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Research on Common Problems and Countermeasures of Highway Interchange Design

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Abstract: *The construction of interchanges is not only the need of local social and economic development, but also the main means to promote the development of regional cities. However, in the engineering design, it is necessary to comprehensively consider the interconnection layout of the entire highway, interconnection distance, the horizontal and vertical indicators of the main lines in the interconnection, and the design of interconnection schemes. To compare and analyze the scheme design to ensure the smooth construction of the interchange, the purpose is to promote the development of the local economy and society as much as possible. Provide a superior external transportation environment for the local government. Starting from the overall design requirements of road interchanges, based on the basis of the intercommunication distance and shape characteristics, this paper makes a theoretical analysis of the problems that often occur in the design process and their solutions, hoping to provide reference for similar projects. Significance.*

Keywords: *Interchange, Design Problem, Countermeasure Research, Highway Network Construction*

1. Introduction

Since the emergence of highway interchange, people's main expectation has been to realize the connection between roads, minimize the number of ramps, and realize the interchange design of all-round interchange with the least cost, the lowest floor area and the least number of ramps. This has always been the main goal of designers. In recent years, the number of vehicles on the road has increased explosively, and the safety and capacity of overpasses designed and built in the past are becoming more and more obvious. Therefore, only carrying out simple design work and promoting simple connection is not enough to meet the needs of rapid social development. It also needs to consider financial, social, environmental and other factors, and complete the design of interchange with the focus of enhancing operation safety, improving traffic capacity, coordinating natural environment and displaying design concept.

2. Design Elements of Interchange

2.1. Interworking Spacing

In terms of interchange spacing, in mountainous areas, the distance between expressway and tunnel is relatively small, while in dense urban expressway network, the distance between New Interchange and original interchange is relatively small [1]. As the ratio of bridge to tunnel on mountain road is quite high, the selection of intersection is based on the intersection between mountain and road, there will be problems such as interchange and too close distance between tunnel entrance and exit. In the preliminary design stage, this should be considered to be included in the road planning [2]. When it is unavoidable to be affected by the site geology and other conditions, the interval between the tunnel exit terminal and the front main line exit, as well as the interval between the main line entrance and exit and the front tunnel entrance shall also meet the requirements of setting warning signs, so that the driver can make more accurate judgment, and it is also an appropriate safety measure for the organization, management and operation of transportation [3]. If the reasonable spacing between nodes cannot be achieved due to the influence of pavement structure and terrain, the clear distance value (the straight-line length of adjacent entrances and exits) can be checked and calculated according to the design speed of the main line. If the given minimum spacing is reached, the flag can be set separately.

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In addition, it should be connected to the auxiliary lane or ramp to form a compound lane, and complete exit signs should be set at the same time [4].

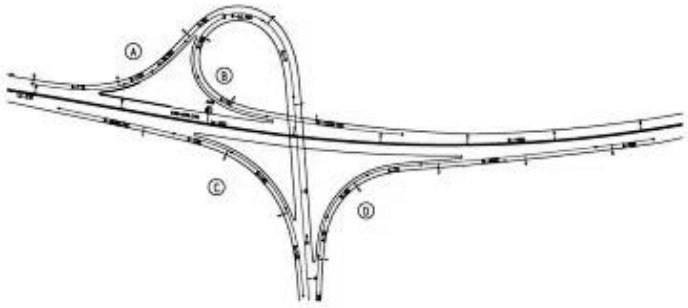

Figure 1: Interchange plane alignment

2.2. Interworking Form

In the overall design of high-speed crossing, the single (double) directional horn scheme has simple shape, stable curve, relatively small quantities and wide coverage, and the toll station is also convenient for construction [5]. In the actual construction, if the geological conditions are complex and the subgrade excavation range is large, this form scheme cannot be used. In the design of interchange, it is suggested to adjust measures to local conditions, properly arrange the road slope, and coordinate with the pavement shape and local natural landscape, so as to avoid or reduce the impact on the natural environment as far as possible [6]. In terms of terrain and natural traffic, reduce the use of roads as much as possible. For example, pear shaped design is a good choice, because although the number of overpasses has increased, the alignment of the main line and plane with the longitudinal plane of the intersection in the design position may more effectively reflect the design advantages [7]. According to the terrain, the characteristics and conditions of the construction site, and according to the amount and direction of traffic flow, the variant horn type and diamond scheme can be flexibly selected. Because of the advantages of small space and simple structure, rhombohedral interchange is widely used in engineering design, but the important disadvantage is that it is unable to design a toll station. Some cloverleaf and cloverleaf interchanges are generally used in the case of small left-hand traffic flow or large traffic flow on main lines. Its main advantage is that it is relatively simple in effect and cheap in cost. At the same time, it also has a very gentle curve, which can easily cooperate with the external environment to create a beautiful street environment. Due to the large floor area of the left turn roundabout layout, the high speed will also affect the steering, thus affecting the economic benefits of its operation. The number of toll stations also needs to be increased, which greatly increases the operating cost.

