Research on design requirements and key technology of green highway

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Abstract. Starting from the development background of green highway in China, this paper analyzes the development process, connotation characteristics, construction concept and main construction ideas of green highway. At the same time, starting from the key source of green highway construction - design stage, this paper analyzes the key technical requirements of green highway design, as well as the key technical points in the design process of each specialty. Through the control of the design source, the core content of green highway design can be more clear, and the direction for the better construction and development of green road in the future can be pointed.

1 Introduction

In the Fifth Plenary Session of the 18th CPC Central Committee, five development concepts of “innovation, harmony, green development, openness and sharing” were put forward. Among them, innovation is the most important development driving force and green development is the necessary condition for sustainable development and important embodiment of Chinese people’s pursuit of better life. Now, establishing green transportation based on innovative views and ideas has become the key direction for transportation industry to change its development mode. It also reflects the implementation of the five development concepts. The implementation of green development concept represents the expansion and extension of the idea of “six persistence and six building-ups” in the new stage. It is also the key point to realize sustainable development of highway transportation under the background that the external rigid constraint is increasing and people’s demands are diversified. As a new highway construction and development mode in the new era, green highway has become the key area of green transportation development and the important symbol of the establishment of a beautiful China, which has important strategic and practical significance.

2 The concept and characteristics of green highway

2.1 The concept of green highway

China has been conducting the green highway study and practice for many years and has already realized some achievements. However, by far, China mainly focuses on

resource conservation, energy conservation, carbon reduction, pollution control and ecological protection, all of which belong to the narrowly-defined green development[1]. The author believes that the word “green” mentioned here is not simply green highway or the greening of highway, nor should it be limited to energy conservation, environmental protection, carbon reduction, recycling and other aspects. Instead, it shall be the broadly-defined green which means to coordinate of all highway development stages and internal and external development environment based on the sustainable development and full life circle ideas so as to realize the system optimization.

Green highway is defined as the highway construction project that can coordinate highway planning, design, construction, operation and management process within whole highway service life based on system theory. It shall be able to coordinate the relationship among highway construction quality, resource utilization, energy consumption, pollution discharge, ecological impact and operation efficiency. It should realize the best construction quality and the highest operation efficiency with the least resource utilization, the least energy consumption, the lowest pollution emission and the smallest environment impact. In addition, it shall realize the best balance between external rigid constraints and the internal highway supply[2].

2.2 The characteristics of green highway

The core idea of green highway construction is to meet people’s multiple demands. It insists the system theory and periodic cost idea, insists to coordinate the relationship of highway construction quality, resource utilization, environmental impact and operation

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efficiency, to coordinate the whole process of highway planning, construction, operation and management and to realize the balance between external rigid constraints and the internal highway supply by multiple measures. It is aimed to finally realize the harmonious coexistence of human beings and nature. The main characteristics of green highway are whole process, all factors, all directions, low consumption, low emission, low pollution, high utility, high efficiency and high benefit.

The detail ideas can be divided into three aspects:

Whole process[3]: The green highway development shall cover all related links, including planning, design, construction, operation, maintenance and management. It shall emphasize the coordination of the whole process.

All factors[4]: It means that green highway development shall cover all related factors, including resource saving, energy saving, emission reduction, pollution control, eco-friendliness, high efficiency, comfortable and beautiful outlook.

All directions[5]: The construction, operation and maintenance of green highway shall meet green development demands. Meanwhile, the necessary conditions shall be created for green transportation and safe operation. The highway with good quality, low carbon emission and energy saving benefits shall be provided and the users demands shall be considered so as to realize comprehensive development.

3 Green highway construction concepts and ideas

3.1 Construction concepts

The green highway construction insists the concept that “no damage is the best protection” and sticks to the concept of “people orientation”, “intensive and economical resource applications”, “elaborate creation

and design”, “flexible selection of technology indicators”, “the lowest cost of whole life cycle”, “history and culture inheriting” and “appropriate landscape planting”[6].

The concept that no damage is the best protection emphasizes to realize the best protection, the least damage and the most effective recovery. It insists that the construction shall follow nature rules and be integrated with nature. Based on this concept, construction design shall be the driving force of environment improvement. The bad habit of damaging first and recovering in the future should be abandoned so as to realize the simultaneous development of environmental protection and highway construction and to realize the harmony of highway development and natural environment.

The concept of people orientation requires to establish the service idea of people orientation and vehicle orientation, the design concept of “prevention, fault tolerance and error correction”, and the safety awareness of life first. It insists that the green highway construction shall be guided by the concept that drivers’ mistakes cannot cost life and by the idea of meeting people’s travel needs in a better way. It adheres to improve the safety of highway infrastructure, change highway development mode, continuously expand service connotation, expand service channels, enrich service content, improve service quality so as to ensure the public can benefit from and share the development achievements.

