Study on the Creation of Landscape Environment for Beautiful Expressway Dynamic Corridor

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Abstract: Beautiful expressways are the traffic practice of the Beautiful China initiative. The visual environment of the highway is not only related to the quality of the highway landscape, but also provides crucial support for improving highway traffic safety. Considering the distinctive aspects of highway engineering and the remarkable attributes of the natural surroundings along the route, this paper proposes the implementation of tolerant subgrade design techniques that are finely tailored to the specific local conditions. These techniques involve the integration of excavation sites with leveled areas. Additionally, this paper suggests the implementation of meticulous adjustments in the micro-topography of roadside areas, interchange zones, service and parking areas, as well as management centers, with the aim of crafting scenic corridors. Furthermore, this paper recommends the restoration of slopes in a manner that closely resembles natural ecology, the safeguarding and transplantation of indigenous mature trees, and the creation of service facilities that exude a garden-like ambiance, thus establishing a linear and dynamic highway landscape corridor, brimming with distinctive local characteristics.

Keywords: Expressways; Visual Environment; Landscape Corridors; Integrated Design

1. Introduction

The construction of a Beautiful China is a significant strategic task personally envisioned by General Secretary Xi Jinping. The 19th National Congress of the Communist Party of China proposed that the goal of "Beautiful China" will be essentially achieved by 2035. The construction of a Beautiful China is an essential part of the realization of the Chinese Dream of the rejuvenation of the Chinese nation and a significant goal of the modernization of socialism with Chinese characteristics.

Beautiful expressways are the traffic practice of the Beautiful China initiative. The visual environment of the highway is not only related to the quality of the highway landscape, but also provides crucial support for improving highway traffic safety. The quality of the highway landscape is becoming increasingly important to human life. Currently, research, discussion, and application in the field of expressway landscape visuals in China are far less than those in other areas of environmental quality. As an essential factor of social environmental quality, many countries worldwide have conducted numerous engineering practices in visual resource protection, improvement, planning, and management. Countries like Europe and America often

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focus on researching, developing, and protecting aesthetic themes in natural resources during the highway planning and design process. They aim to develop visual aesthetic resources through purposeful design, intending to provide highway users with a visually pleasing experience.

From the perspective of the expressway itself, a reasonable visual environment can reduce the destruction of landscapes and environments caused by expressway construction, integrate highways with nature, and create a safe and comfortable environment for highway users. On the one hand, the form, color, and layout of the highway landscape should be fully considered to meet all the requirements for safe driving and satisfy the drivers' visual and psychological feelings. On the other hand, beautiful lines and landscapes can improve drivers' attentiveness, avoid monotony during long journeys, thereby reducing traffic accidents, and ensuring the smooth and safe flow of highways [1].

The visual environment is a resource, and the scope of highway visual resource management includes the total sum of the external and internal landscape visible to humans[2]. Visual resource management includes landscape unit division, recognition and extraction of visual points of interest, visual quality assessment, and analysis of visual absorption capacity. The purpose of improving and managing visual quality is to enhance the visual resource quality for drivers and create a highway environment with good landscapes and safe driving. As a linear landscape, highways, under the influence of operating speed and safety requirements, limit the viewing angle, viewing distance, and recognizability of landscapes for drivers and passengers. Based on the dynamic characteristics of high-speed vehicle movement, research on highway landscapes from the visual perspectives of drivers and passengers meets the requirements of static vision while also satisfying the dynamic visual requirements of people during vehicle movement. This provides real-time changing aesthetic effects for drivers and passengers, and is the functional foundation of expressway landscape technology, embodying a people-oriented approach.

This article analyzes the landscape issues existing in the construction of highways in China, proposes landscape sensitivity evaluation indicators and calculation formulas, and conducts research on highway environmental construction technology based on the classification of right-of-way boundary landscapes. The research focuses on tolerant roadbed design technology, road landscape micro terrain consolidation technology, and near natural slope restoration technology.

2. Analysis of Landscape Problems in China's Expressway Construction

China's expressway construction has developed rapidly, but in the past, the primary method was "extensive" development, focusing on speed and quantity. Little attention was paid to the coordination of expressways with the surrounding landscape, and there was not enough consideration for sustainable resource use, visual resource protection, and usage. With the continuous increase of the country's comprehensive national strength and the deepening of the concept of sustainable development, the construction concept of China's expressways has begun to shift from emphasizing economic benefits to environmental benefits, and from simply focusing on quantity to focusing on landscape and environment[3]. However, since China started relatively late in researching highway landscapes, there are still many problems in expressway construction [4].

