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Research on Road Design in Mountainous Urban Areas based on New Construction Concepts

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Abstract

This article is based on the municipal road and supporting projects of the North Extension of Fenghuang Fifth Road. Following the principles of "safety, comfort, ecology, wisdom, and harmony", it adheres to the concept of comprehensive, coordinated, and sustainable development. Guided by the new construction concept of the Ministry of Transport, it integrates the new design concepts of traffic safety first, resource conservation, environmental friendliness, technological innovation, and intelligent collaboration, and organically combines nature, culture, and roads. The design strives to achieve road aesthetic design, tolerant design, humanistic design, flexible design, and creative design. It has positive reference value and important significance for the research of ecological smart road design, future transportation industry, and sustainable development of nature and culture.

Keywords

Fenghuang Fifth Road; Municipal Roads; Building New Concepts; Ecological Wisdom; Sustainable Development.

1. Introduction

Nowadays, green travel and low-carbon travel have become more and more popular, green environmental protection has become an important part of sustainable development, and people have the need to pursue higher quality of life and better transportation. Urban greenway needs to meet people's demand for path environment, and different residents' choice of travel mode affects the quality of urban environment and living standard. Greenway has become an urban development trend due to its various functions and cost saving advantages. Greenway planning and design can help promote the construction of urban ecological humanities and improve the urban ecological environment. The study of urban greenway planning and design and strategy is of great significance and reference value for the construction of ecologically livable cities, the improvement of urban quality and the improvement of people's living environment.

2. Project Overview

The municipal road and supporting project of Fenghuang Fifth Road North Extension is located in Gaopu Chuangzhi Valley, Taiping Town, Conghua District, Guangzhou City. The project presents a north-south direction, connecting the second phase of Fenghuang Fifth Road East Extension in the knowledge city to the south and the S118 Provincial Road to the north. Along the line, it intersects with the planned first horizontal road, planned second horizontal road, planned third horizontal road, planned branch road one, planned branch road two, planned branch road three, and planned branch road four, with a total length of about 2.63km; And it crosses the North Third Ring Expressway on

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the north side of Maocheling, crosses over Gaopingkeng at K2+111.5, and sets up a 78m long bridge in Gaopingkeng; This project is an urban main road with six lanes in both directions, designed for a speed of 50km/h, and a planned red line width of 40m. It is proposed to use asphalt concrete pavement.

The project construction includes road, transportation, bridge, water supply and drainage, lighting, power cable trench, greening, and sponge city engineering.

The project area is located in Conghua District, Guangzhou City, in a low latitude zone with a subtropical monsoon climate. The Tropic of Cancer crosses Taiping Town, and the climate is mild.

Conghua belongs to the semi mountainous area, and its geology is mainly composed of three categories: sedimentary rocks, igneous rocks, and metamorphic rocks. The city's topography is divided into six categories: plains, terraces, plateaus, hills, mountains, and water bodies. The terrain is high in the northeast and low in the southwest, with a stepped shape.

The proposed project site is located in hilly and mountainous areas with significant terrain undulations. The terrain is high, medium, and low along both sides of the road. The ground elevation of the site is generally 30~80m, and the highest elevation along the route is about 80m.

The transportation conditions in the project location are good, including the current Fenghuang Fifth Road East Extension, Provincial Highway S118, and current village roads.

The section from the starting point of the project to Gaopingkeng basically follows the existing village road, with some sections crossing the hillside, and the rest of the section basically follows the hillside. The total land acquisition area of the project is about 312 acres.

The red line of the project does not involve permanent basic farmland and supplementary land parcels in the three districts and three lines, nor does it involve ecological protection red lines. Some of the land is located within the urban development boundary, but it involves urban land, regional infrastructure land, other construction land, ditches, forests, agricultural facility construction land, gardens, cultivated land, and grasslands in the city's national air resources database.

