



# Design Method and Engineering Application of new Music Road Surface Structure

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**Abstract.** The music highway is a creative road design that has gained a lot of attention recently. It incorporates musical elements into the surface of the road so that when a vehicle passes on the road at a certain speed, the friction between the wheel and the surface can produce particular musical melodies. This essay provides an overview of the idea, the state of play, and the direction that music highway development is headed. A design method for music roads is put forth using road groove structure, which also summarizes the application status of music highway engineering both domestically and internationally. It also discusses the potential role that music highway engineering may play in enhancing public spirituality and cultural life, advancing the growth of the music industry, and raising the standard of urban culture. This article intends to provide technical recommendations for the planning and development of music highways in China by analyzing the features and potential benefits of music highways.

**Keywords:** music road; surface structure; design method; pavement characteristics

## 1 INTRODUCE

### 1.1 Definition and Concept of Music Highway

According to statistics from the Chinese transportation department, over 60% of traffic accidents are related to fatigue driving or speeding. Among them, North China Expressway Co., Ltd. conducted an analysis and research on traffic accidents on the Beijing section of the Beijing Tianjin Tang Expressway and found that fatigue driving ranks first among the causes of traffic accidents, accounting for 27% of all traffic accident causes. Therefore, how to effectively reduce speeding and fatigue driving is the key to ensuring driving safety. Music highway, also known as singing highway or music road, is an innovative road design concept that integrates musical elements into the road surface so that the friction between the wheels and the road surface produces a specific musical melody when the vehicle passes at a specific speed. This design is based on the

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principle of combining musical elements (such as pitch, length and timbre) with a special texture of the road surface, by adjusting the texture interval, depth and shape of the road surface, the vehicle produces a corresponding musical effect during the driving process. The concept of music highway is to combine music with road design, breaking the single function of traditional roads and bringing a new experience to people's travel. This design not only improves the interest and attractiveness of the road, but also enriches people's spiritual and cultural life and improves the cultural quality of the city [1]. The emergence of music highway provides a new opportunity for the development of music industry and becomes a unique cultural tourism resource. The theory of music highway was first put into practice in Japan. In November 2004, Japan's first music highway was built and opened to traffic by Shinoda Industrial Co., Ltd. on the road of Kotsu-Machi, Hokkaido, Japan. Shinoda applied for a patent on the construction method of music highway in 2005, and was approved by the international patent in 2006. In 2011, it obtained the approval of a Japanese patent, and in 2005, it applied for a trademark patent for music road, which was approved in 2006 [2]. Figure 1 shows the Music highway in Denmark and Figure 2 shows the Music highway in Japan. Overall, it can be be concluded that the mechanism of music road surface sound is the regular vibration of the tires caused by the collision between the rolling tires and the road groove structure during the driving process of the car, resulting in a fixed frequency audio. Music road surface can be transformed from chaotic noise into beautiful melodies through the macroscopic structural design of the road surface (see Figure 3)[3].