The concept of intensive and economical resource applications requires to handle the relationship of resource conservation and highway development in a rational way and to utilize resources rationally and effectively. It insists the principle that cyclic utilization is the best saving method, based on which we shall improve the efficiency of resource and energy utilization, reduce the total consumption of resource and energy, decrease waste amount and promote cyclic utilization.

Table1. Proportion of energy consumption and carbon emission of different modes of transportation[7]

Indexes	Transport Styles				
	Highway	Railway	Water	Aviation	Conduit
Energy Consumption	73.0	7.9	8.0	6.6	4.5
Carbon Emission	52.3	15.0	18.5	11.7	2.5

The concept of elaborate creation and design requires to establish the careful creation and design awareness. It requires to change design work into design creation, change common design products into high-quality design works. Based on this concept, the goal of being safer, more environmental friendly and more economic shall be insisted. In addition, more efforts shall be taken to realize refinement and beauty effects.

The concept of flexible selection of technology indicators requires that, while ensuring the good safety and excellent function, we shall also try best to maintain the harmony of highway, the nature environment along the road and human environment by rationally selecting technology standard and flexibly using technology indicators.

Based on the concept of the lowest cost of whole life cycle, the cost shall be analyzed based on the whole project service life and shall be analyzed by putting

highway into environment and society system. It insists that we shall not pay much attention to the initial construction cost of the project but shall focus on the later maintenance and repair cost. It means that we shall not only be aware of the project cost but also be aware of social cost and environmental cost. The designer shall coordinate the design indicators and resources, as well as the operation energy consumption in the later stage. The technical index and engineering scheme can not only be limited to the comparison of construction cost. It also needs to use scientific methods to calculate resource cost, energy consumption cost, carbon emission cost, even accident cost, and use life cycle theory cost analysis and comparison, so as to truly conform to the design principle of green highway technical index [8].

The concept of inheriting history and culture requires to publicize highway development history, popularize highway industry knowledge, expand highway culture,

inherit highway history, carry forward “two roads” spirit and follow the culture construction demands in the new era.

The concept of appropriate landscape planting requires that the improvement of highway green landscape shall be compatible with surrounding environment and economy development. The excessive greening, or excessive landscape planting, or the landscape planting that is not harmonious with the surrounding environment are not advocated and the greening that ignores economic cost is forbidden.

3.2 Construction ideas

(1) Mastering the basic connotation of green highway. Green highway does not simply equal to highway greening, highway beautification, low-carbon emission, energy conservation, emission reduction and ecological restoration, etc. Instead, it is the comprehensive construction that coordinates the whole process and all elements of highway planning, design, construction, operation and management[9]. Therefore, the future green highway construction shall be conducted based on the essence of highway projects and shall implement green construction ideas from the source so as to realize the green highway construction in a better way.

(2) Insisting two directions. During green highway construction process, firstly, the whole process of construction planning, feasibility study, design, construction and operation management" shall be insisted. Secondly, the coordination of people, vehicles, roads, environment and society shall be guaranteed to realize the balance and harmony of these elements.

(3) Emphasizing the “three stages” which are separately realizing green design by the source control, realizing green management based on scientific construction and realizing green service by intelligent operation.

(4) Implementing “four principles” which are the principle of sustainable development, the principle of overall coordination, the principle of innovation driving development and the principle of suiting measures to local conditions.

(5) Taking “five measures” [10], including taking design as guidance and paying attention to scheme optimization; taking required actions, like environmental assessment and water protection; realizing project highlights, highlighting features and effects; trying to realize comprehensive effect and paying equal attention to economic benefit and social benefit; emphasizing the training of all employees, transforming from the mode of assigning employees to work to inspiring employees actively requires to work.

4 Key technology requirements of green highway design

4.1 Strengthen the overall design

The overall design of green highway shall insist the general goals of people orientation, safety first, natural harmony, ecological and environmental protection, adapting to local conditions, saving resources, reasonable technology and service improvement" [11]. It shall demonstrate technology standard scientifically, confirm construction scheme and scale rationally and master the relationship among routes, subgrade, bridge and culvert, tunnel, route intersection, traffic engineering and facilities along the road systematically. This is aimed to coordinate the construction scheme with the relevant requirements of natural resource conservation, ecology and environment protection and to realize the healthy and sustainable development of highway construction.

