkou-Yunyang-Longgang section) is used as an example in this paper. This paper analyses the problems in the safety distance between expressway tunnel and interchange under multi tunnel, and proposes safety distance measures between expressway tunnel and interchange under multi tunnel, based on the current safety distance standard between expressway tunnel and interchange under multi tunnel.

Keywords: Expressway tunnel; Interchange; Safety distance; Improvement measures

Online publication: January 18, 2022

1. Introduction

Although China's regulations on highway design do not put forward clear and specific parametric design requirements for the distance between tunnel and interchange, they generally adopt the design specifications of exit guide signs as requirements. If it cannot be met, the setting can be applied to solve the warning display scheme, but the minimum value of safety distance when conditions are limited is not provided. Due to the unclear relevant regulations, road designers face many puzzles, which indirectly leads to the short design distance between many tunnels and overpasses, which is not conducive to the safe driving of vehicles^[1]. The number of lanes outside the tunnel must vary at least 10 seconds from the tunnel entrance, according to the tunnel regulation. As a result, vehicles outside the tunnel must be able to change lanes safely in less than 10 seconds, and the distance between the tunnel and the interchange must at least match this standard^[2]. At the same time, this paper focuses on the standard of safety distance between expressway tunnel and interchange under multi tunnel because research on the safety distance between tunnel and interchange has major theoretical significance in China's road engineering design.

2. Study on safety distance between expressway tunnel and interchange under multiple tunnels

Kaizhou-Yunyang expressway (Jiangkou-Yunyang-Longgang section) is a part of the newly added encryption network planned for Chongqing expressway to realize "free inside, connected outside and interconnection." After the completion of the project, to the south, the expressway interconnection between Yunyang and Lichuan and Enshi will be implemented. To the north, Kaiyunwu expressway can be connected with Yinbai expressway to form a new northbound channel and improve the overall traffic efficiency of the road network. At the same time, it will open up a large vertical channel for Yunyang. This

will improve its regional advantages, and boost the development of poverty alleviation and rural revitalization in Yunyang.

3. Analysis of factors affecting the spacing between tunnel and interchange

3.1. Speed

Speed is one of the most important factors. On one hand, the higher the speed, the longer it takes to complete lane change or deceleration. On the other hand, the higher the speed, the more easily the driver's psychology is stimulated and affected, which increases the possibility of causing driver tension and anxiety. As a result, the response time for lane changes or deceleration behavior increases, influencing the distance to the vehicle indirectly. Besides that, vehicle speed has a significant impact on the interchange distance between Huangshi tunnel and Xuetaoguan junction interchange. According to the study perspective, several definitions of vehicle speed exist. Design speed refers to the maximum speed that can be maintained only under the control of road design characteristics under good road, traffic, weather, and other conditions. Driving speed refers to the maximum speed that can be maintained only under the control of road design characteristics under good road, traffic, weather, and other conditions.

Generally, it refers to the speed limit of local design sections. The driving speed refers to the statistical value of the representative vehicle speed observed at the characteristic points of the road section when the vehicles are unobstructed and the weather conditions are good. The driving speed is a dynamic speed value, and 85% of the driving speed is commonly used as the alternative value of the driving speed at home and abroad. The estimated speed is the highest "safe" speed that the driver can expect under certain road conditions and driving environment. In this case, the vehicle is not or almost not affected by other vehicles while driving. Speed limit refers to the management speed of vehicles on the road set by the road traffic administration in order to completely show road traffic efficiency while ensuring vehicle safety. Several popular expressway design speed criteria are primarily concerned while assessing the safety distance between Huangshi tunnel and Xuetaoguan junction interchange: 120 km/h, 100 km/h, and 80 km/h^[3]. When investigating the distance, however, it is necessary to examine the connection between the design speed, driving speed, predicted speed, and speed limit in order to pick the appropriate speed for the study.

3.2. Response characteristics of the driver

In the process of driving, the driver's response to the action continuously according to the driving environment (including people, vehicles, road conditions, weather, etc.) is called the driver's response. The driver's response is divided into simple responses and complex responses. Simple response generally means that the stimulus source to stimulate the driver is relatively simple. The driver can respond directly without too much thinking and judgment, which is action. Complex response generally means that the driver needs to think and judge to a certain extent in order to receive complex and multifaceted stimuli and make corresponding operational response. For example, the driver's lane change behavior will cause complex reactions, because the driver's lane change will consider a variety of factors, including vehicle speed, traffic volume, road conditions, traffic sign information and traffic organization mode. The standard to measure the driver's reaction characteristics can be expressed as reaction time^[4]. At the same time, the length of reaction time is also related to the driver's physical condition, psychological state, surrounding environment and other factors. For example, the reaction time of people of different ages is different. The reaction time of women is slightly longer than that of men, and the reaction speed becomes slower when excited. Therefore, the driver's response characteristics have a great impact on driving safety. The distance design between Huangshi tunnel and Xuetaoguan hub interchange should take into account the response characteristics of most people and try to meet the needs of most drivers for safe driving.

