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A Study on Innovative Design and Application of Noise Barrier from the Perspective of Urban Culture

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Abstract. In recent years, as China's urbanization process accelerates, its urban roads, tunnels and other traffic infrastructure have also been vigorously developing, and its urban road network is becoming perfect. In terms of traffic planning, some first-tier cities in China focus on sound absorption and noise reduction when renovating roads in mature residential areas and commercial districts, so as to protect the environment and ecology of the existing areas. When planning and designing medium-and long-term highways, viaducts and tunnels, they also predict where the sensitive sections will be and take relevant measures to absorb sound and reduce noise. In this context, road noise barrier material is widely used in recent years as the main means of sound absorption and noise reduction. The main materials of noise barrier in China are concrete, ceramic plate and perforated metal plate, which have different characteristics and advantages. However, it is found that the convergence phenomenon exists in most application cases, which is mainly manifested as that most noise barrier projects only meet the basic functional requirements, and appear rough and crude in the performance of modeling language and structural language. With the progress of China's comprehensive national strength in recent decades, national image has become an important window to showcase cultural soft power, and urban infrastructure construction is directly related to the output of urban cultural image. Therefore, the noise barrier not only needs to have the basic functions, but also needs to consider its role in cultural communication as a traffic landscape. In this paper, the innovative design and application of contemporary noise barrier will be proposed from the perspective of urban culture on the basis of taking into consideration user experience.

Keywords. Noise barrier, urban culture, innovative design

1. Research background

In August 2022, the National Highway Network Planning jointly issued by the National Development and Reform Commission and the Ministry of Transport proposed that by 2035, the total planned length of China 's highway network would increase to about 461,000 km, up by about 60,000 km compared with the 2013 version of the planning, including a total planned mileage of 162,000 km of national expressway network (including about 8,000 km of perspective line), the future construction and reconstruction demand is about 58,000 km (including about 30,000 km of expansion and reconstruction), an increase of about 24,000 km compared with the 2013 version; The planned total mileage of ordinary national highway network is about 299,000 km, and

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the future construction and reconstruction demand is about 110,000 km, an increase of about 35,000 km compared with the 2013 version. The integrated solution of comprehensive noise control will become an important focus of traffic construction. In the context of national development and urban innovation, the study of urban human landscape noise barrier will become an important topic of the times.

Most of the traditional noise barriers, with relatively monotonous structure and boring visual effect, are built from the engineering perspective. The application of traditional materials cannot meet the needs of urban development in modern society. The research on the innovative design and application of noise barrier is still relatively scarce in China, and the research on the noise barrier from the cultural perspective is hardly ever seen.

The research in foreign countries focuses on practical application, and the application of noise barrier materials is diversified. For example, Australia MODULARWALLS and Ausgroup, with relatively mature and perfect product system and service process, have relevant technical and service support experience in noise barrier applications in all fields.

Figure 1. Application case of MODULARWALLS and Ausgroup Projects.

2. Research status

Throughout the development history of road noise barrier materials at home and abroad, most of them are innovative materials independently developed by material manufacturers, such as concrete, organic glass, foamed aluminum and so on, which are mainly used as road noise barrier. These materials represent the corporate cultural attributes and social responsibility of their industry. In the use of materials, they either match with traditional noise barrier materials or innovate directly in their own forms. Among them, the material research of foreign enterprises is the most valuable for reference and application.

2.1. Current situation abroad

Germany is the world's most innovative economy and Rohm GmbH is the world's leading supplier of methacrylate chemistry. The Soundstop series of PLEXIGLAS products are widely used in road noise barrier products by taking advantage of the high transparency and high light transmittance of their materials. Soundstop series products focus on driver's sensory experience and urban aesthetics. Its product feature is to reduce road noise by using a whole transparent noise barrier; Moreover, the highly transparent material does not cast a shadow on the road, improving safety and providing better

visibility. Soundstop's application projects are spread all over the world. In the projects for different countries, they fully consider the integration of products and regional culture and the continuation of urban spirit. Fig. 2 shows the project cases in Japan, Germany and South America. One can clearly feel the integration and expression of products and regional culture; as for user experience, there's no sense of disobedience; it fully shows its accurate analysis and positioning of the city images.