3. Necessity of Project Construction

(1) The project is to improve the external transportation needs of Gaopu Chuangzhi Valley

At present, the external transportation of the region is not yet perfect. The North Third Ring Expressway has opened at the Huaqiufeng exit, which is only over 600 meters away from this project. It is connected to the Qiufeng Interchange at the planned Second Cross Road at K1+007, which is about 1 kilometer away from the highway entrance and exit. After the completion of this project, the Gaopu Chuangzhi Valley area can directly access the Guangzhou North Third Ring Expressway through Fenghuang Fifth Road, solidly promoting the interconnection of infrastructure between Gaopu Chuangzhi Valley and Huangpu District, and assisting the development of surrounding industries. Therefore, the construction of this project is urgent and aims to improve the existing road network, which can effectively enhance the efficiency of external transportation.

(2) The project is to connect the transportation needs of Conghua and Huangpu districts

Industrial cooperation and linkage, transportation interconnection is the foundation. At present, the transportation between Taiping District and Knowledge City is not yet perfect. The starting point of this project is the Fenghuang Fifth Road Knowledge City section, which is currently under design. The construction of the project will directly connect the Gaopu Chuangzhi Valley in Conghua with the Zhongxin Guangzhou Knowledge City, effectively strengthening the connection between the two areas and opening a new window for urban-rural integration development. It provides a convenient channel for the two-way flow of development factors such as people, goods, information, capital, and technology, and provides strong support for promoting the high-quality construction of the Huangpu Conghua Industrial Cooperation Zone.

(3) Can effectively guide and support land development and economic growth on both sides

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Through this project, Guangzhou's "Eastward Expansion" strategy can be extended to the Huangpu Conghua border area, further strengthening the connection between the area and Conghua and Huangpu districts, sharing regional urban functions. Therefore, the construction of the project can provide important infrastructure guarantees for the development of the region and promote regional urban economic and social development.

The construction of this project will help improve land use efficiency, enhance the urban image and taste of Taiping Gaopu Creative Valley, attract advantageous industries and high-end talents, and promote regional economic development.

In summary, the construction of this project is necessary for improving the external transportation of Gaopu Chuangzhi Valley and connecting the transportation needs of Conghua and Huangpu districts. The construction of the project can effectively guide and support land development and economic development on both sides of the road. Therefore, the construction of this project is very necessary.

4. Design Research based on New Construction Concepts

Adhere to the concept of comprehensive, coordinated, and sustainable development, guided by the new construction concept of the Ministry of Transport, propose a design concept that prioritizes traffic safety, resource conservation, environmental friendliness, technological innovation, and intelligent collaboration.

The design of this project is based on the principles of "safety, comfort, ecology, wisdom, and harmony", integrating new concepts of transportation construction and organically combining nature, culture, and roads to promote the sustainable development of transportation and natural culture.

4.1 Overall Route Comparison

This project will conduct a partial route comparison on the front and rear sections of the North Third Ring Expressway, with a total of two route options selected, namely Line A and Line B, with a length of approximately 900m.

Line A is a planning scheme, with a smaller radius at the intersection of the North Third Ring Road and a larger excavation at Maocheling; The B line is offset towards the east before and after the North Third Ring Road, with a good alignment. The excavation at Maocheling is relatively small, but some of the line positions occupy basic farmland.

Conclusion: Although the earthwork of Line A is relatively high, it basically follows the planned line position, and there is basically no need to adjust the plan, and it does not occupy basic farmland. Therefore, after comparison, it is recommended to adopt the Line A scheme this time.

4.2 Design of Underpass North Third Ring Expressway Section

Figure 1. Design Drawing of the North Third Ring Expressway under the Project

The section of the project that passes under the North Third Ring Expressway is designed with a left-right split design. When passing under the bridge piers, the third ring bridge piers are placed in the

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road green belt for protection. The road median and side median each need to include 4 bridge piers, and the green belt is relatively wide, with a central green belt of 7.5m and a side green belt of 10.5m.

4.3 Horizontal and Vertical Design

(1) Horizontal Linear Design

There are a total of 8 horizontal curves within the scope of this project design, with a minimum radius of 400m for circular curves and a minimum length of 45m for transition curves. There is no over elevation widening along the entire line.