3.3. Traffic flow

The traffic demand is predicted before the site selection, design and construction of Huangshi tunnel and Xuetaogwan junction interchange, and the road parameters are reasonably designed by estimating the traffic flow after the completion and operation of the project. The design length of Huangshi tunnel and Xuetaogwan junction interchange is also affected by traffic volume, because the ratio of traffic volume to road length (traffic density) can be used as the measurement standard of traffic volume ^[5]. After predicting the future traffic volume of the road through road congestion and vehicle freedom index, if the design section is too short, it will cause excessive traffic density and congestion, while if the design section is too long, it will increase the project construction and operation costs. Therefore, if the section length between Huangshi tunnel and Xuetaogwan junction interchange is reasonably designed according to the traffic flow, the traffic flow in the section can be evenly distributed and effectively buffer the traffic flow ^[6].

3.4. Setting of traffic signs

If the driver does not find the warning sign of elevated off ramp in time during driving, he will miss the ramp and can only go to the next exit on the closed expressway or turn around at the toll station. Or if the driver does not find the exit ramp warning sign, he may find the exit when approaching the ramp and forcibly change lanes to catch the exit ramp, which is extremely likely to cause traffic accidents. Therefore, the export guide sign should be set up before the exit of the Xuetaogwan junction interchange, which reminds drivers to adjust ahead of time, so as to predict the location of the next exit.

4. Spacing setting measures between expressway tunnel and interchange

4.1. Measures for handling traffic safety facilities

An overpass exit warning sign shall be set at an appropriate position in front of the entrance of Huangshi tunnel to remind drivers to get close to the overpass exit and remind vehicles leaving the main road to change lanes in advance. The communication vehicles in the left lane can change lanes to the right lane by placing a solid line on the right side of the dotted line on the left side of a specified stretch of the tunnel. The length of the left dotted line and the right solid line is mostly controlled by the distance travelled by a vehicle while waiting in the outside lane for insertion, as well as the distance travelled when modifying speed and position ^[7]. The distance while changing is determined by the distance that may be inserted and the reaction time when the vehicle changes lanes. Xuetaogwan junction interchange, particularly ramp A1, will be equipped with colour anti-skid vibration signs at the entry and departure sections of Huangshi tunnel (or deceleration vibration signs).

While drawing the driver's attention, the marking also serves as an anti-skid and deceleration feature, allowing the car to lower speed and safely enter and depart the tunnel. To eliminate the hidden threat of traffic accidents caused by Huangshi tunnel's inaccurate up and down speed limits, complete speed limit signs will be installed in the Xuetaogwan junction interchange region. Perfect traffic guidance signs must be organised in the Xuetaogwan transfer area (with monitoring facilities) to improve the consistency and accuracy of sign setting, advance notice, and multiple notices at an appropriate distance before the information point (or accident point), so that drivers and passengers can accurately and timely understand traffic information and road condition information and achieve the goal of active guidance. To lessen the loss of life and property caused by traffic accidents, it is vital to strengthen the level of protection provided by railings in the region. A guiding anti-collision pad must be installed at the triangular end of the main line outlet. A deceleration indication line shall be set 300m before the starting point of the extended Lane transition section in the tunnel and extended to the exit. At the starting point of the transition from the tunnel interchange exit to the deceleration lane, 2km, 1km, 500m and 0m exit guidance signs shall be installed, and internal luminous photoelectric signs shall be adopted to ensure the safety of the tunnel. The export

notification symbol matches the ground export notification text, as shown in **Figure 1**.