Figure 2. Application Effect of Soundstop Series Road Noise Barrier in Different Countries.

The development and application of concrete materials rise in Europe, based on the development history of European building materials. With the production of environmentally friendly and economical innovative concrete at its core, the Austria Rieder Group is one of Europe's leading companies in continuous innovation in construction concrete, road noise reduction and road safety. Guided by materials production and solutions, it gives concrete a new meaning of economy, wisdom, aesthetics and emotion. Among them, sawdust concrete material mixed by sawdust, concrete and minerals is widely used in road and rail transit noise barrier by Rieder.

Rieder's corporate culture is characterized by a combination of tradition and innovation. The product system architect works closely with artists and architects, using their flexible and abstract creative thinking to stimulate the market application of enterprises, so that their products are successful cultural project demonstration cases in the fields of architecture, exhibition hall, exposition, road, etc., as shown in Fig. 3. Based on this, Rieder's road noise barrier field continues the advantage of strong creativity of enterprises, perfectly combines architectural aesthetics with urban landscape, and greatly enhances the visual integration between products and environment by taking advantage of the strong plasticity of concrete. Coupled with the excellent acoustic properties of

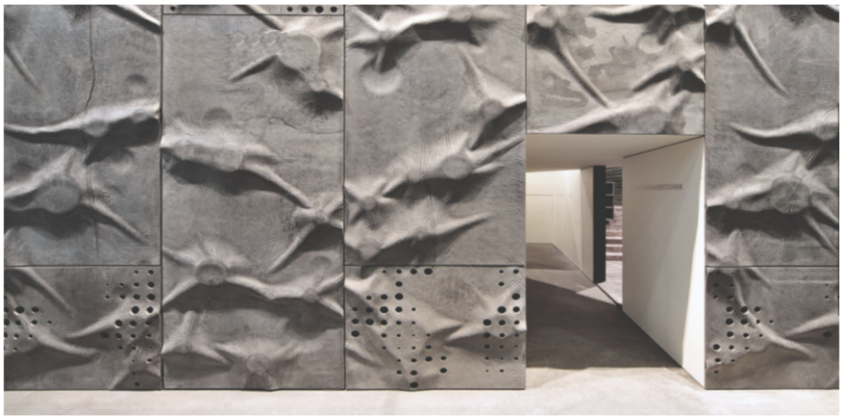

Figure 3. Rieder Sculpture Concrete Building.

wood chip concrete, a supernatural driving experience is formed with art and function side by side, as shown in Fig. 4.

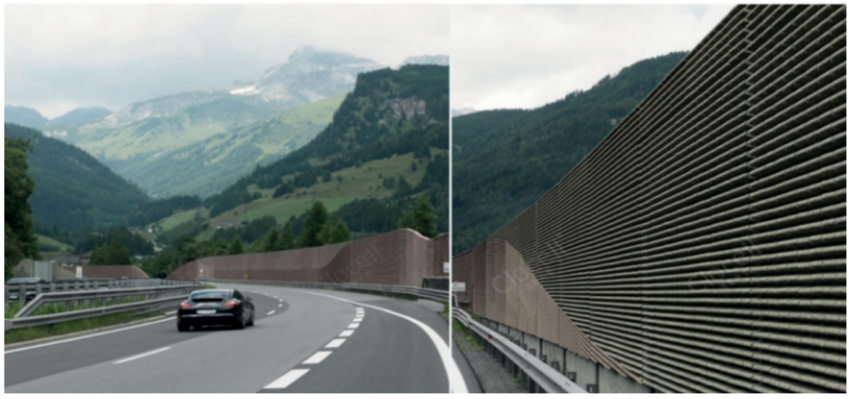

Figure 4. Rieder Road Noise Wood Barrier.

