

Research on the Same Direction Separation and Common Board Problem of Freeways Based on Tolerance System Design

Wang Hui

Jiaoke Transport Consultants LTD, Beijing, 100191, China

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Abstract: This article takes the renovation and expansion project of the Jieyang Xinheng to Meizhou Shejiang section of the Shankun Expressway as the background. Through a systematic analysis and research on the problem of common separation boards in the same direction of the expressway, the main problems of common separation boards in the same direction are summarized. Through analysis and summary, the key points of tolerance system design are proposed to effectively ensure operational safety and provide reference for similar problems in subsequent projects.

1. Introduction

With the basic improvement of the national highway network, the implementation of the new development concept and the concept of resource conservation and strengthening, the expiration of fees, the continuous increase of car ownership, traffic congestion, service level saturation and other factors, the increasing number of renovation and expansion projects has brought about many new problems that urgently need to be solved. For example, there is currently less research on the same direction separation and common board problem in renovation and expansion projects both domestically and internationally. However, practical engineering application cases are gradually increasing. It is of great significance to ensure the safe and smooth operation of vehicles through tolerant system design.

2. The problem of separation and common board on highways in the same direction

The problem of simultaneous separation and sharing of boards on highways refers to the situation where, due to factors such as controlled urbanization, bridges, tunnels, and interconnectivity, there are no conditions for complete separation of lanes in the same direction and the establishment of an integrated roadbed, resulting in the formation of a unidirectional $m \times n$ multi lane joint board section on the half width of the road, and the formation of simultaneous separation and sharing of boards through safety facilities. In this operating condition, the same lane is artificially divided into two parts by safety facilities on a single slab, which is different from the conventional integrated and separated subgrades, forming an unconventional section with the same direction separated and shared slabs. This makes it difficult for drivers to recognize the road conditions, worry about wrong driving, and

may cause a series of problems such as speed reduction and uneven traffic flow on the section. The overall traffic capacity is reduced, combined with complex traffic conditions such as being close to interchanges or tunnels, making it a sensitive section for operational safety. Tolerance system design is an important way to solve problems and ensure operational safety.

The "tolerance" of improving highways refers to not forcing drivers to change their state to apply the road, not demanding drivers to make absolutely correct judgments, and responding quickly to compensate for accident hazards caused by road factors. Even if some drivers occasionally make operational errors, they can still maintain certain safe driving conditions, play a role in eliminating or mitigating dangers, avoid traffic accidents or reduce the degree of damage caused by traffic accidents.^[1]

For example, the Shankun Expressway Jieyang Xinheng Meizhou Shejiang section renovation and expansion project (hereinafter referred to as the Shanmei renovation and expansion project) is the first mountainous and hilly area expressway renovation and expansion project in Guangdong Province. There are many controlled factors along the route and the technology is complex. After comprehensive comparison and demonstration, multiple same direction separation and common plate sections are adopted, among which the Yuhu Interchange Rongjiang North River section and the Fengshun Interchange Tangkeng Tunnel section are more typical.

Due to factors such as severe urbanization around the Yuhu Interchange, flood control and navigation of the Rongjiang North River, and the reuse and maintenance of the existing Beihe Bridge, the Yuhu Interchange in the Rongjiang North River section is controlled. The scope of the Yuhu Interchange adopts a plan of widening both sides and then constructing a single side separation to cross the Rongjiang North River. That is, the existing integrated two-way four lane section is changed to a 2+2 separation section in the same direction, and a new one-way four lane section is constructed to expand the expressway from four lanes to eight lanes^[2]. The starting point of the same direction separation and common plate section is 3271m away from the diversion end of Yuhu Interchange, and the lane line adopts a linear continuous design, forming a 650m oncoming diversion triangle area+1788m same direction separation and common plate section+696m oncoming merging triangle area+97m operating road conditions Figure 1. The second and third lanes are prohibited from changing lanes within this section; Advance guidance to the outer two lanes through strengthened signs and signs for the next interchange; Preserve the hard isolation of the same direction divider of the Beihe Bridge to prevent lane changes, and splice all other sections. The same direction divider adopts soft isolation; Improve safety measures such as vibration markings, night light warnings, and restricted areas, and set up collision pads and other safety measures in the diversion triangle area for oncoming vehicles^[2].

