Optimum Study of Electric Electrode of Conductive Asphalt Snowmelt Pavement Based on the Melting Effect

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Abstract: The design and optimization of electrode is the key work in the design of conductive asphalt concrete structure. On the basis of preliminary experimental research, two most representative electrode forms were selected for influencing factor analysis and optimization scheme design. Then the distance, length and material of electrodes were changed respectively to compare the snowmelt effect of conductive asphalt specimens. The optimization results demonstrate that copper is selected as the electrode material, considering the cost and the influence of the later stage on the pavement performance, single beam copper electrode is recommended as the best electrode form, with spacing of 4cm and the heating effect of asphalt pavement is the best. The relevant research results provide data reference for the engineering application of conductive asphalt concrete.

1. Introduction
Because the asphalt concrete material itself is a kind of bad conductor, the resistivity of the asphalt concrete mixed with the conductive phase is significantly reduced. At this time, the electrode design is the core of the conductive asphalt concrete pavement design, which will directly affect the cost of the conductive asphalt concrete pavement and the use quality in the later stage, and it is also the key work of large-scale promotion of such technology in the later stage of engineering practice [1].

The conductive asphalt concrete has its own conductive capacity, so it is necessary to optimize the electrode design of the conductive asphalt concrete based on the conductive mechanism of the conductive asphalt concrete, study the optimal form of electrode layout, and propose the electrode optimization scheme that can effectively improve the conductive performance of the asphalt concrete, and at the same time reduce the electricity. The processing cost of electrode can reduce the damage and failure of electrode during the construction of asphalt concrete pavement, and ensure good durability after the pavement is opened to traffic, which is of great value for the promotion and application of conductive asphalt concrete in the future.

2. Conductive mechanism of conductive asphalt pavement
The electrical resistance of asphalt concrete itself is large. After adding graphite inside, if the content of graphite is small, the graphite particles exist in the form of isolated or small collective, the particle
spacing is large, and the overlap is small, so the conductive chain and network cannot be formed. After adding carbon fiber, the material has conductivity and certain fiber length, so it provides convenient conditions for forming conductive network. On this basis, copper fiber is added, and several conductive phases form conductive chain in asphalt concrete [6]. Graphite particles are dispersed in the voids of asphalt concrete as fine fillers. Carbon fiber has a certain length of conductive phase. As the main component of conductive connecting skeleton, the existence of copper fiber can further improve the conductivity of asphalt concrete, and strengthen the structural skeleton of asphalt concrete, which has the effect of improving its high and low temperature stability. If the resistivity of asphalt concrete is less than the current seepage threshold, then asphalt concrete becomes a stable conductor.

3. Optimum design of conductive asphalt concrete electrode

3.1. Electrode form
On the basis of the electrode design of conductive asphalt concrete which has been completed before, two kinds of conductive system forms, transverse single beam and transverse plate metal are selected to optimize the electrode form design. The arrangement of electrodes inside the test piece is shown in Figure 1 and Figure 2.

![Figure 1 Layout of single beam electrode](image1)
![Figure 2 Layout of plate metal electrode](image2)

3.2. Comparison of heating effect of different electrode materials
In order to facilitate the specimen processing and horizontal comparison, the indoor scale model test method is adopted in the comparative test, and the asphalt rutting specimens with different materials and electrodes are made respectively, with the specimen size of 300 × 300 × 50mm. In order to compare the conductive effect of different electrode materials, copper wire, aluminium wire and steel wire are selected as the main electrode materials, which are buried in the asphalt test piece in the way of 5mm diameter single beam electrode. The electrode spacing is 4cm, input 36V DC power supply and conduct test. The initial temperature value of the test piece is selected as - 5 ℃, and temperature data are collected every 12min. The time temperature curve obtained is shown in Figure 3.