2.2. Domestic situation

China is still in the early stage of traffic noise control. The green plants on both sides of the road, as traffic auxiliary facilities with single visual form, can only meet the basic noise reduction function as noise barriers, while the integration of noise barriers and urban construction, and the adaptability of modeling color and environment have not been fully considered. In the early stage of application, the most common is the simple vertical noise barrier with micro-perforated plate, color steel plate, tempered glass, concrete and other main materials. Among them, the metal noise barrier is easy to rust and steal; its color is the least resistant to ultraviolet ray and easy to fade; the quality of light-transmitting noise barrier products is uneven. Long-term exposure to sunlight will cause yellowing, atomization and poor light transmission-the loss of light transmission after ten years is as high as 6% -20%, and its sound absorption and insulation effect is far from satisfactory, as shown in Figure 5.

Figure 5. Current Situation of Noise barrier in China.

With the rapid development of China's urban transportation development, urban planning and construction, as well as the high-quality projects and highway network construction in the new era, domestic schools and enterprises have innovated and developed a variety of "composite" sound absorption and insulation materials with the support of foreign technologies. At present, the common ones are foam metal, foam ceramic and microporous particle board. These materials themselves highlight active sound reduction and absorption, and sound insulation by noise reduction and absorption

has become a widely used research direction. In addition, most innovative materials have strong plasticity, which not only helps to improve the construction efficiency of the project, but also changes the structure and overall visual effect of traditional plates, shapes artistic urban landscape and promotes the integration of technology and art.

The author has carried out practical design related to MICROCK, a new material, in recent years, and added cultural expression design strategies to the design, which has been applied to good effect in the domestic market. The specific application strategies are elaborated in the following.

MICROCK sound absorption and insulation material adopts the latest technology in Germany, using silicon-based polymerization principle to polymerize sandstone into plate, which not only overcomes the problem of insufficient fire resistance of common sound absorption material, but also provides customized products for low, medium and high frequency absorption requirements according to acoustic design. MICROCK sound absorption and insulation material has remarkable noise control effect. Featuring convenient installation and simple maintenance, it is a novel, green and low-carbon material which can be recycled to saves resources. In September 2014, it passed the appraisal of scientific and technological achievements organized by China High-tech Industrialization Research Association, which concluded that "its overall technology has reached the international advanced level".[2]

MICROCK sound absorption and insulation material selects natural sand, adopts Germany special process to apply an inorganic silicon-based solvent evenly and thinly on the surface of all sand grains, so that a melting and re-solidification reaction occurs between the outer layers of sand grains, thus the sand grains are polymerized together as if they were welded. There are numerous micropores in the microporous rock sound absorption and insulation materials, which are characterized by small pore diameter and irregular pore path. When sound waves pass through the micropores, friction is generated between the sound waves and the air in the micropores, and the sound waves are converted into heat energy to be consumed. In this way, its sound absorption function can be realized.

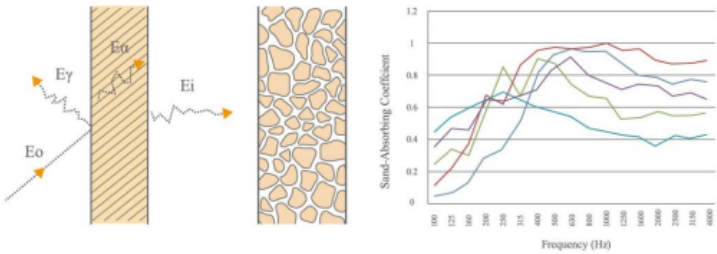

Figure 6. Principle Diagram of Sound Absorption of Microporous Rock.

2.3. Performance comparison of innovative and traditional materials

The MICROCK material mentioned above is selected for a multi-dimensional performance comparison with traditional metal and EPC plate, and the transverse comparison of performance can be used as supplementary data of this study.