The key control of this section of the plan is to cross the Rongjiang North River on the existing Beihe Bridge, with controlled flood control and navigation Figure 2. It adopts a staggered layout of $8 \times 30\text{m}$ continuous T-beams and is located on a 2% super high horizontal curve. The upper structure of the bridge will have longitudinal joints due to deformation incompatibility, resulting in prominent maintenance problems and poor durability of the bridge; Due to the height difference of 4cm caused by the superelevation of the bridge, there is a safety risk of lane changing during operation. Therefore, the existing bridge and the same directional partition guardrail are maintained, and the same directional 2+2 separation and common board scheme is adopted. The old road is fully utilized and safety facilities are strengthened for systematic and tolerant design^[2].



Figure 1: Overall Plan of Yuhu Interchange to Rongjiang North River Section

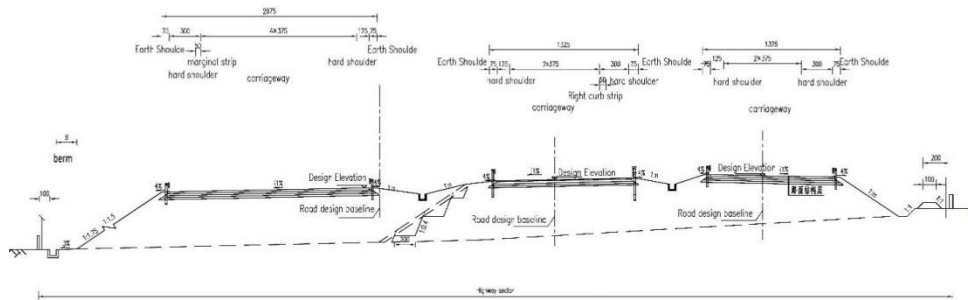


Figure 2: Standard Cross Section of Yuhu Interchange to Rongjiang North River Section

The Fengshun Interchange~Tangkeng Tunnel section is controlled by factors such as severe urbanization around the Fengshun Interchange and the reuse of the existing Tangkeng Tunnel. After widening on both sides of the Fengshun Interchange, a single side separation and construction of a one-way four lane tunnel scheme will be adopted, that is, the existing separation type two-way four lane tunnel will be changed to a one-way 22 separation type tunnel for use, and then a one-way four lane tunnel will be added to expand the expressway from four lanes to eight lanes^[2]. This section is a separated section in the same direction. Due to the fact that the separated tunnel is easier to identify than the bridge, drivers are more likely to recognize the road conditions. However, there are also issues with short weaving sections and triangular areas for oncoming traffic in the interchange area. The second and third lane access roads are prohibited by drawing lines, and anti-collision mats are installed to improve relevant safety facilities to ensure operational safety Figure 3.



Figure 3: Overall Plan of Fengshun Interchange to Tangkeng Tunnel Section

The problem of same direction separation and common board mainly exists in special bridges that cannot be spliced in renovation and expansion projects, old sections of double arch tunnels or main and auxiliary roads of municipal roads, such as Fokai Expressway, Guangqing Expressway,

Guangshen Expressway, etc. Through research on cases of same direction separation and common board in renovation and expansion projects, it was found that the main problem is the high accident rate of collision with same direction separation guardrails in the triangular area of short oncoming vehicles in the weaving section, which needs to be eliminated through tolerance system design. Summarize the main issues of co directional separation and common board:

(1)The road section with the same direction separation and common board is an unconventional road condition, which makes it difficult for drivers to accurately identify the road conditions, and there is no coordination between people and the road.