Table2. Green function of influencing factors[12]

All stages of green road life cycle	Influencing factors of Green function
Project decision stage	Environmental factors
	Resource factors
Project design stage	Risk factors
	Technical factors
	Ecological factors
Project bidding stage	Economic factors
	Quality factors
Project construction implementation stage	Geographical factors
	Mechanical factors
	Material factors
	Safety factors
Project operation management stage	Management factors
	Maintenance factors

4.2 Flexibly select technology standard

The technology standard of green highway construction shall be determined based on the comprehensive analysis of highway function, that is the role of highway in road network (main traffic line, distribution line, branch line). It shall also be decided based on the consideration of traffic volume, construction conditions, safety,

environment, resource carrying capacity and other factors. The determined standard can be a little advanced but shall not be excessively advanced. If the construction project is located in the area with high altitude, extremely low temperature, frequent geological disasters, mountains and hills and limited land use conditions, it is recommended to adopt different technology standards for different construction sections. It is also recommended to

use technology indicators flexibly, like adopting the minimum or limit value of regulated technology indicators. Under the premise that the safety is guaranteed, some functional objectives and secondary indicators can be decreased. The technology standard demonstration shall be strengthened for highway reconstruction and expansion projects, especially for the upgrading of low-grade highways[13]. The study shall focus on how to make full use of the old roads, how to flexibly use technology indicators and how to reduce impact on environment and project cost on the premise that good safety is guaranteed.

4.3 Rationally confirm the cross section of subgrade

The number and width of traffic lanes shall be determined based on the high way technology level, designed traffic volume, terrain condition, service function and service level. The lane number of special projects can be determined based on seasonal traffic volume, peak traffic volume, different highway sections and directions. The layout of subgrade cross section and the width of all component sections shall be decided flexibly and the embankment height and cutting depth shall be decreased rationally so as to reduce the impact on surrounding ecological environment and to integrate the highway with surrounding environment. The subgrade cross section shall be designed based on the surface cross slope, natural conditions and engineering geological conditions. Normally, the integrated cross section is adopted if nature surface cross slope is gentle. But the highway with four or more lanes can adopt separate cross section under the conditions that the surface cross slope is sharp, that the terrain fluctuates greatly, and that the engineering geology is complex. If the terrain and geological conditions are complicated, the separate cross section with one-way lane can be set up based on terrain condition for ordinary highway with two lanes.

4.4 Coordinate the intensive and economical utilization of resources

Coordinate the allocation of transportation, urban, industrial, agricultural resources and other resources to realize the intensive conservation of regional resources. If the channel resources for expressway construction are limited, it can be considered to share channels with railway, ordinary highway, communication, monitoring, power supply pipelines and other system pipelines or with mobile network construction. In addition, the intensive and economical utilization of resources can also be realized by integrating highway and railway together or constructing embankment and highway together. Besides, the low embankment, shallow cutting or viaduct shall be preferred and the subgrade excavation and filling shall be controlled reasonably so as to reduce the land occupation.

5 Key points of green highway design

5.1 Optimize route and interchange scheme and realize intensive conservation of land resource

The principle of terrain alignment shall be insisted and the optimization of indicators, the selection of continuous balanced horizontal and vertical indexes shall be emphasized so as to improve the traffic safety. The balance and continuity of the technology index adopted by the connection of different design units shall be emphasized in route design to realize the reasonable transition of high and low indexes. The speed difference shall be decreased by improving the index combination of adjacent road sections, which is benefit for improving driving comfort and eliminating the potential safety hazards. In addition, the harmonious integration of safety and comfort shall be realized and energy consumption of road users shall be greatly decreased. Meanwhile, the interchange type should be decided reasonably and the ramp alignment should be designed carefully to realize the construction of compact interchange.

5.2 Integrate related facilities in the area with limited terrain conditions to reduce land occupation

The overall design shall be greatly emphasized during the design process and the location and form of the facilities along the line, including interchange, service area, parking area and maintenance area, shall be determined reasonably according to local conditions. The detail requirements include. (1) Realize the compact layout of interchanges to reduce land occupation. Flexibly decide the location of service area based on local conditions, adopt asymmetric layout, unilateral layout, lead-out layout and other layouts. (2) Consider to integrate the interchanges, main line toll stations and service areas to realize the intensive conservation of land resource. (3) Making efforts to combine temporary and permanent facilities along the line together. For example, the highway connecting Jiuzhaigou area, Sichuan Province and Mianyang City adopts the design of using interchange to surround the land, coordinating the acceleration and deceleration lanes and integrating the service area and parking area[14]. The Wanglang interchange and the service area are compactly designed for Jiuzhaigou-Mianyang expressway. The design of the service area adopts the three-in-one mode of interchange, mainline station and service area. It integrates interchange, service area and interchange together, and then sets up service area separately in right and left sides.