Table 1: Design linear index of main line of highway interchange

Design speed/(km/h)	Minimum circular curve radius (minimum) /M	Minimum radius of circular curve (general value) /M
60	350	500
80	700	1100
100	1000	1500
120	1500	2000

Table 2: highway interchange ramp parameters and linear indicators

Ramp design speed/(km/h)	Cyclotron parameters/M	Gyrotron length/M	Minimum radius of circular curve (general value)/M	Minimum radius of circular curve (limit value)/M
30	20	25	30	25
35	30	30	40	35
40	35	35	60	50
50	50	40	100	80
60	70	50	150	120
70	100	60	210	175
80	140	70	280	230

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3. Key Elements of Highway Interchange Design

3.1. Design Speed Limit - Upper and Lower Separation

In bad weather, due to the different conditions of urban roads, the driving lane and speed will be limited. Therefore, in order to improve the reliability of vehicle speed per hour, vehicle designers must define several elements of geometric speed curve, namely apparent height, vehicle speed, etc., to determine their balance in the process of vehicle driving. At present, the maximum speed of many roads in the world is based on the design speed of urban roads and highways. The slope connection mode is mainly adopted between the central road and the main line. In order to limit the height of the slope, most highway interchange designers choose the design mode of up-down partition [8]. The design method not only ensures that the car can drive on the road in the city, but also ensures the traffic location of the interchange, but also reduces the time and resources, thus reducing the pollution, effectively maintaining the natural environment and reducing the possibility of traffic congestion. For sidewalks, more stringent road design will help to improve the management level of the whole city. Therefore, on the urban highway directly connected to the airport, the design and management personnel should pay attention to the vehicle speed on the highway, monitor and manage the total amount and density of vehicles in real time, and ensure that the bridge road monitoring device is equipped and set in time [9]. To drive safely on urban roads.

3.2. Diverse Service Objects-Unify Driving Standards and Open Up a Second Lane

Urban roads include intersections, highways and sidewalks. Among them, due to its high speed and strong traffic capacity, expressways can be built on a large scale between big cities or mega cities. The trunk road is the backbone of the public transport network. It not only connects the passenger transport and bus service center, but also connects large service buildings such as airports, railway stations and buildings, and plays many important functions. In order to ensure the driving speed of vehicles on the main road and reduce the risk of large-scale traffic accidents, designers should not set up too many vehicle intersections and sidewalks along the main road. The second lane has the function of perfect public transport service facilities, which can help the main road bear the necessary road traffic pressure. Setting some practical equipment on its side or creating a parking space with a reasonable scheme [10] can also help solve the problem. The branch road is the link between the village and the main road, and its main purpose is to provide services and transportation for cars on the main road. For cars, it can be divided into driving on urban roads and highways. It can be divided into cars, trucks and Van trucks on the road. In China's cities, it can be divided into ordinary cars and ordinary vehicles. The standards of vehicles under these two road conditions are the same in terms of vehicle and volume. Therefore, although there are slight differences between large and small vehicles, they can run on the same two roads, and there is no need to adopt different driving standards in the field of vehicles, so they should be unified.

3.3. Safety Issues - Set a Moderate Driving Section and Adopt a Single Exit on the Left

As a large-scale structure, the main purpose of the interchange channel is to carry out the function of road transfer. Due to the relatively small space height of the building, the traffic density coefficient is very high, and the alignment is usually complex It's where many accidents happen. If the project is constrained by various factors such as natural environment and region, or the comprehensive design is wrong, it will affect the traffic capacity of the highway and even cause accidents. Generally, the interconnection intersection should be set at the intersection where the road is relatively stable and the line of sight can be wide, so as to facilitate the identification of drivers [11]. When the workload of hub interconnection and exchange is small, the left single exit shall also be selected, and an appropriate spacing shall be reserved in front of the interchange. The set warning signal should also keep the amount of information as simple as possible, so that it is easier for the driver to identify. For the ramp of the main road, a designated middle lane area must be designated so that the driver can adjust to the expressway to the lane with lower speed. For those requiring curve slope, the curve radius shall be gradually reduced and controlled according to the actual speed [12].