2.1. Existing Problems

2.1.1. Emphasis on the pollution evaluation of the physical environment in environmental impact assessments, neglecting landscape aesthetics and visual impact assessments.

During the construction of expressways, environmental assessments focus more on air, noise, geology, society, ecology, etc., and the evaluation is more detailed. However, impact assessments in the field of landscape aesthetics are scarce. Most are still qualitative descriptions of the current landscape along the highway, lacking comprehensive considerations from the perspectives of topography, vegetation, landscape resource protection, etc. [5].

2.1.2. Expressway route selection emphasizes geological and socio-economic factors, overlooking the protection of landscapes along the route.

The phase of expressway route selection is the most crucial stage related to the coordination of expressways and landscapes along the route. Currently, China pays more attention to geology, engineering volume, and economic savings at this stage, lacking concern for the landscape environment of the road area. This has caused serious damage to natural landscapes in some projects, often resulting in a large amount of slope cutting, hill excavation, ditch filling, tree felling, wetland encroachment, grassland segmentation, and other infringements on the natural terrain and ecological environment. This has resulted in a lack of integration and coordination between China's expressways and the surrounding environment, leading to the separation of expressways and natural landscapes along the route.

2.1.3. Focus on expressway engineering design standards, neglecting coordination with landscapes along the route.

For a long time, the design of China's expressways has often only considered functionality, focusing on the completion of design standards, lacking connections with topography, natural space, and visual landscape space[6]. This has led to a lack of coordination between expressways and landscapes along the route, making it difficult to blend in with the broader landscape.

2.1.4. Expressway survey and design are not synchronized with highway landscape design.

Domestic expressway landscape design begins in the middle and later stages of the project progress. At this point, the basic structures of the highway have taken shape, and the task of landscape design is to decorate and greenify these structures, leaving little room for maneuvering. In addition to potentially causing environmental pollution and ecological destruction, the construction of highway projects can also bring other impacts, including those on the landscape and visual effects. Many developed countries and regions have noticed this problem and have taken corresponding measures. They always accompany landscape supporting designs and implementation plans during the highway planning and design process to minimize the visual impact of highway structures on the surrounding environment and provide a pleasing environment for highway users. Therefore, in the early stages of expressway planning, the planning, design, and evaluation of the landscape environment must be considered. This is also one of the problems that urgently need to be studied and solved for China's expressway construction to achieve sustainable development.

3. Evaluation Index - Landscape Sensitivity

Expressway landscapes incorporate natural and social attributes, functionality and aesthetics, practicality and artistry, forming a comprehensive landscape system in conjunction with the surrounding landscapes. In past studies, many scholars have used landscape sensitivity as the primary evaluation index.

Landscape sensitivity refers to the measure of how easily a landscape attracts people's attention. A person standing aimlessly has no focus, but as their movement speed increases, so does their attention. For observers, paying too much attention to objects unrelated to movement becomes increasingly dangerous. The design of highway landscapes should help focus people's attention on the road and minimize distraction from other objects. Therefore, elements along the expressway must be stationary, their main image should serve the visual axis line, and they should not draw too much attention from the driver [4]. Compared to static landscapes, the dynamic sensitivity of highway landscapes will be greatly weakened during vehicle travel. To achieve the same visual effect for the passengers and drivers as in a static state, it must be compensated by special design to offset the weakened effect of vehicle speed on dynamic landscape sensitivity [7].

The size of landscape sensitivity (S) in dynamics is closely related to four major factors: vehicle speed (V), the maximum distance (D_{max}) within the driver's front view where objects can be clearly identified, the minimum object scale that can be clearly identified (H_{min}), and the minimum distance (D_{min}) at the side of the road where objects can be clearly identified. Their relationship can be expressed as follows:

$S= f(V, D_{max}, H_{min}, D_{min})$

Based on related research results, to achieve the optimal dynamic landscape sensitivity (S_{max}), there is a certain correlation between different vehicle speeds (V) and D_{max}, H_{min}, D_{min}. Refer to Table 1.

Table 1. Relationship between Vehicle Speed (V) and D_{max}, H_{min}, D_{min}.