(2) Road profile design

The control elevation of this project includes the Fenghuang Fifth Road Knowledge City section, S118 Provincial Road, the planned control elevation of the intersecting road, the entrance and exit of important construction sites, and the underpass of the North Third Ring Expressway section. Except for the completed renovation and expansion design of the terminal connection and the ongoing construction of S118 provincial road, the design elevation of the rest of this project is based on the planned elevation.

There are a total of 14 vertical slope change points on the road, with a maximum longitudinal slope of 3% and a minimum slope length of 130m.

Table 1. List of Vertical Section Design Indicators

Standard value / Project	Unit	Standard	Design
Calculate vehicle speed	km/h	50	50
Maximum longitudinal slope (general)	%	5.5	3
Maximum longitudinal slope (limit)	%	6	
Minimum slope length	m	130	130
Minimum radius of convex shape	m	1350	1360
Minimum radius of concave shape	m	1050	2000
Vertical curve length (general)	m	100	100

(3) Road cross-section

Taking into account factors such as project functional positioning, upper level planning, transportation service level, traffic volume forecasting, basic data, and long-term functions, this project plans to adopt a two-way six lane section.

Cross section design: 40m=2.5m (pedestrian walkway)+2.5m (non motor vehicle lane)+2.25m (side lane)+10.75m (locomotive lane)+4m (median)+10.75m (locomotive lane)+2.25m (side lane)+2.5m (non motor vehicle lane)+2.5m (pedestrian walkway).

Figure 2. Perspective view of road section

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4.4 Roadbed Design

(1) General roadbed design

Remove topsoil and planting soil from the original ground of general road sections, temporarily place them in a centralized manner, and use them for greening purposes after completion. After surface cleaning, the compaction degree of the ground should be ≥ 90%. If the original ground is damp, corresponding engineering measures should be taken (such as sun drying, replacement, or adding ash) to ensure compaction.

When the surface layer of the foundation is made of construction waste or miscellaneous fill soil, it should be removed to 30cm below the original soil and then compacted to a compaction degree of 90%.

(2) Connection between new and old roadbeds

1) When widening the old road, the surface and original slope surface should be cleared first, with a 50cm thick slope brushing. The cleared soil should not be used for filling the roadbed.

2) For road sections with a filling roadbed height greater than 1.5m, connect the old and new roadbeds, and lay three layers of two-way geogrids on the roadbed and foundation. Tie the overlapping part with iron wire.

3) Excavate steps along the direction of the roadbed at the widened section of the new and old roadbeds.

4) In general, the impact pressure is applied 20 times and the driving speed is between 10 and 12Km/h, which will be determined based on the experiment The gravity retaining wall is 2 meters away from the inner side of the platform back; The distance between the buttressed retaining wall and the inner side is convenient at 2.5m; Wire benchmark pole 10m; Underground pipeline 5m, interchange bridge 30m.

5) When the width of the widened roadbed is less than 8m, the geogrid should be fully laid, and the ends should be folded back with a width of 200cm.

(3) High fill roadbed

1) Firstly, remove the cultivated soil layer at the base, and choose vibration compaction, impact rolling, or dynamic compaction to treat the base according to the thickness of the soil layer and the length of the road section.

2) For embankments that meet the stability verification requirements, retaining walls and other supporting structures should be installed at the foot of steep ground slopes when necessary.

3) In response to the current situation of short settlement period of embankments during construction, in order to reduce the later settlement of embankment bodies, the roadbed is compacted with impact compaction. For roadbeds with fill height greater than 15m, reinforcement compaction is carried out for 10-20 times.

(4) Steep slope roadbed

Lay geogrids in the middle and bottom of the roadbed, and for sections with a filling height greater than 5m and a length greater than 100m, impact compaction shall be carried out every 2m of filling height.