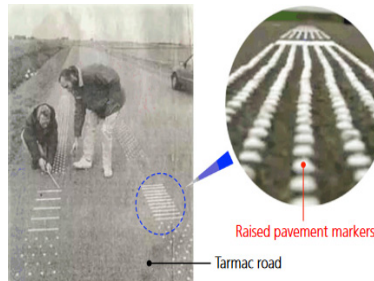


Fig. 1. Music Highway in Denmark



Fig. 2. Music Highway in Japan

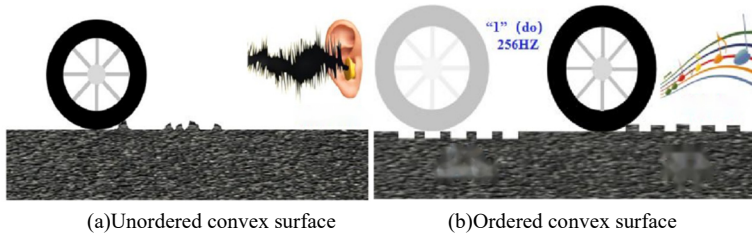


Fig. 3. Music Road Principle

## 1.2 Research Status of Music Highway

The idea of music highway was first proposed by a Japanese man named Shinotsuo Joda, who accidentally used a bulldozer to run some debris into the road, and when he drove by, he accidentally heard various sounds coming from under the car. Later, engineers in Sapporo, Japan, improved Joda's design and developed this new technology. Denmark is the first country in the world to officially have a music road, as shown in Figure 1. In October 1995, Danish artists Steen Krarup Jensen and Jakob Freude-Magnus coded music and tones into the road surface, called Asphaltphone. Use parallel ripples on the asphalt. They used a series of raised pavement markings (similar to Botts dots), arranged at alternating intervals, which, when driven over at a certain speed, produced a simple four-tone horn, the first artistic attempt to make the road play music. In 2007, the National Industrial Research Institute of Hokkaido, Japan, conducted a study on the music highway, and they found that the grooves are cut at a specific distance on the road surface. The closer the grooves are, the greater the sound audio generated by the contact between the tire and the grooves, and the higher the pitch of the sound. Then the comfort and pleasure that music highway brings to driving [4]. In 2012, Liu et al.[5] proposed a grooving machine to cut square grooves on the road to achieve the issuance of road music. The width of the groove is 0.8~1.2cm, and the depth is 0.5~1cm. The groove spacing is equal to the design speed of the car (m/s) divided by the frequencies corresponding to the seven basic notes in the simplified score of the song. Nakajima et al.[6] calculated tire vibration noise by combining finite element and boundary element methods, analyzed tire vibration response in finite element software, and substituted it as boundary condition into boundary element to calculate sound pressure.

## 2 DESIGN METHOD OF MUSIC HIGHWAY

### 2.1 Production Mechanism of Music Pavement

The music road surface and the acoustic-vibration belt have the same place, but also have a big difference, the arrangement of the acoustic-vibration belt is single, the plane is arranged a concave or convex convex vocal cord that is always perpendicular to the direction of the road, and the audio frequency of the sound is single, often noise. Music road makes use of the connection between the tire and the road in the process of noise generation, using regular Angle or smooth grooves or convex grooves, when the vehicle

passes through the road, the tire and the road contact different frequencies of sound, after special design to form music, more humanized. Grooves of different widths, depths and spacing are laid on the road surface, and the contact between the tire and the road surface and the vibration sound of air holes are generated, and the sound of different frequencies [7-8] is generated by the contact between the tire and the grooves. Figure 4 is the schematic diagram of the musical road marked by rows.

The boundary condition of tire road noise is the external sound field, while tires and road surfaces are generally considered as a closed space, and the sound field outside them is called the external sound field. There are three conditions on the structural boundary of the tire: continuous sound pressure condition, continuous speed condition, and impedance boundary condition.

For the Helmholtz equation, the weight integral in the sound field  $V$  can be expressed as:

$$\int_v \tilde{p}(\nabla^2 p(x, y, z) - k^2 p(x, y, z) + j\rho_0 \omega q(x, y, z)) dV = 0 \quad (1)$$

According to the Gauss integral theory, the formula is transformed to obtain:

$$\int_v (\nabla \tilde{p} \nabla p) dV - \omega^2 \int_v \int (\frac{1}{c^2} \tilde{p} p) dV = \int_v j\rho_0 \omega \tilde{p} q dV - \int_{\Omega} (j\rho_0 \omega \tilde{p} v \bullet n) d\Omega = 0 \quad (2)$$

The frequency of the sound is determined by the circulation of the grooved pavement structure, assuming that the vehicle speed  $v$  is constant, the grooves of the road are equally spaced, and the time for the vehicle to pass through the single grooved structure

$$T = l/v \quad (3)$$

Where  $l$  is the length of the adjacent groove structure,  $v$  is the running speed;