5.3 Optimize route scheme, reduce the height of cutting slope and protect ecological environment

The cutting slope will greatly affect the vision field and landscape effect. It is also the area that can easily damage the mountain ecological environment. Therefore, cutting slope design shall follow the green ideas and rational

design principles shall be decided based on project characteristics and construction requirements. The height of cutting slope shall be reduced to the level lower than 25m, which can effectively reduce the mountain excavation and vegetation damage, and can help to improve the road environment and traffic safety.

5.4 Coordinate the earth filling and excavating, try to achieve zero earth dumping and less earth borrowing

The principle of zero earth dumping and less earth borrowing shall be well considered and controlled in highway construction design. It represents the overall goals and direction of land allocation. It is not the imperative provision of green land construction but it is the direction that we shall make efforts to realize[15].

The core idea of zero earth dumping is to transform wastes into treasures. It means to preserve and utilize the earth dumped in traditional practice, to try best to increase the utilization rate of dumped earth and to decrease the dumped earth field. The following methods can be adopted to realize this. Firstly, rational construction procedure shall be established and the tunnel excavation shall be started as soon as possible so that the waste residue can be produced in time and efforts can be made to improve waste residue utilization. Secondly, an area shall be set up to handle with the dumped earth in the highway construction area. In addition, efforts shall be made to transform wastes into treasure and to study how to use waste residue in the construction of viewing platform, self-driving camp, service area and other facilities. Besides, actions shall be taken to combine the waste residue with land construction, decrease the subgrade slope in some sections, explore to use waste residue in land construction and cultivation field construction so as to bring benefits for local people. The waste residue can also be used for local planning, loading berm, wastegully filling, gravel recycling, concrete components of auxiliary projects and so on. What's more, the waste residue generated by tunnel excavation can also be used in other comprehensive methods. The application methods of waste residues shall be decided based on lab analysis results. The waste residues can be used for subgrade filling and it can be processed into sand, stone and other building materials so that it can be used for the construction of other project substances. Great efforts shall be made to reduce earth waste and land occupation.

The key point of less earth borrowing is to select routes scientifically. The routes shall be repeatedly optimized for the road section with large earth borrowing amount so as to reduce the subgrade height, reduce the earth borrowing and save land resources. The best method is to optimize the route design because the earth borrowing can be greatly decreased by route optimization. Meanwhile, the route optimization can also bring some additional effects, such as reducing the size of bridges and culverts, reducing land occupation, and greatly saving investment cost.

5.5 Strengthen the environment protection design for ecological sensitive area

In accordance with the green highway construction requirements, the route layout shall insist the rules of avoidance and less disturbance and shall strictly follow the ecology and environment protection rules. The design of the route in narrow valley area, the horizontal and vertical routes in the area with steep cross slope and extensive geological diseases shall be furtherly adjusted and optimized. The area with landslide, rock falling danger and the slope with collapse risk shall be avoided to decrease the impact on nature environment. In addition, the professional environment monitor shall be established and the environment production manual about the construction in wildlife habitat shall be edited. Related signs shall be set up to protect the wildlife habitat and cooperation with related protection agencies can be carried out to monitor the species diversity, etc.

5.6 The application of BIM and other information technology in the design

The application of GIS+BIM from the initial design to the whole work process shall be explored. BIM technology can be used for emergency decision-making, including collecting field information, deciding disaster relief and rescue plan. In addition, BIM can also be used to review and optimize construction drawing and design documents, to improve the efficiency of service area planning and site selection, engineering scheme design, and to carry out 3D planning of the service area, which can furtherly enhance the accuracy and visualization of the design[16].

5.7 Expand the highway tourism function according to local conditions

It is one of the important tasks of green highway construction to build beautiful tourism landscape. Therefore, it is necessary to establish tourism themes and construct and improve the landscape along the whole highway line based on the culture, folk custom, natural environment and other elements along the road. The great attention shall be paid to establish the service area with characteristic themes and establish the slow-driving and landscape viewing system. Efforts shall be made to expand the highway tourism function so as to realize the combination and coordinated development of highway and local folk culture and tourism industry. What's more, guided by smart transportation and tourism, the mobile terminal service system and signal guidance system shall be established and the tourism advantages of the road, the tourism resources and cultural elements along the line shall be promoted.

6 Conclusion

Green highway construction is closely related with the sustainable development of highway transportation and it is the important action for highway industry to

implement five development concepts and the ecological civilization strategy put forward by Party Central Committee. Design work plays the guidance role in highway construction. Thus, the excellent green highway construction design is very important for implementing green ideas. We shall furtherly understand the importance of the overall design in the whole design process, implement key construction points of green highway in every professional design detail, show our great attention on environment protection and reflect our emphasis on and improvement of construction quality from the details. Only when green ideas and overall design ideas are fully implemented can green development be truly implemented and realized.

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