Journal of World Architecture, 2023, Volume 7, Issue 3
http://ojs.bbwpublisher.com/index.php/JWA
ISSN Online: 2208-3499
ISSN Print: 2208-3480

Design Strategies of Expressway Routes and Interchanges

Xiaomin Wu*

China Merchants Chongqing Communications Technology Research & Design Institute Co., LTD., Chongqing 400067, China

***Corresponding author:** Xiaomin Wu, wuxiaomin@cmhk.com

Abstract: Road traffic conditions can have an important impact on the economic development of various regions. Under the background of rapid social and economic development, more and more expressway construction projects are initiated in various regions, including both new expressways and expansion of old expressways, and interchange design plays an important role. Scientific and reasonable interchange design can not only realize energy saving and low carbon footprint, but also be people-oriented and promote regional economic development. Therefore, this paper mainly analyzes the highway route and its interchange design strategy for reference.

Keywords: Expressway; Route; Interchange design strategy

Online publication: June 28, 2023

1. Introduction

When designing expressway routes and their interchanges, it is necessary to consider the traffic demand, town layout, road network distribution, management requirements, and surrounding geographical environment, etc. Besides, it is also necessary to fully understand the preconditions such as relevant opinions, approvals, and previous experiences before initiating the project. Then, the perspective different parties should be considered, and various design schemes should be compared to determine the most scientific and reasonable design scheme [1]. For the design of expressway interchanges, it is necessary to fully understand the relevant conditions such as the intersecting highways, interoperability, traffic volume, and related control conditions. Moreover, it is important to ensure that the design content is fully consistent with the Highway Route Design Specifications, can improve the road network, traffic volume, and can promote the economic level of the area along the route. Therefore, it can be seen that it is very important to discuss the expressway route and design strategy of interchanges.

2. Overview of expressway routes and interchange design

For the design and planning of expressway network, the design of expressway routes and interchanges play an important role. Improving the rationality of the designs of the main expressways and interchanges can make travelling much more convenient for locals, and it can also improve the level of economic development in the region. Therefore, before designing the route, it is necessary to fully investigate the traffic situation in the region and development needs to ensure that the various types of transportation can continue to be in a balanced state, and the role of the interchanges can be maximized. In this way the regional transportation system can be optimized, and the coverage of the road network can be maximized. Interchanges are nodes for the connection and transformation of the road networks in the area. Therefore,

in the design of interchanges, it is necessary to fully consider the long-term traffic demand, reasonably select the roads that are to be intersected, and ensure that the distance of the interchanges are scientific and reasonable, so as to maximize the function of the interchange and promote the improvement of economic and social benefits. In addition, the direction of vehicle traffic and the state of regional development should be considered, to ensure that the highway routes and their interconnected routes are consistent with the existing local routes and is coordinated with the surrounding buildings. It is also important that the routes meet the local transportation needs and at the same time effectively provide an important foundation for local socio-economic development [2].

3. Expressway routes and basic strategies for their interconnection design

3.1. Key points of expressway route selection and design

3.1.1. Ensuring safety

The first principle in selecting expressway lines is to ensure safety. Highway safety does not only refer to the safety of the main structures such as the roadbed, bridges, and tunnels of the expressway itself, but also the safety when driving on the expressway. Therefore, when selecting highway routes, care should be taken to avoid unfavorable geology such as landslides, debris flows, high-seismic areas, fault zones, and areas with soft soils. Other factors that affect the safety of road operations such as explosives and electricity should also be avoided to improve the safety of the line.

3.1.2. Improving economic efficiency

Expressways are one of the main arteries of social and economic development, and the main purpose of expressway construction is to improve economic benefits. The construction and maintenance of expressways are costly, so we must pay attention to the economic benefits. For expressways, economic benefits refer to the usage and service life upon completion of the expressway. Particularly, if the expressway passes through areas with complex terrain, it needs to be reasonably modified, which will lead a further increase in the cost of construction. Therefore, when selecting expressway routes, the development of major economic support industries in the region should be considered, such as the service industry and tourism, to maximize the cost-effectiveness of expressways and their role in driving local economic development [3].

3.1.3. Meeting environmental protection requirements

The building and construction of expressways will inevitably affect the surrounding environment to a certain extent. Therefore, when designing expressway lines, we should try our best to ensure the environmental friendliness of the project, especially the effect on water sources, historical relics, nature reserves, farmland, etc. The line can be appropriately extended to bypass the above-mentioned areas, and it is also important to avoid damage to environmentally sensitive points along the line during the construction process.

3.1.4. Adapting to local conditions

The expressway route should be reasonably designed according to the actual geological conditions and terrain characteristics of the area, and the route should be coordinated with the terrain and compatible with the geology to the greatest extent, so as to ensure that the expressway integrates into the natural environment to reduce construction difficulty and save construction cost.

3.2. Expressway interchange design

There are many forms of expressway interchanges. At present, interchanges are usually constructed in cities

at the municipal level and in counties below the city level, because the population in counties are usually scattered, and the number of vehicles is relatively small, which may lead to relatively less congestion. The four-branch interchange is usually used in cities with a large population and rapid urban development. In this type of cities, the population and number of vehicles is large, so traffic congestion is more likely to occur. In addition, common expressway interchange designs also include multi-branch interchanges, which contain multiple lines and are relatively complex [4].