The interchange can also separate the trunk line from other traffic and make the ramp design a combination of plane and vertical. The vehicle can not only save driving time, fuel and vehicle loss, but also reduce accidents and ensure the life safety of drivers [13]. However, in real life, many designers cannot align the ramp design with the plane and longitudinal plane when designing the ramp, so they

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must adjust the distance from the variable slope point on the outside of the ramp. In addition, when the protruding vertical curve of the pavement intersects with the plane of the uphill road, the design of the sidewalk entrance and exit also needs to be consistent with the longitudinal profile of the urban road followed by the ramp, so as to facilitate the drivers to move towards a reasonable route and get familiar with the time road. At the same time, when the convex vertical curve intersects with the plane of uphill and downhill ramps, the convex vertical curve should also be lengthened to ensure the sight distance from vehicles. At the same time, the designer should continue to adjust in the design process to realize the perfect combination of ramp, horizontal and longitudinal contour, so as to reduce the potential traffic safety hazards [14].

3.4. Building and Variable Speed Lane Issues - Setting Standards

Due to the continuous improvement of China's economic development level, the transportation demand across the country is also increasing at the same time. Therefore, large vehicles often drive in urban areas. Cities have high requirements for vehicle passing standards. The original specified height of road vehicles is 4.5m, but it is adjusted to 5.0m considering different conditions. This modification is rooted in the current actual road conditions in China, and it is also a prediction of the evolution potential of the future transportation system. It is more rational than before and more in line with the people's living needs. According to applicable national regulations, urban roads exceed certain standards and there shall be no obstacles on both sides to ensure the safety of people and vehicles. However, because different cities have their own unique terrain environment and different road slopes, the width of urban roads is limited to floating space, but the limited height is often formulated according to existing laws and regulations. According to the highway standard, the design height of I, II and expressway shall be 5.00m, and that of class III and IV shall be 4.50M. The alternate lane of highway intersection consists of two parts: acceleration lane and deceleration lane. The acceleration lane is an additional lane, which is designed to enable the vehicle to accelerate the speed of the general section to the speed of the interchange section under the condition of safety. The deceleration lane is an additional lane to slow down without risk and adjust the vehicle from the interchange section speed to the general section speed. The width of acceleration and deceleration lanes is controlled according to the design speed of Expressway and the number of acceleration and deceleration lanes. The guidance value of the acceleration lane width of ordinary expressway is about 0.6 to 0.9 times of the city code [15].

If the main line of the road in the variable speed driving section is a straight line section or a curve section without superelevation, it shall be designed according to the normal road arch. When the main axis of the variable speed motor vehicle lane section is a circular curve with a certain height, if the variable speed motor vehicle lane section is located on the inner side of the curve, the whole section uses the same height as the main line; If it is located on the outside of the curve, the sections from the whole transition section to the width of the next lane use the same height as the main line, and additional cambers are set in other roads for reverse height transition. The ramp transverse slope at the nose end uses two percent (one percent) of the camber, and the algebraic difference between the ramp transverse slope and the main line transverse slope shall not be more than six percent.

4. Common problems and Countermeasures

(1) During the preliminary design comparison, selection and demonstration of interworking schemes, there is a lack of rationality evaluation of interworking schemes (including connecting lines) on the planning and layout of local road networks. It is suggested to include the road system within 3km outside the interchange toll station into the scope of node traffic capacity evaluation, and carry out the adaptability evaluation of the traffic capacity of the entrance and exit nodes of the toll station, so as to ensure the rationality of the scheme.

(2) There are some problems in the layout of some interchanges, such as the design index adopted by the ramp does not match the size of traffic flow, does not adapt to the terrain, the layout is not compact, the land occupation is large, and the investment is high. It is suggested to flexibly select ramp technical indicators to adapt to the surrounding terrain and environment. We should not only avoid blindly pursuing high indicators, but also avoid breaking through the standard unsafe indicators.

(3) The single circular alignment is adopted for the design of the single trumpet interchange, and the alignment combination is rigid and unreasonable. It is suggested to adopt the "water drop shape" design with smooth alignment and beautiful shape.

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(4) The balance of earthwork and Subgrade in the main interchange area is not considered. It is suggested that the interchange node be used as an important node to adjust the earthwork balance of the project, and can also be used as the borrow and spoil ground of each road section.

(5) The setting of connecting line is unreasonable. Some projects arbitrarily adjust the technical standards and increase the scale of connecting lines, without providing necessary basis. It is suggested to strictly control according to the early approval, and strengthen the coordination and communication with relevant departments in case of special circumstances.

(6) The location of interchange toll station is unreasonable. It is suggested that the toll plaza should be as close to the main line confluence as possible to shorten the length of the closed section, which can save the project scale and land.

(7) The layout of roads in interchanges is not reasonable. Generally, it is suggested that pedestrian crossing roads directly passing through the middle area of the interchange should not be considered in the area of the interchange. In order to facilitate the travel of the surrounding people, it can also be considered to set sidewalk sections at the outer side, inner end (separation and confluence) of the triangle area of the interchange and appropriate places around, and make it convenient for pedestrian crossing in a short distance as far as possible.