(2)There are conflicting points in the oncoming and diverging triangle areas of the same direction separation and common board section, and they cannot change lanes with each other, resulting in reduced functional impairment.

(3)The traffic volume on the section is uneven, and drivers are worried about making mistakes. Generally, the traffic volume on the outer side is greater than that on the inner side, resulting in a reduction in traffic capacity.

(4)If it is close to the tunnel or interchange site, the weaving section is short, the usage function will be reduced, and the traffic organization will be complex, making it a sensitive section for operational safety.

The main factors affecting the operational safety of the same direction separation and common board problem include drivers, highway system design, design speed, and traffic composition. The higher the design speed, the more prominent the problem is, and the larger the proportion of trucks, the more prominent the problem is. However, a well-designed highway system can effectively ensure operational safety.

The same direction separation and common board has strong adaptability, land use and engineering scale in Jieyang, which can effectively avoid large-scale demolition and construction, facilitate transportation and increase the use of old materials. Therefore, it can be well applied to the renovation and expansion of municipal road main and auxiliary road projects.

3. Key points in the design of tolerance system for the same direction separation and common plate section of highways

Through the above analysis, it is found that the problem of co directional separation and common board is mainly a coordination problem between people and roads. By adopting a scientific, comprehensive, and reasonable tolerance system design, it is easy for drivers to accurately identify the co directional separation road conditions, which can effectively ensure operational safety and reduce project scale. Through the analysis of the problem of common plate separation in the same direction, the design points of the tolerance system of common plate section in the same direction are summarized:

(1)Ensuring lane continuity design is the foundation of systematic design. The planar design should be balanced and continuous, and the longitudinal design should meet visual requirements. The cross-sectional superelevation should not exceed 3%, and the combination of horizontal and vertical should be reasonable.

Due to the problem of common separation and separation in the same direction, the mileage is generally short and not coordinated with the surrounding environment. Drivers should not recognize the road conditions and strictly ensure the design of lane continuity; The graphic design and the alignment of the front and rear road sections should be balanced and continuous, avoiding adverse combinations such as long downhills and small radii; The longitudinal plane should meet visual requirements and be easy to identify the same directional divider; The height should not be too high, providing a fault tolerance rate for trucks.

The Yuhu Interchange~Rongjiang North River section adopts a centerline and the second and third lanes for separate plane division design to ensure lane continuity, and uses the original centerline for longitudinal design to ensure that the longitudinal and transverse sections are completely aligned. The original horizontal curves of the single and double side transition sections are changed to egg shaped curves to connect, ensuring a good combination of horizontal and longitudinal sections.^[2]

(2)The traffic diversion triangle area should have good visual conditions, and the length should meet the parking sight distance requirements. In special cases, the length should not be less than 3 seconds, which is an important safety guarantee measure for tolerant design.

The length of the oncoming traffic diversion triangle refers to the distance from the starting point of the same direction separation common plate to the hard isolation end of the same direction separation strip, representing the length of the road section that the driver focuses on identifying. The triangle area for oncoming traffic diversion is a key area for drivers to recognize road conditions. Reasonable recognition time should be given to drivers, and tolerance design should be moderately increased. It is advisable to control the design according to the stopping sight distance. Especially controlled road sections can be controlled according to a length of 3 seconds, and guidance from markings, signs, and signs should be strengthened.

The section from Yuhu Interchange to Rongjiang North River only adopts hard isolation with the same directional separation strip for the North River Bridge section, while the rest adopts soft isolation. The length of the diversion triangle in the oncoming direction is 800m, combined with safety facilities, ensuring that the driver has a sufficiently long identification section, ensuring operational safety, and increasing tolerance design.^[2]

(3)In the same direction separation and common board section, if the horizontal spacing between m+n lanes is less than 3m, according to the length of the same direction separation and common board section, reasonable setting of the same direction separation and conversion strip or opening of the same direction separation and conversion strip is required to ensure lane change and enhance usage function.