V/km* h^{-1}	D_{max} - Maximum clear recognition distance in the front view/m	H_{min} - Minimum object scale identifiable in the front view/m	D_{min} - Minimum clear recognition distance at the side of the road/m
20	150	0.35	1.71
60	370	1.10	5.09
100	660	2.00	8.50
140	840	3.00	11.9

There are many factors causing changes in landscape sensitivity in dynamics. In addition to the four major factors listed in this paper, V, D_{max}, H_{min}, D_{min}, the change in sensitivity is also affected by many uncertain factors such as the slope of the object surface relative to the line of sight, the chance of the object appearing in the field of vision, the color, texture, brightness of the object, and human vision, mood, and weather changes.

As a linear project, highways cross areas with diverse landscape features, water conditions, historical and cultural factors, vegetation conditions, etc. To highlight the features of each section, the entire landscape area can be divided into several small landscape units. Each landscape unit responds to the overall highway style while having its own distinct characteristics.

The purpose of improving and managing visual quality is to improve the quality of visual resources for drivers and create a good, safe driving environment. Visual quality management focuses on: introducing off-road landscapes into the highway, creating a beautiful driving environment, providing rest and parking areas, providing comprehensive service facilities and establishing tourist information centers, and creating a humanized functional space. Highlighting regional features of different landscapes, creating a changing, rich visual experience. Utilizing the embellishment and regulation role of plant landscapes, enriching the highway environment through planting layers, and changes in tree shapes.

Based on this, the author believes that it is necessary to take into account the distinctive aspects of highway engineering and the remarkable attributes of the natural surroundings along the route. This involves the implementation of tolerant subgrade design techniques that are finely tailored to the specific local conditions, including the integration of excavation sites with leveled areas. The author suggests meticulous adjustments in the micro-topography of roadside areas, central dividing zones on the main road, interchange zones, tunnels, building projects, service and parking areas, as well as management centers. This approach aims to craft scenic corridors, restore slopes in a manner that closely resembles natural ecology, and safeguard and transplant indigenous mature trees. It also involves the creation of service facilities that exude a garden-like ambiance. The ultimate goal is to establish a linear and dynamic highway landscape corridor, brimming with distinctive local characteristics.

4. Technology for Creating Beautiful Expressway Environments Based on the Boundary of the Road Right-of-Way Landscape Classification

The landscapes of expressways can be divided into intrinsic landscapes and along-the-line landscapes based on the boundary of the road right-of-way. The intrinsic landscape refers to the landscape within the range of expressway land use, including the roadway alignment, structures, ancillary facilities, bridges, tunnels, etc. The along-the-line landscape refers to the landscape beyond the range of highway land use, which includes different natural and cultural landscapes.

Natural landscapes mainly refer to naturally formed terrains, landscapes, and features, such as plains, mountains, grasslands, forests, oceans, marshlands, etc. Cultural landscapes refer to various buildings, transportation facilities, towns, villages, temples, and other social-cultural artifacts created by humans to meet their material and spiritual needs. This classification method includes all visual information within the highway itself and a certain area along the line. It is suitable for research on the protection, utilization, development, and creation of natural and cultural landscapes within a certain range along the expressway. This is also the classification method adopted in this study, treating the expressway landscape as an objective material system for research, emphasizing the visual environment of the expressway's intrinsic landscape and along-the-line landscape [8].

4.1. Tolerant Subgrade Design Technology

Tolerant subgrade design technology refers to the green highway design concept of reasonably utilizing highway land, integrating cut-and-fill sites with highway subgrade design, to create

resource-saving, environmentally friendly, and ecologically sustainable expressways. According to the new national land use approval policy, organic soil and clay from the mainline dredging should be used for farmland improvement, and the soil from existing wastelands should be used for mainline soft foundation replacement and roadside fill leveling. This approach realizes rational resource utilization. The fill-leveling area can be used for local farming, orchard development, and forest land, creating economic value for the locality, digesting excess earthwork, and avoiding large-scale land requisition for waste soil sites. The excavation leveling area is generally set at low excavation and curve places to increase the driving sight distance, improve the driver's visual sense, and enhance the highway landscape effect. This method reduces the temporary land use of off-line borrow pits, thereby saving land. The fill-leveling area improves the highway landscape, not only counteracting the pressure on the roadbed, increasing the stability of the roadbed, but also improving the local irrigation and drainage system through the fill-leveling area, which reduces the project's own drainage works. As show in figure 1.

Figure 1. Diagram of Tolerant Subgrade Design.