Before designing the interchange, the overall actual situation in the road section should first be understood, mainly including the traffic flow, the layout, the data, etc., of the road network. Besides, the surrounding geological conditions should also be considered, such as the geographical environment, hydrological characteristics, and other aspects [5]. It should be noted that because the service life of the interchange is relatively short, and it can also be affected by various natural factors, the frequency of maintenance should be appropriately increased after the construction is completed. In addition, the location of the interchange should also be strategic and suitable for setting up toll stations. Moreover, it is important to pay attention to maintaining an appropriate distance between the parking area and the toll stations to ensure the normal passage of vehicles [6].

4. Basic principles of expressway routes and interchange design

The scientific and reasonable design of expressway routes and their interchanges can greatly improve traffic efficiency, thereby effectively relieving traffic congestion, reducing the incidence of traffic accidents to a certain extent, and at the same time improving the travel experience and transportation of the people. Therefore, ensuring the safety of various types of transportation vehicles in expressway routes and their interchanges can maximize role and advantages of the routes and further improve the road network [7]. Therefore, in order to ensure the rationality and effectiveness of the expressways and their interchanges, it is important to adhere certain principles, as shown in **Table 1**.

Table 1. Basic principles of expressway routes and interconnection design

Serial number	Principle	Content
1	Fulfill the four traffic development requirements	Resource saving, energy saving and high efficiency, construction environmental protection, green service
2	Low cost	Comparing multiple construction plans and strictly controlling the quantity of work
3	People-oriented	Ensure the safety, comfort, and integrity of the route
4	Harmonious development of multiple industries	Maintain an optimal relationship between the expressway and surrounding agriculture and industry
5	Promote regional development	Urban planning and regional economic development must be considered comprehensively when designing schemes

5. The specific situation of expressway routes and interconnection design

5.1. Basic information

Taking the north-south expressway as an example, the starting point is the expressway in Area B in the area where it is located. The main purpose of this project is to connect the north and south ends of the expressway to optimize the transportation network in the area, while reducing the detour distance of vehicles. Before officially launching the design scheme of the interchange, a comprehensive on-site survey should first be carried out, and photographs should be taken of the existing cultural relics, schools and other important

environmentally sensitive areas. If there are high-voltage lines, factories, etc. in the area, the relevant authorities should be consulted in advance to ensure the rationality and feasibility of the design scheme, and areas such as cultural relics and schools must be avoided [8]. Factors such as urban planning, traffic planning, social and economic development status, and development needs in the area should also be considered to select the most economical, safe, environmentally friendly and beautiful design. It should be noted that continuous communication and coordination with relevant local government departments should be carried out to ensure that the interoperability design scheme fully adapts to social impacts and economic development needs [9].

5.2. Design plan

Based on the highway route design specification and the actual situation, several design schemes were put forward. A 1:10000 topographic map was used to study the rationality of the route. After selecting multiple schemes, 9 design schemes with high comparative value were determined , namely Line A , Line B , Line C , Line D , Line E, Line F, Line G, Line K, and Line K2. After fully considering the regional development plan, social impact and geological conditions along the line, K line was chosen as the final design scheme, as shown in **Figure 1**.

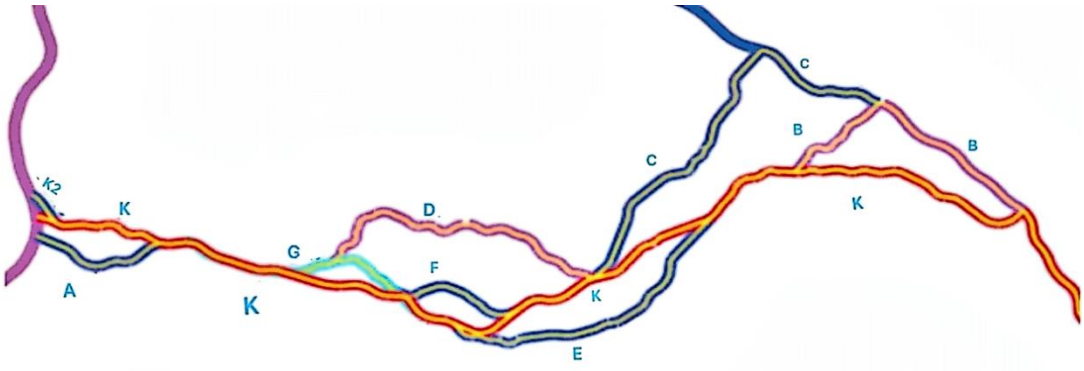

Figure 1. Schematic diagram of the design scheme

According to **Figure 1**, Line K is able to connect the entire line. Through field surveys and taking local opinions into consideration, except for Line K, most of the route schemes have obvious shortcomings, and they are not ideal in terms of economy and feasibility. As far as the comparison between Line A and Line K is concerned, a special curved bridge need to be built in Line A, and the route is 193 meters longer than Line K. Therefore, Line A comparatively less ideal compared to Line K. In terms of comparison between Line B and Line K, the plane index of Line B is poor, and there are detours in the route. The actual distance of Line B is 33 meters longer than that of Line K. Therefore, Line B is less ideal compared to Line K. After several comparisons, Line K is the optimal solution, and Line K should be taken as the main line, with a total length of 91.4 km. At the same time, Lines A and B were compared at the initial stage of design. The lengths of the two alternative lines A and B are 25.4 km and 12.6 km respectively, accounting for 41.64% of the overall length of the line.