Frequency

$$f = 1/T \quad (4)$$

So music pavement plays music that is broken down into a series of single notes. According to the specified speed  $v$  and note frequency  $f$ , the spacing of two adjacent notched lines  $l$  is calculated through this relationship. The specific formula is

$$l = v/f \quad (5)$$

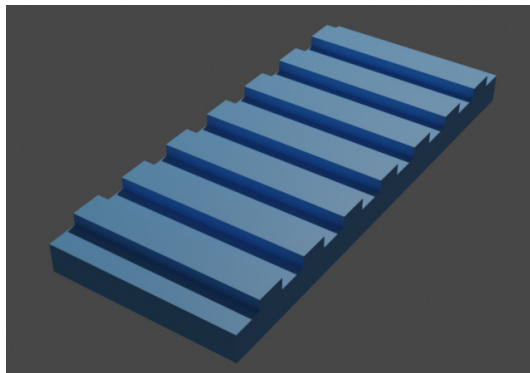


Fig. 4. schematic diagram of the musical road

Assuming the vehicle is traveling on the road at a speed of 40km/h, calculate the road construction parameters corresponding to the notes, and the results are shown in Table 1

**Table 1.** Music pavement construction parameters

Key number	Frequency/Hz	Groove spacing/mm
49	440.00	25.25
50	466.16	23.84
51	493.88	22.50
52	523.25	21.23
53	554.37	20.04
54	587.33	18.92
55	622.25	17.86
56	659.26	16.85
57	698.46	15.91
58	739.99	15.02
59	783.99	14.17
60	830.61	13.38

From the table, it can be seen that the higher the frequency, the smaller the gap between grooves, and the denser the grooves; Based on the beats of each note obtained from the sheet music, the required construction parameters can be calculated, such as the length of the road segment and travel time required for each note, to facilitate construction.

## 2.2 Steps of Design

Determining the level and shape of pavement texture in music pavement design is a tough task that must take into account a variety of factors such as safety, vehicle speed, pavement material, and musical melody. Here are some important activities and ideas to consider about:

(1) Music melody analysis: First of all, the designer needs to analyze the pitch, length, timbre and rhythm of the selected music melody in detail. This will help determine the design parameters of the pavement texture.

(2) Vehicle speed: The designer needs to understand the speed range of the vehicle in a specific section of road. Musical road texture should be designed to ensure that the desired musical effect is produced at different driving speeds.

(3) Pavement material characteristics: Different types of pavement materials (such as asphalt, concrete, special synthetic materials, etc.) have different requirements for the depth and shape of the texture. Designers need to consider the wear resistance, elasticity, compressive strength and other factors of the material to determine the appropriate texture design.

(4) Safety assessment: The design of the music road texture must ensure driving safety. Designers need to assess the impact of texture depth and shape on vehicle stability and the driver's line of sight, and take steps to reduce potential safety risks.

(5) User experience: Designers need to consider the experience of different users, including drivers and passengers. The texture should be designed to minimize interference with driving comfort and sight lines.

(6) Experiment and test: Before the actual construction, designers usually conduct small-scale experiments and tests to verify whether the texture design can produce the expected musical effect. This may involve simulated vehicle driving trials and field tests of music effects.

(7) Adjustment and optimization: Based on the results of experimentation and testing, the designer may need to adjust the depth and shape of the texture to optimize the musical effect and ensure safety.