[2] Ma Shiyong. New Sound Absorbing and Insulating Material -- Micropore Rock Sound Absorbing and Insulating Plate [J]. New Material Production

It can be found from the data that the innovative material microporous rock is superior to the traditional material in the core data such as noise reduction coefficient, aesthetics, carbon emission, maintenance, cost performance, etc.

Table 1. Performance comparison of innovative and traditional materials

		Innovative materials	**Conventional materials**	
Serial No.	Item	Microporous rock sound absorption and insulation board	Metal panel sound absorption and insulation board	ECP Board
1	Acoustic performance	Noise reduction coefficient: 0.6~0.9	Noise reduction coefficient ≥0.6	No sound absorption effect
		(With sound absorption function; there is no change in sound absorption performance in its whole life cycle)	(Sound absorption cotton is needed; the sound absorption cotton is easy to move and then lose its sound absorption function gradually)	External sound absorption cotton can be used to absorb sound
		Weighted sound insulation ≥30dB	Weighted sound insulation ≥26dB	Weighted sound insulation ≥33dB
2	Mechanical properties	Compressive strength ≥15MPa	It is of hollow structure, resistant to pressure difference and easy to deform under stress	Compressive strength ≥15MPa
		Wind pressure resistance meets JT/T646.4-2016	Wind pressure resistance meets JT/T646.4-2016	Wind pressure resistance meets JT/T646.4-2016
		The impact resistance meets the requirements of impact with energy of 30J±1J	The impact resistance meets the requirements of impact with energy of 30J±1J	The impact resistance meets the requirements of impact with energy of 30J±1J
3	Weight	30kg/m 2	25kg/m 2	≥62kg/m 2
4	Aesthetics	It has various structures, and can be used for manufacturing various embossed patterns according to requirements to meet the ornamental requirements; With rich color, fine and even texture, it fits well with the surroundings	The structure is simple, and its color can also be rich and colorful by spray	The structure is simple, and its color can also be rich and colorful by spray
5	Durability	The ultraviolet-resistant retention rate is more than or equal to 95%; After 25 freeze-thaw cycles, there is no damage such as delamination and cracking	Glass wool is easy to be weathered, and the product is easy to rust.	Good
6	Fire resistance	Fire resistance rating: A2	Class A	Class A
7	Environmental protection	TVOC emission ≤0.15mg/m·h	The surface needs to be sprayed; the internal sound absorption cotton is easy to run off and pollute the environment	Pretty good
8	Construction technology	Mature construction technology	Mature construction technology	Mature construction technology

9	Installation firmness	High installation maturity; the fix module is one time longer than the conventional part, so the safety is improved, and the fixing module is firmer	High installation maturity and good firmness	High installation maturity and good firmness
10	Service life	15 years	15 years	15 years
11	Cost-performance ratio	Higher than similar products	General	General
12	Is it easy to install	Lightweight material, easy to install, can be cut on site	Lightweight material, easy to install, can be cut on site	Heavy material
13	Disassembly and replacement	Easy to disassemble	Easy to disassemble	Difficult to disassemble
14	Maintenance	Not easy to pollute, easy to clean	Easy to rust, difficult to clean	Not easy to pollute, easy to clean
15	Carbon emission reduction	The whole production process is energy-saving and environment-friendly with extremely low carbon emission; Compared with different materials, the CO emission per unit area can be reduced by 47.68 - 196.6kgCOe; It is a green certified product	Both the metal panel and the built-in glass wool need to be heated at high temperature during the molding process, resulting in extremely high carbon emissions	Consolidation requires heating, leading to high carbon emissions

3. User Experience of Noise barrier from the Perspective of Urban Culture

3.1. The connotation of urban culture

Urban culture is the mix of material and spiritual products created by people in the process of the formation and development of cities. It is the overall form of abilities and habits acquired by people living in urban social organizations for a long time.[3] Through the connection and precipitation of time and space, urban culture has its original personality image. Urban noise barrier landscape, as a direct display window of urban image, is the field where the public and urban culture resonate directly. Therefore, in the front end of the design, it is necessary to comprehensively sort out and summarize the historical context and regional information of the city, and excavate the core of the city's cultural spirit; In the follow-up design process, these cultural elements should be transformed and embodied in combination with contemporary aesthetic needs, and solutions should be proposed on the basis of considering factors such as implementation process, modeling language, color elements, cost budget, etc.