(4)Based on factors such as the relationship between the characteristics of the adjacent reverse running half width roadbed and the length of the same direction separation common plate, the cross-sectional form is comprehensively determined. In general, if the longitudinal plane of adjacent reverse half width roadbeds is not controlled, they can form an integral roadbed with the same direction separated common slab roadbeds. The central divider is used to connect and form a common slab roadbed, which can effectively save land; If the longitudinal plane of the adjacent reverse half width roadbed is controlled and forms a separated roadbed with the same direction separation and common board, it should be emphasized whether a left hard shoulder is set on the inner side of the same direction separation and common board roadbed based on the length of the common board. Generally, if the length of the same direction separation board is greater than 500m, a left hard shoulder should be set up for emergency parking of vehicles to prevent secondary accidents.

The section from Yuhu Interchange to Rongjiang North River is 3271m long due to separation in the same direction, so a 2.5m left hard shoulder is set on the inner two lanes to ensure operational safety.^[2]

(5)Except for sections where structures cannot be spliced, hard isolation should be used for the same directional separation strip. For other sections, the difference in left and right transverse slopes should not exceed 4%. Soft isolation should be used, and the design of safety facilities for the transition section between soft and hard isolation should be strengthened, such as setting collision pads and actively setting up night warning facilities such as vibration markings and reflective signs.

The hard isolation of the same directional divider is used in sections with safety hazards when changing lanes, while soft isolation should be used for the rest to increase tolerance design. The section from Yuhu Interchange to Rongjiang North River, except for the North River Bridge section

which adopts hard isolation, has undergone overall stitching design and gradually adjusted to a consistent cross slope. During this period, soft isolation is set up to prevent lane changes.^[2]

(6) Signs and signs should provide advance warning and guidance to enable drivers to accurately identify the road conditions ahead and make reasonable lane changes.

For unconventional road sections, signs and signs should be provided in advance to guide and improve safety facility design to prevent accidental travel.

(7) The road section with the same direction separation and common board is wider than the overall roadbed, and the drainage of the same direction separation strip and road surface is strengthened.

Due to the fact that the same direction separation and common board section generally occurs on highways with eight lanes or more in both directions, and the road width is relatively wide, road drainage is an important factor affecting operational safety. In addition, the same direction separation strip generally has no cross slope. Therefore, in soft isolation sections, the same direction separation strip cross slope transformation should be carried out to meet drainage needs, and drainage road surfaces should be used if necessary.

(8) For the problem of co directional separation and sharing of boards with more than eight lanes in both directions, it is necessary to reasonably divide $m+n$ lanes based on traffic volume characteristics and interchange turning traffic volume, and m or n should not be less than 2 lanes.

Generally, the proportion of trucks is relatively large, and in principle, the number of outer lanes is greater than the number of inner lanes. The problem of separation and sharing of boards in the same direction should be considered comprehensively for sections that are close to interchanges, and the number of outer lanes should be reasonably determined based on the traffic volume requirements of up and down interchanges. If necessary, auxiliary lanes can be added.

(9) Further strengthening of operational management can be achieved through measures such as smart highways.

The problem of co directional separation and common board is caused by special control factors encountered in civil engineering. If it is to be completely eliminated, it will require a significant cost, which does not meet the requirements of the new development concept of "innovation, coordination, green, openness, and sharing". Soft measures such as smart highway forecasts and guidance can achieve twice the result with half the effort.

The problem of same direction separation and common board is highly targeted, and the actual situation of each project may vary. It is necessary to carry out multi-disciplinary linkage design based on the characteristics of the project and road section, conduct system design for the problem, increase road fault tolerance design, and ensure vehicle operation safety.

4. Conclusion

With the increasing number of renovation and expansion projects, the problem of co directional separation and common slab will continue to increase, especially when encountering special bridges that cannot be spliced or arched tunnel sections that cross rivers, seas, or lakes. Through analysis and research, adopting a tolerant system design can effectively solve the problems of people and roads, effectively eliminate operational safety hazards, and have good social benefits.

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