### **3 Application of music highway engineering at home and abroad**

#### **3.1 Application of Music Highway Engineering in Foreign Countries**

In 1995, Giring, Denmark, built the world's first road capable of emitting short musical melodies. The road was built by Danish architects Jacob Freude-Magnus and Steen Karup-Jensen, and although the Asphaltophone has already been paved over the road, it is so short in length that they see it as an artistic design experiment. This idea was not widely used and developed at that time. In 2004, Japanese company Shinoda built the world's first true music road with a length of 500 meters. After the rise of Japan, the United States, South Korea and other major countries have also begun to build music roads, of which Japan has built more than 30 music roads, these examples of construction mark the construction of music road pavement ushered in a new period of development. In 1995, Giring, Denmark, built the world's first road capable of emitting short musical melodies. The road was built by Danish architects Jacob Freude-Magnus and Steen Karup-Jensen, and although the Asphaltophone has already been paved over the road, it is so short in length that they see it as an artistic design experiment. This idea was not widely used and developed at that time. In 2004, Japanese company Shinoda built the world's first true music road with a length of 500 meters. After the rise of Japan, the United States, South Korea and other major countries have also begun to build music roads, of which Japan has built more than 30 music roads, these examples of construction mark the construction of music road pavement ushered in a new period of development.

#### **3.2 Chinese Music Road Application**

In China, the construction of music highway has also made some progress. For example, Change City, Henan Province, has the country's first music highway, the music road is more than 300 meters long, two sides of the music road, the music design of the

north side is "March of the Volunteers", the music design of the south side is "Jasmine flower". In Beijing, the first music highway is located in Qianling Mountain scenic area of Fengtai District. When the car drives at a constant speed of 35 to 40 kilometers per hour across this special road of more than 300 meters, the friction sound of the car tires and the ground will become a 30-second "Ode to the Motherland", and the music highway in Yantai City of Shandong province will play "Carmen" and "Ode to Joy". In addition, Yangzhou city also plans to build the country's first music highway with accompaniment.

## **4 ADVANTAGES AND FUTURE DEVELOPMENT OF MUSIC HIGHWAY**

### **4.1 Characteristics of Music Road**

(1) Creativity and innovation: The design of music highway combines music with road construction to create a unique driving experience, breaking through the single function of traditional roads and providing people with a novel way to travel.

(2) Fun and interactive: The design of music highway enables drivers to experience unique music feelings in the process of driving, improving the fun and attraction of the road, and enhancing people's sense of participation and experience.

(3) Cultural and local characteristics: The design of music highway often integrates local cultural elements and musical styles, reflects regional characteristics and cultural heritage, and becomes an important carrier to display local culture.

(4) Sustainability and environmental protection: The design of Music highway focuses on environmental protection and sustainability, and reduces the impact on the environment through the use of environmentally friendly materials and design concepts, which is in line with the pursuit of green transportation in modern society.

(5) Educational and popular: the design of music highway can be integrated into music education and popular science knowledge, so that people can understand the basic knowledge of music and improve music literacy while enjoying music.

(6) Entertainment and sociability: The design of music highway can become a good place for people's leisure and entertainment, where people can take photos and share, enhance social interaction and improve the quality of life.

(7) Safety: The design of musical highway pays attention to driving safety. Through reasonable design of road texture and music rhythm, driving fatigue is reduced and driving safety is improved.

### **4.2 Development Trend of Music Road**

The future development trend of music highway is mainly influenced by digital technology and innovation. With the development of virtual reality (VR) and augmented reality (AR) technologies, Music Highway will be able to provide a more immersive experience. From songwriting to performance, AI-driven tools will assist artists,

streamline the creative process, open new possibilities for artistic expression, and expand the accessibility of music production. These trends suggest that the future of music Road will focus more on technological innovation, immersive experiences, and direct interaction with the driver. As technology advances, the way music is created, distributed and experienced will also change dramatically.

## 5 CONCLUSIONS

Music highway integrates music elements into the road surface, so that when the vehicle passes at a specific speed, the friction between the wheels and the road surface will produce a specific music melody, highlighting the cultural characteristics of the highway. This paper conducts a systematic research on the relevant conceptual theory of music road surface and the design method of sound groove, summarises the concept, current situation and future development trend of music highway, establishes the relationship between the groove spacing of the road surface and the musical notes, puts forward the design method of music highway, and sums up the current situation of the application of music highway projects at home and abroad. The potential role of music highway in enriching the spiritual and cultural life of citizens, promoting the development of music industry and improving the cultural taste of cities is discussed.

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