[3] Du Xue-na, Yu Fei-yue. Research on Street Landscape Design from the Perspective of Urban Culture [j]. Beauty and Times (urban Edition), 2021(10):107-108

3.2. User experience requirements of noise barrier

Noise barrier users can be roughly summarized into two categories, one is in-vehicle users, including drivers and passengers, and the other is off-vehicle users, i.e. users who can see the noise barrier. Noise absorption and reduction are the basic functional requirements, and the relatively scientific application area of noise barrier can be measured and calculated through the sound absorption coefficient and sound insulation performance of materials. For the first category of people, that is, on-board users, drivers need a safe and stable environment while driving. Noise barrier mostly appears in the form of fragments in expressway, so the visual presentation of sound should be coordinated with the surrounding environment, and at the same time, it should produce changes to bring drivers visual stimulation and pleasure, reduce fatigue and increase excitement; For passengers and users outside the vehicle, besides the auditory experience, the most direct performance is visual experience, and the visual pleasure will act on psychological feeling, which naturally forms the opportunity point of urban culture transmission, that is, the humanistic perception experience from the city image.

3.3. Study on cultural expression of microporous rock noise barrier

In recent years, the author has fully participated in the research and development of MICROCK products. On the premise of ensuring the function, safety and social demand of noise barrier, the flexibility, adaptability and user demand of the design are fully considered. Based on the background of the times and the needs of culture, product designers should grasp the flexibility of design, provide a variety of texture combinations to flexibly meet the needs of different regions and different characteristics, so as to achieve a harmonious integration of commonness and individuality.

From the perspective of regional characteristic culture, the basic functions and decorative role of products are combined into one, and the perfect fit between landscape noise barrier and urban style can be highlighted.

4. Design and application

MICROCK sound absorption and insulation materials are designed for different cities. Based on the research of aesthetics, cultural history and regional characteristics, the appearance of materials is innovated to form a brand-new noise barrier product system. When taking into consideration the material characteristics, the product implementation process and cost factors in the design application as a whole, it can be roughly divided into three-dimensional expression technique, plane expression technique, color expression technique and lighting-based product. In addition, the construction process is optimized. Based on the research on the universal height of noise barrier in different scenes in China, the structure format of noise barrier suitable for specific scenes is formed.

4.1. Three-dimensional expression

Based on the material characteristics of the noise barrier, the realization form of the expression of urban history and culture and regional characteristics in the product has a

broader idea. Plain noise barrier provides an interface for cultural expression of products. Based on the ecological symbol, cultural symbol and architectural symbol of the city, the city graph is extracted and the culture is conveyed in the form of embossment. With layered aesthetic feeling, embossed decoration offers unique advantages in scene atmosphere building, and is more penetrating in the dissemination of urban culture, allowing drivers to get better visual enjoyment on the road.

- Shenzhen Pingyan Expressway noise barrier

Shenzhen is a coastal city in southern China and "water" is one of its most important natural elements. Shenzhen also got its name due to its dense water. It has become an international city after decades of development, which is closely related to its hydrological resources. The form of water is expressed in embossed decoration and sound insulation barrier. The relief decoration vividly reflects the softness and flow of water, endowing Shenzhen urban image positioning of a dynamic capital, with ecological, green and sustainable development.

Figure 7. Noise barrier of Shenzhen Pingyan Expressway.