4.2. Landscape Micro-topography Arrangement

During the construction process of landscapes along expressways, the following principles should be adhered to: low and flat slopes should be kept in their original form, while high and steep slopes should be designed with a curved surface, and the foot and top of the slope should be designed to be gentle; the excavation of cut slopes should adopt a streamline method and be properly trimmed to reduce the creation of construction faces; at the same time, excavation and protective greening should be carried out in parallel to restore the natural landscape to the greatest extent and fully conform to the surrounding environment. The landscape micro-topography of the road area is created differently, combining the construction requirements and functional characteristics of roadside, median strip of the main line, interchange area, tunnel, building construction, service area and parking area, management center, and so on. The slopes at the location of the flat curve are excavated to the same elevation as the road surface, broadening the driver's field of vision, increasing the driving sight distance, eliminating safety hazards, and enabling more along-the-road scenery to be seen. The excavation of slopes adopts a streamlined method, and the plant protection of slopes adopts a combination of herbaceous and flowering plants. The interchange nodes are combined with terrain processing to increase the creation of landscape micro-topography. By combining more humanized activities and landscape spaces, the areas with more people flow are added with landscape micro-topography,

making the space more varied and interesting. The full-line filling area is used, combined with the actual size and section theme color, adopting evergreen as the background and flowering groups as the highlight of the planting method. The same planting method is used in the site space, combined with the actual size and section theme color. Through the creation of landscape micro-topography, the cut slope is processed into a face-on curved slope, the excavation method is changed from the conventional knife-cut style to streamline, reducing the construction face, integrating the slope into the natural landscape, realizing the four-season blooming of the slope scenery, beautiful as a painting, blending the scenery into the road. As show in figure 2 and 3.

Figure 2. Landscape Creation for Interchange Areas.

Figure 3. Landscape Creation under Bridges.

4.3. Near-Natural Slope Ecological Restoration

In order to restore the natural landscape to the greatest extent, the conventional knife-cut excavation mode should be changed during highway construction. In the process of slope construction, this project adheres to the principle of "incorporating the road without bringing in destruction", fully conforms to the terrain, adopts micro-treatment design, and refrains from excavating low and flat slopes as much as possible to preserve the original topography. For slopes that need to be excavated, a curved surface design is adopted, which is consistent with the curve of the surrounding mountain peaks, while adhering to the parallel progress of construction and greening. As show in figure 4.

Figure 4. Construction Diagram and Effect Diagram of Near-Natural Slope.

4.4. Protection and Transplantation Techniques for Native Large Trees

Large trees generally refer to trees with a diameter at breast height (DBH) of more than 15cm [9]. Native large trees refer to non-alien large trees, those that have not been transplanted due to human factors and naturally grow in that place. In expressway construction projects, new technologies are applied to carefully transplant valuable native large trees within the red line area. Some large trees are used in the landscape greening project of the expressway after the road construction is completed. This move will become an important measure to protect native vegetation, restore the ecological environment of the highway, and construct a green highway. Through the application of protection and transplantation techniques for native large trees, the local ancient and famous trees are protected, the environmental damage and disturbance caused by highway construction are reduced, and at the same time, the trees become a beautiful scene beside the road.

4.5. Garden Courtyard Landscape Creation Technology

Expressway service areas, toll stations, management centers, and other building areas are important architectural places for external services and internal management use. The comfort of the environment is of great significance to improve the environmental quality of expressways[10]. In areas where conditions allow, garden courtyard design techniques can be used to make full use of the site terrain to excavate lakes and pile up mountains. The existing fish ponds are used to set up artificial lakeside water landscapes. The rainwater in the field is collected as pond water, creating a natural ecological circular environment. For plant greening, the choice of plants focuses on color and seasonal changes, using trees, shrubs, and grasses to create a garden landscape style. Emphasis is placed on the selection of local greening plant species with strong carbon fixation and oxygen release capabilities for greening planting, shaping a comfortable and beautiful garden landscape living and working environment, and increasing the comfort of the field area. In addition, the stones that can be collected from the main line of the highway can be used as landscape stones in the green space of the management center, creating a beautiful and elegant living and working environment. In terms of sponge construction, the management center will collect, purify, and reuse waste water. The site pavement will use permeable materials to put the sponge design concept into practice [11].

5. Conclusion

This study thoroughly discusses the "Tolerant Subgrade Design Technology", "Landscape Micro-topography Arrangement", "Near-Natural Slope Ecological Restoration", "Protection and Transplantation Techniques for Native Large Trees", and "Garden Courtyard Landscape Creation Technology". These techniques can provide references and lessons for the construction of Beautiful China and Beautiful Highways.

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