Bridge Expansion Joints Cleaning Device Based on Design of Temporary Deceleration Belt

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Abstract. The bridge expansion joints are an important structure of bridges, and its cleaning work is also important. The common way of cleaning is manual cleaning now, which has low cleaning efficiency and will bring obstacles to the traffic. Therefore, we propose a bridge expansion joints cleaning device which imitates the design of temporary deceleration belt. The innovative design of temporary deceleration belt slide can be laid on the expansion joint. The cleaning tools can move to a position through the slide rail, and the internal design of water cannons is used for flushing, so as to achieve an efficient cleaning of expansion joints without affecting transportation.

Keywords: bridge expansion joints; temporary deceleration belt; efficient cleaning.

1. Research background

Bridge expansion joint is a kind of structure that can freely expand due to the influence of temperature, concrete shrinkage, creep, and live load, and ensure the service life of the bridge. It is of great significance in roads and bridges engineering.

However, a large amount of sand, stones, cigarette butts and other small garbage will be brought into the expansion joints in the running process of vehicles. At present, most of the bridge expansion joints are cleaned manually, but the disadvantages of manual cleaning are as follows:

1) The cleaning work is heavy. Taking Xiamen, China as an example, the total number of bridges managed by the Municipal Highway Bureau is 79, with a total length of 58601.742 meters. Each expansion joint on the bridge needs to be cleaned at any time according to the maintenance situation.

2) In the process of manual cleaning, bridge closure is often needed, which brings great obstacles to the traffic, and the decrease of traffic flow directly damages the economic benefits;

3) When the staff cleans the expansion joint, there is a big traffic safety hazard;
If the garbage in the expansion joints isn’t cleaned in time, it is easy to reduce the life of the expansion joints and damage it in the process of squeezing each other on both sides of the bridge deck. [1]

The damage of bridge expansion joints is easy to cause deformation of the bridge deck, affect traffic safety and cause different degrees of economic losses. The impact of vehicles on the expansion joint structure will affect the stress of structure of the bridge and reduce the life of bridge. Therefore, once the expansion joint is damaged, it needs to be replaced. But the replacement of the expansion joints is more cumbersome, and will further affect the normal traffic. [2]
Many cities in the municipal work discussion and arrangement have mentioned to carry out bridge expansion joints cleaning work regularly to ensure the normal use of bridge. In order to solve the contradiction between the urgent needs of municipal bridge expansion joints cleaning and the existing inefficient cleaning methods, and to reduce the contradiction between the cleaning of bridge expansion joints and the normal traffic operations or the staff's own safety, we design a bridge expansion joints cleaning device based on design of temporary deceleration belt.

2. Total solution

2.1. General work introduction

The bridge expansion joints cleaning device designed in this project is shown in Figure 5. The overall modeling including trapezoidal slide rail module, cleaning and maintenance module, tool conversion module, etc. The placement scene of device is shown in Figure 6:

![Figure 5](image)

Figure 5 Overall schematic diagram of the device

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![Figure 6](image)

Figure 6 Schematic diagram of placement scene

After the device is fixed in a specific position, the trapezoidal slide rail module covers the entire expansion joint. The upper part is designed with a water cannons, which can flush the impurities in the expansion joint. The sand and gravel inside the expansion joint is cleaned by cleaning the maintenance module; after cleaning, the rubber water stop is protected. The tool conversion module is used to switch tools to change the two working-states.

2.2. Design of trapezoidal slide rail module

Temporary speed bumps are common in the construction sites of highways and bridges. It can not only reduce traffic impacts, but also remind the drivers to control the speed of vehicles. When cleaning the bridge expansion joints, it is also necessary to control the speed of vehicles. Because of the frequent cleaning, the traffic can’t be greatly affected in the working process. The design of temporary deceleration belt can solve this problem better.

The trapezoidal sliding rail module is shown in diagram group 7. The module is composed of trapezoidal shell, sliding rail, water cannons and internal slider.
Figure 7 trapezoidal slide module diagram

The hollow part is used for placing the sliding rail and slider, and the contact position with the bridge is made of ZYY composite anti-skid material. The slide rail is fixed inside the trapezoidal shell, and there are two pairs of wheels on the sliding block, which are stuck in the specific position of the slide rail. The whole cleaning part can be moved back and forth by controlling the rotation of the wheel.

The distribution order of sliding rails is: first level the trapezoidal slide at the front end, then level the rear slide rail, push the first slide rail forward, and so on.

A number of water cannons are designed beside the sliding rail, and these water cannons are connected with the external water tank through the designed internal pipes. The water in the tank flows to the booster pump. After the booster pump, the water pressure increases and shoots into the expansion joint to flush sand and gravel.

2.3. Design of cleaning and maintenance module
As shown in diagram group 8, the cleaning and maintenance module is composed of slotting and soil breaking part, cleaning wiper part and talcum powder spraying device.

Figure 8. Schematic diagram of cleaning and maintenance module

The slotting and soil breaking part is shown on the left side of diagram group 8, which is combined with the high-pressure water gun to break the sediment at the expansion joint opening for cleaning; the cleaning wiper module is shown on the right side of diagram group 8 to clean up the residue that has not been washed off; the talcum powder spraying device can carry out the last step of maintenance after cleaning.

2.3.1. Slotting and soil breaking part. The slotting and soil breaking part is composed of rotary knife and slotting-plough.

The surface of the rotary knife is provided with a plurality of convex structures, and the middle part is connected with the motor. The rotary knife can rotate at high speed, which produces a large impact force on the sediment and completes the first step of crushing work. [6]

The slotted plough is located at the rear, with sharp front and can move with the sliding block. The combination of the two can make the sand break more fully.
2.3.2. **Clean the wiper section.** The cleaning wiper is composed of rotary cleaning brush and rubber wiper.