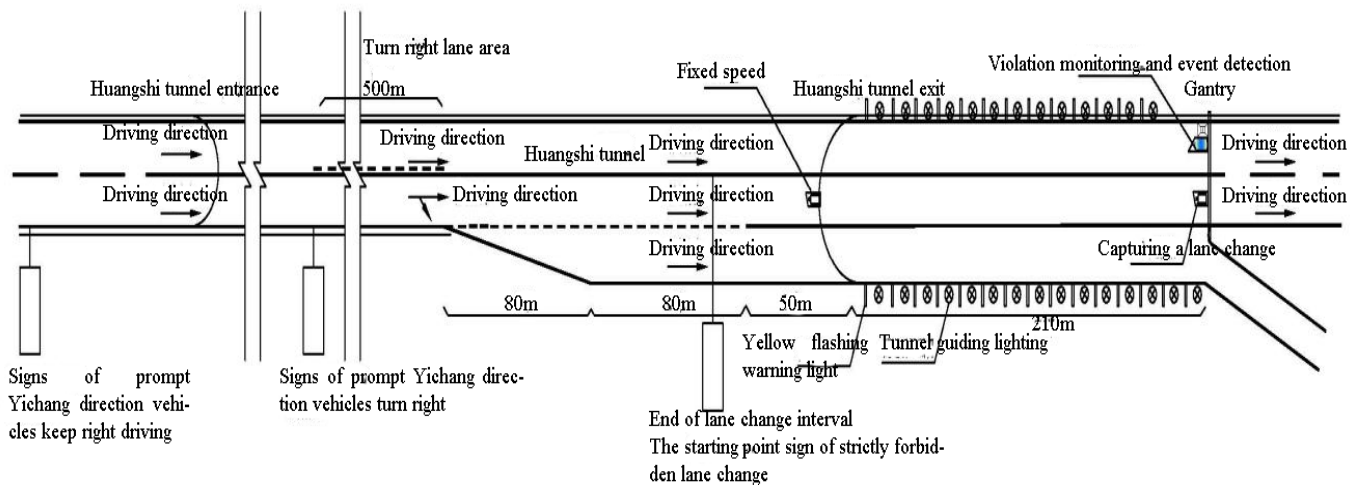


Figure 1. Layout of traffic facilities

4.2. Disposal measures for tunnel structures

The tunnel structure treatment measures consider extending the deceleration lane into the tunnel and widening the tunnel entrance. The length of the extension line is mainly determined according to the lane change distance and immutable lane distance of the vehicle. The lane change distance of the vehicle mainly includes the right turn distance determined by the driver and the lateral driving distance of the vehicle [8]. The deceleration lane is extended by comprehensively considering the specification requirements of the deceleration lane, the distance of the lane-changing vehicle, the distance between the deceleration lanes, and the constant lane 50m away from the opening.

4.3. Traffic monitoring measures

The first is the local speed limit. An inter-district speed limit is installed at Xuatangwan junction interchange to ensure that vehicles in the area travel at the required speed and reduce the risk of accidents. The second is the violation detection of the accident risk department. The traffic accidents in this area are reduced by installing constant speed measurement and violation monitoring facilities at the exit of Huangshi tunnel. The take off ramp intersection of Xuatangwan junction interchange is supplemented by lane change violation monitoring facilities to capture illegal lane change vehicles and reduce traffic accidents caused by random lane change.

4.3.1. Accident detection

By installing an accident detection surveillance camera at the junction of the Xuatangwan interchange exit ramp, traffic accidents in the area can be identified in time, and treatment and rescue can be carried out in time.

4.3.2. Danger warning

In order to improve drivers' safety awareness and reduce potential safety hazards, yellow lights and other warning facilities are installed between Xuatangwan interchange exit and Huangshi tunnel exit in cooperation with traffic safety facilities. The information prompt is improved, combined with traffic signs, and portal signs are set at the interchange entrance of the hub to provide complete traffic information for drivers.

4.3.3. Disposal of tunnel

Lights by strengthening the lighting of the tunnel entrance section and the lighting of the tunnel lane change section, the brightness of the light inside and outside the tunnel is gradually changed to improve the safety of tunnel lane change. The illumination brightness and layout length of the guiding section of Huangshi tunnel should be appropriately increased (the layout length should be from the exit of Huangshi tunnel to the exit ramp of Xuatangwan interchange) to provide the best driving conditions for drivers. When driving at night, the traffic accident time is reduced due to poor vision at the exit of Huangshi tunnel.

According to the specification, we can formulate the lighting enhancement scheme at the exit of Huangshi tunnel, and appropriately increase the parameter value to reduce the traffic accidents caused by the black hole effect.

5. Conclusions

It is necessary to ensure the safe operation of Xuatangwan hub interchange and Huangshi tunnel of Kaiyun Expressway (Jiangkou-Yunyang-Longgang section), give full play to the safe and smooth operation of the expressway, and conduct a safety assessment on the sections closely connected with the tunnel interchange. Starting with engineering and management technology, we will carry out comprehensive safety improvement of expressway tunnels, strengthen monitoring and management, improve safety facilities and other measures to ensure the safety of Kaiyun expressway.

Disclosure statement

The author declares no conflict of interest.

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