(5) Special roadbed design

Some areas within the red line of this project have unfavorable geological soil conditions such as fish ponds, farmland, ditches, artificial fill, and miscellaneous fill. Therefore, it is necessary to treat this soft foundation. According to the requirements of the soft foundation construction period of this project and combined with treatment experience, the soft foundation treatment method of this project is: when the thickness of the unfavorable geological soil layer $H \leq 3m$, the removal and replacement method is used; when the thickness of the unfavorable geological soil layer $H>3m$, the cement mixing pile method is used for deep foundation treatment. The foundation located under the North Third Ring Expressway Bridge is treated with high-pressure rotary jet grouting piles.

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4.5 Slope Protection Design

The maximum excavation slope height of this project is about 38 meters, and the maximum filling slope height is about 12 meters. Therefore, further design research will be conducted on the high slope of the road cut.

(1) Fill slope

The filling slope of this project is 8m in one level, with a slope ratio of 1:1.5 for the first level and 1: 1.75 for the second level. A 2m platform is set between multiple levels, and a 2m wide retaining slope and a 0.5m wide drainage ditch are set at the foot of the slope.

For road sections with a slope height of H≤4m, spray seeding and grass planting are proposed for protection; For road sections with a slope height of 4m <H≤12m, it is proposed to use three-dimensional mesh grass planting protection, and the slope protection of the waterfront foundation section will use M10 mortar rubble protection.

(2) Excavation slope of general road sections

The excavation slope of general road sections is divided into 8m levels, and the slope ratio is currently considered to be 1:1. A 2m platform is set between multiple levels, and a platform interception ditch is set on the platform. A 0.5m wide side ditch is set at the foot of the slope, and interception ditches are set in sections according to demand 5m outside the top of the slope.

H≤16m road cut slope protection: For road sections with a slope height H≤4m, spray seeding and grass planting are proposed for protection; For road sections with a slope height of 4m<H≤16m, it is proposed to use three-dimensional mesh grass planting for protection.

(3) High slope of road cutting

According to existing data and local project analysis, the high road cut slopes in this area are generally dominated by rock slopes, with some high road cut slopes being soil slopes.

When the excavation slope is over 20m high, it is a high road cut slope, which can be divided into 10m levels. If the high road cut slope is mainly composed of rock slopes, the slope ratio below can be 1: 0.75 except for the highest level which is 1:1, and a 2m platform is set between multiple levels.

If the high road cut slope is mainly composed of soil slopes, the slope ratio can be 1:1 except for the highest level which is 1:25, and a 2m platform is set between multiple levels. The slope ratio of the road cut in this design phase is set to 1:1.

There are three types of slopes in this project where the height of the road cutting slope exceeds 16m, namely: third grade slope (16-24m), fourth grade slope (24-32m), and fifth grade slope (32-38m). The protection design for each graded slope section of the high slope is shown in the table below.

Table 2. Slope reinforcement measures for each graded slope section

Slope / Section	Slope protection form				
	1	2	3	4	5
3 slope 16~24m	Skeleton	Skeleton	3D Grass	—	—
4 slope 24-32m	Anchor beam	Anchor beam	Skeleton	3D Grass	—
5 slope 32~5m	Anchor beam	Anchor beam	Skeleton	Skeleton	3D Grass

4.6 Road Surface Design

Based on factors such as climate, hydrology, geology, and roadbed stability along the project route, and in accordance with the basic principles of pavement design, combined with the traffic characteristics of the road section, the pavement design is comprehensively considered. The quality requirements for this project are high, and the current Fenghuang Fifth Road East Extension Line is

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an asphalt pavement. Based on the principles of good landscape effect and uniformity, this project plans to use an asphalt concrete surface layer.

(1) Main design indicators:

a) Natural zoning: IV7

b) Standard axle load: BZZ-100

(2) Design of pavement structure layer

According to the road grade, traffic volume prediction, and relevant regulatory standards, the design of the pavement structure layer is as follows:

1) Road surface structure for vehicles:

∑90cm thick=4cm fine-grained modified asphalt concrete AC-13C+6cm medium grained asphalt concrete AC-20C+8cm coarse-grained asphalt concrete AC-25C+1cm lower sealing layer (SBS modified hot asphalt + scattered sunflower stone), permeable layer (PC-2)+2 × 18cm 5% cement stabilized graded crushed stone+20cm 4% cement stabilized graded crushed stone+15cm graded crushed stone (wet road section)

2) Non motorized vehicle road surface structure:

∑25cm thick=4cm C25 color permeable concrete+6cm C25 original color permeable concrete+15cm C20 permeable cement concrete.