- Jingyang Section of Xi'an North Ring Expressway noise barrier

Xi'an is one of the four ancient capitals of China and one of the four ancient capitals of the world. As a famous historical and cultural city in China, Xi'an is unique in its history and culture. The urban construction system of the ancient capital city is extracted with modern aesthetic characteristics, and the center of the "geodetic center" spreads around layer by layer. The light and shadow relationship enriches the texture and details of the embossed version; through geometric and symbolic techniques, Xi'an's urban temperament and civilization characteristics are reflected.

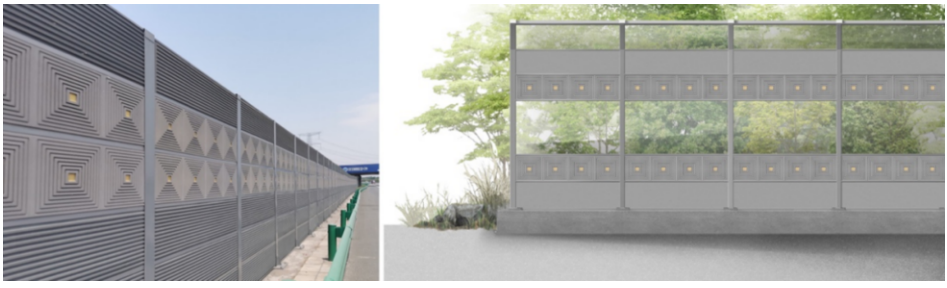

Figure.8 Jingyang Section of Xi'an North Ring Expressway Noise Barrier.

4.2. Plane expression technique

Compared with embossed decoration, the advantage of plane decoration lies in the construction of big vision. The embossed decoration takes a single plate as the creation interface, while the plane decoration takes the whole noise barrier as the design interface for overall consideration.

Take Xi'an Gaoling County noise barrier as an example. During the Ming and Qing Dynasties, Longchang Temple Bathed in Moonlight, Luyuan Waters, Weishui River and Autumn Wind, and Yunhuai Temple were written in Gaoling County Annals as the famous "Four Scenes of Gaoling." However, after a hundred years, the scenery is no longer recorded in history. The visual screen reproduces the beautiful scenery of Gaoling's history with the "four sceneries" as the main content, reflects the geographical characteristics of Gaoling's four sceneries in the noise barrier, and highlights Gaoling's history and culture. The length of the screen gives drivers a stronger visual impact and more clearly reflects the city culture. The visual pattern can form color distinction with the ground color in a more direct manner.

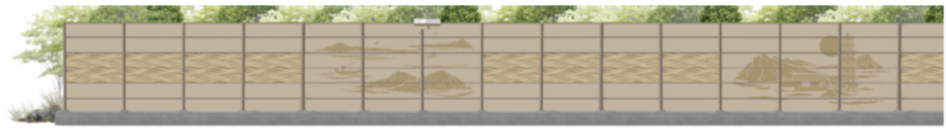

Figure.9 Xi'an Gaoling County Noise Barrier.

4.3. Color expression technique

Color is the impression of a city, reflecting the cultural history of the city to a certain extent. While observing things, the first cause of visual response is color. According to the survey, color accounts for 80% of people's visual attention, shape only accounts for 20%; after two seconds, attention to shape increases to 40 percent, while attention to color drops to 60 percent. After 5 seconds, color and shape each takes up 50%. While driving, people focus a very limited time on roads, so color has a huge impact on attention. [4] Contemporary product innovation attaches great importance to the integration of cultural elements. The reasonable application of color in the product can make people feel the history and culture contained in the product directly, and form the impression of a city psychologically; also, color has a great influence on people's attention. As an integral part of urban road traffic, the safety of noise barrier is also the first concern. Therefore, while choosing colors, much too high saturation should be ignored to avoid visual stimulation on the drivers.