The rotary cleaning brush is made of hard plastic, which can rotate under the drive of the motor; the rubber wiper is used to scrape away the residue that has not been washed out, so as to prevent the residue from remaining and causing greater impact on the expansion joint. The wiper scrapes the residue to the outlet of the expansion joint and is discharged with the water flow.

This part is mainly composed of arc-shaped soft rubber structure and connecting shaft controlling rotation. The curved soft rubber structure adapts to the groove of the water stop belt; the connecting shaft can fine tune the position of the two wipers. The combination of the two can improve the cleaning effect of residues.

2.3.3. **Talcum powder spraying device.** Talcum powder is a kind of odorless, tasteless, white, fine and sand free powder. It is soft, delicate, stable and easy to cover. It can increase the stability of the product shape, reduce the deformation of rubber products and delay the aging time of rubber products when coated on the surface of rubber products.\[4\] Talc powder is very common, low price, good dispersion in the rubber, it is very suitable for the maintenance materials used in this project.\[5\]

The talcum powder spraying device is located on the trapezoidal slide rail. The talcum powder stored inside is mixed with liquid, which is easier to spray. The use of large diameter nozzle can prevent the nozzle from clogging.

2.4. Design of tool switching module

The tool switch module is shown in Figure 9:

![Figure 9 schematic diagram of tool switching module](image)

The module is mainly composed of tool connection position, rotary disc, control shaft disk. The tool connection position is used to connect the two cleaning tools. The rotating disc is installed on both sides of the control shaft, and can rotate synchronously under the control of the stepping motor. The control shaft disk and the rotating disk are connected by intermittent structure.

When the rotating disc rotates one turn, the control shaft plate rotates 90 degrees. When the rotating disc rotates for 2 turns, the tool switching can be realized.

3. **Feasibility analysis**

3.1. Feasibility analysis of the design

The moving track adopted by the device is in the shape of a ladder. Now, the feasibility of the vehicle passing through the ladder track will affect the normal operation of the trapezoidal track.
Supposing the mass of the daily car is \( m \), the speed change caused by the deceleration belt to the vehicle is \( v \), the time of applying pressure on the side of the slide rail is \( t \), and the pressure is \( f \). According to the formula:

\[
F \times t = m \times v
\]

According to relevant data and statistical data, the weight of a common car is about 1.500 tons. When the car passes through the deceleration strip, the speed reduction caused by the deceleration strip is about 7.200 meters per second, and the pressure time is about 1.200 seconds. According to the calculation, theoretically, the pressure of automobile on trapezoidal slide rail is 9000N.

The trapezoidal slide rail is regarded as a particle, and the antiskid coefficient of ZYY composite anti-skid material is \( \mu \), and the angle between the trapezoidal slide rail side and the horizontal plane is \( \theta \). The pressure on the ground caused by the mass of the trapezoidal slide rail is smaller than that caused by the vehicle, so only the vehicle part is considered. The sliding friction force between the ground and the trapezoidal slide rail is \( f \). According to the formula:

\[
f = \mu \times F \times \cos \theta
\]

According to the inquiry data, the anti-skid coefficient of ZYY composite anti-skid material in dry state is 0.857; in wet state, it is 0.739 \([3]\). The angle between the trapezoidal moving module side and the ground is 30. According to the calculation, the friction between the ground and the sliding rail is about 6679.654N in dry state and 5736.552N in wet state.

Let the impact force of the vehicle on the slide rail in the horizontal direction is \( F_X \)

\[
F_X = F \times \sin \theta
\]

According to the calculation, the impact force of the car on the slide rail in the horizontal direction is \( F_X = 4500N \).

Through the comparison, the friction force between the ground and the slide rail is greater than the horizontal impact force of the car on the slide rail. Therefore, the impact of the car passing on the normal operation of the slide rail is small, and the design is feasible.

### 3.2. Benefit analysis

The sediment cleaning effect of the device is analyzed.

Taking a cleaning operation of a municipal company in Xiamen as an example, the traditional manual method takes about 10 minutes to clean an expansion joint (12m), and it often requires 3-5 people to operate. Suppose ‘a’ is the length of an expansion joint, ‘b’ is the width of the expansion joint, ‘h’ is the height from the bridge deck to the rubber waterstop of the expansion joint, and ‘v’ is the volume of highway garbage cleaned by traditional methods per minute

\[
v = \frac{a \times b \times h}{t}
\]

According to the national standards, the width of the expansion joint is generally 2-10 centimeters, and the height from the bridge deck to the rubber waterstop of the expansion joint is generally 5-10 centimeters. The volume of highway waste cleaned by traditional method per minute is \( v = 0.012 \text{ m}^3 \).

It takes about 3 minutes to clean an expansion joint with the device, which improves the cleaning efficiency by 70%. The volume of highway garbage that can be cleaned up more per minute by using the device is as follows:

\[
\sigma = 0.012 \times 70\% = 0.0084\text{ m}^3
\]
Through calculation, it can be seen that the device can greatly improve the efficiency of road waste cleaning, and at the same time, it can cost fewer human resources.

4. Conclusion
The innovative trapezoidal track can be laid on the expansion joint, and the internal cleaning and maintenance tools can move along the track to clean up the garbage in the expansion joint. Compared with manual cleaning, this work is more efficient and can reduce the impact on traffic. Through theoretical analysis, it is proved that the device will not affect the normal operation of the device when the vehicle passes through, and the cleaning efficiency can be guaranteed, which can be widely used in the maintenance of roads and bridges.

Acknowledgments
National innovation and entrepreneurship training program for college students S202010497080

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