![Figure 3 Heating time temperature contrast curve](image3)
The test data shows that under the same heating time, because of the high conductivity of copper, the temperature rise value of copper electrode is the highest, followed by aluminium electrode, because the conductivity of steel is the worst among the three materials, the temperature rise value of steel electrode is the lowest, and the temperature of the sample heated for 120 min is still near 0 ℃. Therefore, copper is an ideal electrode material for conductive asphalt concrete pavement.

3.3. Comparison of heating effect of different electrode spacing

The electrode spacing has a great influence on the snow melting performance of conductive asphalt concrete. If the distance is large, the heating efficiency of the road surface will be low. At this time, the asphalt pavement cannot be heated smoothly, and the snow will not melt smoothly. If the distance is too small, it will cause waste of electrode materials, improve the construction difficulty of the road surface, and increase the construction cost of the road surface. In this paper, the test pieces with different electrode spacing are designed and manufactured. The electrode diameter of single beam electrode is 5mm, and the electrode spacing is 2cm, 4cm, 6cm and 8cm respectively. The initial temperature value of the test pieces is chosen as -5 ℃, and the time temperature distribution diagram under different electrode spacing conditions is drawn based on the test data, as shown in Figure 4.

![Figure 4 Time temperature distribution of single beam electrodes with different spacing](image)

According to the test comparison data, it can be found that with the increase of electrode spacing, the temperature rise value corresponding to the same power on time decreases gradually, the temperature rise amplitude of 2cm spacing is the highest, and the temperature rise amplitude of 8cm spacing is the smallest. The test results are in line with the engineering practice, but because the diameter of copper wire is 5mm, the density of copper wire electrode is larger and the cost is higher when the spacing is 2cm.

3.4. Comparison of heating effect of different electrode forms

In order to compare the conductive effect of different electrode forms, the plate metal electrode is used as the test piece of the comparison group, the electrode height is 3cm, the electrode spacing and single beam are 2cm, 4cm, 6cm, 8cm respectively, and the temperature rise test data of single beam electrode of copper wire is compared horizontally. The temperature sampling interval of the test piece is 12min, and the specific heating time temperature curve and conductive heating efficiency curve are shown in Figure 5 and Figure 6.
Figure 5 shows that the heating amplitude and efficiency of plate electrode are better than that of single beam electrode under the same space and heating time. Taking 2cm spacing as an example, when heating for 40 minutes, the surface temperature of single beam electrode test piece is 2.2 ℃, and the surface temperature of plate electrode test piece is 2.7 ℃. The main reason is that the plate electrode size is large, the current conduction area is larger, but the same consumption of electrode materials is more, significantly increasing the cost of road structure. Figure 6 shows that the heating efficiency of plate electrode is better than that of single beam electrode, with a difference of about 10%, the gap is not obvious. Because the conductive electrode needs to be buried in the conductive asphalt concrete of the pavement middle surface, its rigidity and stability will affect the service effect and service life of the pavement structure. At the same time, under the repeated action of vehicle load, the durability of the electrode itself is not clear. In this case, the stress characteristics and stability of the single bundle copper wire with circular section should be obvious due to the large length width ratio Plate electrode.

4. Conclusion
This study is aiming at the optimal design of conductive asphalt concrete electrode, and different electrode materials, different electrode spacing and different electrode forms are used to carry out indoor comparative tests, and the following research results are obtained:

(1) The results show that among the three materials, copper is the best for conducting electrode, followed by aluminium;

(2) When 5mm diameter copper wire is used as electrode, 2cm electrode spacing has the best heating effect, 4cm electrode spacing has 20% lower heating efficiency, but it can save 50% electrode cost, and is more suitable for engineering application;

(3) The comparison test of different electrode forms shows that when heating for 40 minutes, the surface temperature of single beam electrode with 2cm spacing is 2.2 ℃, and the surface temperature of plate electrode is 2.7 ℃, the heating efficiency of the two is similar, but the mechanical characteristics and stability of single beam copper wire with circular cross section are obviously due to the plate electrode with large length width ratio, which is easier to meet the needs of engineering application.

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