Beijing is the capital of China. It is the political center, cultural center and international communication center of China. Take the color as the clue to refine the ancient capital culture. The architecture of a city is the epitome of the city's cultural life. "Blue bricks and grey tiles" are the condensed features of old Beijing architecture. The blue bricks of different depths and scattered arrangement have built up the history of Beijing and represent the value orientation of a generation. The design of the noise barrier in the south extension of Wanshou Road, South Fourth Ring Road is purely from the color performance, which is to refine the gray of "blue brick and gray tile"; In the

[4] Feng Shufen. Color Psychology and Safety of Urban road Landscape Design [J]. Art Education Research, 2014(22):82+84

decorative language, the form of plain surface is maintained, reflecting the simplicity of the gray wall; In terms of arrangement, modern waves with a sense of rhythm are employed, reflecting a rhythm and conveying the charm of the ancient capital in a modern form.

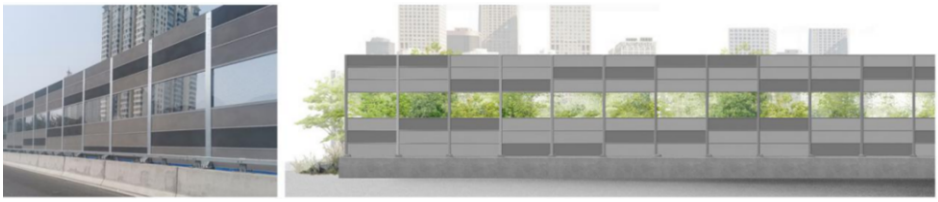

Figure.10 South Extension Noise barrier of Wanshou Road, South Fourth Ring Road, Beijing.

4.4. Lighting-based product

- Beiqing Road Landscape Noise Barrier

Beiqing Road of in Beijing is the core skeleton of road network in the northern region with the leading functions of scientific and technological innovation and cultural center. It is an important fast channel for the development of traffic links among the new highland of "three cities." The positioning of the key road of scientific and technological innovation in this section is of epoch significance. In order to show the theme of scientific and technological innovation, the facade of noise barrier of this section is planned during design and application. The scheme adopts modern geometric figures with progressive size and arranges decorative belts with a sense of speed. The combination of modern decorative patterns and lighting decoration highlights the sense of modernity and science and technology, successfully creating the concept of "Scientific and Innovative Corridor", which optimizes the city image while meeting the sound insulation demand.

Figure.11 Beiqing Road Landscape Noise barrier.

- Beijing East Sixth Ring Road Tunnel

After investigation and study, it’s found that after entering the tunnel, the space is relatively closed, and the driver's visual field is controlled in a tubular space. In such an extremely monotonous environment, driving is easy to produce visual fatigue. When the continuity of the driver's field of vision is obstructed by the external environment, they logically need a visual compensation. If this visual coherence is not compensated in time inside the tunnel, they will naturally seek it outside the tunnel, which makes it easy for them to escape and subconsciously raise the speed to look for visual coherence as quickly as possible. This situation may easily lead to violation of regulations, over speed, or even excessive speed, which may cause accidents. The deeper the tunnel, the more obvious

this is. In order to solve this phenomenon, the product is combined with the light. Three kinds of sound insulation boards with different depths are used in the tunnel for color jumping strip to produce visual jumping, so that the tunnel space produces rich visual effect of vigorous layers, and the fatigue of drivers due to closed space can be relieved.

Figure.12 Beijing East Sixth Ring Road Tunnel.

5. Conclusion and prospects

In the design work, the road landscape noise barrier not only needs to coordinate with the architectural environment, style, and decoration language, the harmonious relationship between nature and humanity also needs to be further considered. Integration and systematization of spaces, decoration and other visual elements, as well as a focus on details, will become the trend of future development. The method of combining urban culture planning and design will also solve the relevant design and practice problems of road landscape noise barrier more scientifically and systematically.

It is hoped that by systematically combing the urban culture, this paper can empower the continuation of urban spirit and the dissemination of urban culture, jointly create beautiful urban landscape, and improve the travel experience and quality of life of Chinese residents.

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