3) Pedestrian pavement structure:

∑25cm thick=8cm colored permeable brick+2cm 1:2 cement mortar+15cm C20 permeable cement concrete.

4.7 Road Traffic Design based on New Construction Concepts

(1) Traffic Engineering Design

This project is an urban main road with six lanes in both directions, designed for a speed of 50km/h, a planned red line width of 40m, lane widths of 3.5m and 3.25m, and a traffic facility level of B.

The road network density in the project area is relatively low, including the east side of Fenghuang Fifth Road, existing village roads, and Provincial Road S118. Among them, the north extension of Fenghuang Fifth Road connects with the east side of Fenghuang Fifth Road, and there is a high degree of linear overlap with the current village road. During the construction period, it is necessary to ensure the traffic flow between the east side of Fenghuang Fifth Road and the current village road. Therefore, this project needs to carry out traffic evacuation in sections and stages.

Advance construction work area reminders will be set up on the east extension of Fenghuang Fifth Road, existing village roads, and Provincial Road S118 to warn vehicles to drive cautiously and ensure driving safety.

(2) Smart Transportation and Ecological Roads

This project design incorporates new transportation construction concepts such as smart roads, technological innovation, resource conservation, environmental friendliness, and ecological synergy on the basis of traffic safety.

The intelligentization of roads is closely related to the construction of municipal facilities, with many projects focusing on improving road quality and comprehensive traffic management. The core construction content includes: ① the construction of facilities and equipment based on intelligent transportation; ② Multi pole integrated smart light pole; ③ Construction of intelligent road management and service platform.

The design takes "smoothness, intelligence, ecology, and vitality" as the theme, adopting "municipal roads + vehicle road collaborative unmanned driving + intelligent facilities + U-shaped space integration + ecological integration", striving to create the quality standards of an international level new area, and turning the north extension of Fenghuang Fifth Road into the urban exhibition hall of Conghua District and the demonstration model of Gaopu Chuangzhi Valley Road.

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Figure 3. Smart and Ecological City Road

The road design adheres to the design concept of integrated street space, focusing on the principle of people-oriented. It integrates traffic, recreation, and commercial spaces, enhances the landscape of the existing road through slope plants, and shapes a street space with pleasant scale, beautiful environment, and green low-carbon.

Respecting the existing road system and spatial logical relationships, integrating various new technologies and ecological restoration into smart city projects through integrated design methods, its significance is not only the improvement of the physical spatial environment of urban roads, but also the renewal and restoration of urban ecology and functions, with strong economic, cultural, social, and ecological benefits. As a pioneer of park cities, we empower urban roads with humanistic, efficient, intelligent, and ecological concepts, allowing them to truly return to serving humanity and life.

5. Summary

This project is based on the municipal road and supporting engineering of the North Extension of Fenghuang Fifth Road. Following the principles of "safety, comfort, ecology, wisdom, and harmony", it adheres to the concept of comprehensive, coordinated, and sustainable development. Guided by the new construction concept of the Ministry of Transport, it integrates the design concepts of traffic safety first, resource conservation, environmental friendliness, technological innovation, and intelligent collaboration, and organically combines nature, culture, and roads to promote the sustainable development of transportation and natural and cultural industries. We strive to achieve road aesthetic design, tolerant design, humanistic design, flexible design, and creative design in our design.

Road design is not only the process of realizing road functions, but also the process of endowing the designer's ideas and concepts into the creation of roads. The exploration and experimentation in the application of new concepts during the engineering design phase have positive reference value and important significance for the research of ecological smart road design, future transportation industry, and sustainable development of nature and culture.

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