(8) Some interchanges, especially the intersection nodes with existing expressways, did not fully consider the construction work space and construction traffic organization scheme, resulting in the later scheme change. (9) The drainage design of the interchange area was not paid attention to, and the ponding problem occurred in the later stage. It is suggested that the drainage in the interchange area should be jointly negotiated by the route, subgrade, bridge and culvert, and solved by making full use of the topographic conditions and natural ditches.

5. Conclusion

Interchange design has an important strategic position in China's urban traffic, and it is also an important factor affecting the quality of road traffic. It plays a very key role in the smooth and rapid transformation of roads. The operation quality of expressway interchange is closely related to the safety of expressway traffic operation, vehicle operation quality and the traffic capacity of road network. The design of interchange confluence area is an important part of the whole interchange design. The connection between ramp and main line is closely related to the traffic safety and efficiency of confluence area. In engineering design, we should balance consideration, understand the difference between expressway and highway in urban planning, carry out scheme design, improve engineering design quality and service level.

According to the design characteristics of highway interchange, this paper points out the common problems in the design, and puts forward the corresponding solutions. The paper proposes that in the process of architectural design, the designer should fully grasp the basic landform and natural conditions of the project location, and adhere to the design principle of transportation hub guided by public interchange and meeting safety standards and the principle of reducing geological damage. In the design stage, it is necessary to consider three factors: vehicle operation safety, operation environment and interchange function. In the design, the designer is usually limited by capital and geographical environment, which makes the design difficult to have both operation safety and driving environment. In the driving process of interchange, the road environment changes complex and the factors affecting driving safety are complex. Generally, the designer's ability can not fully grasp and be familiar with all the influencing factors, so the design scheme is not the optimal scheme to a certain extent. Generally speaking, there are three major factors affecting traffic operation safety: people, vehicles and roads. Although the designer's design object is the carrier of roads, vehicle factors and driver factors are also closely related to traffic safety. While providing driving conditions for drivers and vehicles, roads should also consider the adaptability of drivers and vehicles in road operation.

References

[1] Zhu Tiangao, public wealth, Chen Jinghuai Discussion on key points of subgrade compaction construction technology in highway engineering. Theoretical research on Urban Construction: electronic edition, 2015, 5 (24): 2-4

ISSN 2706-655X Vol.4, Issue 4: 93-98, DOI: 10.25236/IJFET.2022.040413

[2] Zhang Zhike Key points of pavement construction technology of highway engineering. Construction engineering technology and design, 2015:32
[3] Wang Hancheng, Zhang Lin Analysis on key points of construction technology for soft soil foundation treatment of highway engineering.. 2021 (2015-12): 72-72
[4] Fu Yanbo Key technical points and quality control of subgrade construction in highway engineering. Science and technology innovation, 2012 (34): 253-253
[5] Li Si, Zhang Shengli Key points of subgrade and pavement compaction construction technology in highway engineering. Technology and market, 2014, 21 (11): 2
[6] Zhou Yefei, Jiang yongxiao. Analysis on the application of prestressed anchor cable anti slide pile technology in highway landslide. Enterprise development technology, 2015 (12). 50-51
[7] Wang Peng, Wu Fei, Zhang Sihai, sun Yongliang Design of transportation integrated application platform based on Internet of things. China Arab Technology Forum (Chinese and English), 2020 (08): 95-98
[8] Tan Hanhua, Meng Qingshan. Study on large-scale direct shear test of phyllite residual slope soil. Geotechnical mechanics, 2011 (4). 360-364
[9] Liu Jian. Design of urban expressway interchange crossing with highway -- Taking Baguazhou West hub as an example.. Heilongjiang transportation science and technology, 2021, 44 (02): 5-7 + 11
[10] Yang Hongzhu, bin Yongquan. Study on design technical scheme of Pingsha interchange and North 2nd Ring Interchange for rapid reconstruction of Guanghua first-class highway. Urban roads and bridges and flood control, 2020 (09): 38-42 + 11
[11] Shao Changqiao, Yang Zhenhai, Chen Jinchuan A probabilistic statistical model for determining the length of acceleration lane. Mathematical statistics and management, 2001, 20 (4): 42-45
[12] Li Wenquan, Wang Wei, Li Tiezhu Analysis of merging characteristics of vehicles on Expressway acceleration lane. Journal of Southeast University, 2002,32 (2): 252-254
[13] Li Wenquan, Wang Wei, Zhou Ronggui Distribution characteristics of headway of Lane 1 in the influence area of Expressway confluence. Highway transportation technology, 2003,20 (1): 114-117
[14] Yang Xiaofang, fan Botong, Fu Qiang Research on speed control of Expressway on ramp based on vehicle communication. Transportation research, 2019,5 (6): 69-76
[15] Zhang yachong, Li Min, Yang Biqi Study on acceleration characteristics of large vehicles on the ramp of interchange. Management of standards and regulations, 2020, 22, 30-75