5.3. Analysis of interoperability

A project has been initiated to solve the problem of traffic conversion between urban ring and ring roads. The design speed limit of the main expressway is 120km/h, and the roadbed width is 34.5 m. Because the position of the interchange of the project is within the flood storage area, the main line of the urban ring road is a bridge. The volume of subgrade of the road section is large. At the crossing position, the upspan method is used to ensure that the flood control requirements are met. Within the range of the interchange,

all main lines adopt the form of bridge overspan, and the part of the interchange ramp is also a bridge [10]. Therefore, the scale of the project's interchange is relatively large, and the cost is relatively high. According to the function of the interchange and the traffic demand, the designed speed of the main traffic flow of the interchange part is 60 km/h, the minimum radius of the circular curve is 150 m, the ramp part is double-lane, the width is 10.5m, the entrance and exit part is single-lane, and the maximum longitudinal slope is more than 4%. The secondary traffic flow is connected by the inner ring ramp. The design speed of this part of the ramp is 40km/h, the width is 8.5m, the minimum radius of the circular curve is 60 m, and the maximum longitudinal slope does not exceed 4%. Two parts of the inner ring ramp are on the right side of the main line, and there are multiple entrances and exits on the right side of the main line. Therefore, in order to reduce the impact of the ramp-turning traffic on the straight traffic on the main line, the method of lane distribution and/or merging exits should be adopted to ensure the consistency of interchange entrances and exits.

Through the design of the interchange, the road network between the expressway in Area A, the expressway in Area B, and the urban ring road in Area C has been effectively connected and transformed. This is how the hub-type interchange has greatly improved the traffic efficiency and safety in this area. Due to the beautiful interchange and the many and irregular free areas formed between the ramps, the green landscape of the interchange area is also one of the key points in the design of the interchange. Greenery is often the main highlight in the entire expressway project. In the process of greening design, natural forms should be mainly used to fully display the local natural landscape, improve the external aesthetics of expressway routes and interchanges, and then realize the full integration of natural environment and transportation, which will in turn achieve the "harmonious coexistence between man and nature" [11].

6. Conclusion

Expressway routes and their interchanges are one of the key points in road traffic planning, which can have an important impact on the integrity and rationality of the overall design of the highway. Scientific and reasonable expressway routes and their interchanges can effectively relieve urban traffic pressure, and improve the efficiency of highway, making the travelling more convenient, and the economic level of the region can also be improved. Therefore, when designing expressway routes and their interchanges, it is important to consider various factors such as urban development planning, road network composition, management conditions, traffic demand, and topographic and geological conditions, so as to ensure the interoperability of the expressway routes and interchanges.

Disclosure statement

The author declares no conflict of interest.

References

[1] Li P, 2021, Discussion on Optimum Design of Expressway Routes. Traffic World (Early Journal), 2021(6): 75–76 + 94.

[2] Wang Z, 2021, Design Optimization of Expressway Interchanges in Canyon Mountainous Areas. China Highway, 2021(22): 113–115.

[3] Lu M, 2021, Discussion on the Route Design of the Reconstruction and Expansion of Guiliu Expressway. Western Transportation Science and Technology, 2021(6): 83–86.

[4] Sun P, Deng X, 2021, Research on Interconnection Scheme Selection of Expressway Hubs in Mountainous Areas under Complex Conditions. Subgrade Engineering, 2021(4): 124–128.

[5] Wang W, 2021, Discussion on the Interchange Design of New and Old Expressway Intersection. Architectural Engineering Technology and Design, 2021(24): 646.

[6] Chen H, Wang Z, Chen K, et al., 2021, Research on the Overall Scheme of the Widening Project of Xinling Tunnel Section of Hangjinqu Expressway. Highway Engineering, 46(1): 103–111.

[7] Ni L, 2022, Design and Case Analysis of Expressway Routes and Interconnections. Jiangsu Science and Technology Information, 39(21): 38–40.

[8] Chen Y, 2023, Discussion on Line Sight Distance of Expressway Interchange. Zhonghua Construction, 2023(2): 76–78.

[9] Li X, 2022, Safety Design and Evaluation of the Exit Ramp of Expressway Interchange. Traffic World (Last Period), 2022(8): 32–34 + 54.

[10] Qi X, 2022, Research on Route Intersection Problems and Optimal Design in Highway Design: Taking a Highway Reconstruction Project as an Example. Engineering Construction and Design, 2022(19): 94–96.

[11] Nie W, Guo F, Li T, et al., 2022, Application Research of BIM Forward Design Based on Automatic Modeling in Interchange Bridge. Hunan Communications Technology, 48(1): 105–111.