The Influence of Interlayer Contact on Structural Performance of Epoxy Asphalt Concrete Composite Pavement

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Abstract: with the Growth of Air Traffic and the Emergence of Large Aircraft, Some Large Airport Runways Built in the Early Days in Our Country Are Seriously Damaged in Pavement Structure and Their Service Performance Has Dropped Sharply, Which Can No Longer Meet the Requirements of Normal Operation of Airports. in This Paper, the Contact Element in the Finite Element Software Ansys is Used to Simulate the Interlayer Bonding Condition of the Pavement, the Finite Element Calculation Models under Different Interlayer Bonding Conditions Are Established, and the Deflection Variation Characteristics Are Analyzed. the Results Show That the Contact Condition between the Old Cement Concrete Pavement Slab and the Foundation Has a Slightly Greater Impact on the Deflection of the Overlay. the Contact Condition between Epoxy Asphalt Concrete and the Old Cement Concrete Pavement Slab Has an Obvious Impact on the Stress Index of the Composite Pavement Structure. Strengthening the Interfacial Bonding Strength of the Overlay Can Improve the Stress State of the Composite Pavement Structure. Therefore, a Reasonable Interlayer Contact State Should Be Considered When Designing the Overlay.

1. Introduction

For a Long Time, Plain Cement Concrete or Fiber Cement Concrete Has Been Used as Overlay Material for Airport Cement Concrete Pavement, and the Phenomena of Plate Angle Fracture, Peeling and Loosening Often Occur [1]. If the Adhesive Force between the Laid Waterproof Layer and the Bridge Deck Pavement Layer and the Bridge Deck is Insufficient and the Horizontal Shear Resistance is Weak, the Overall Mechanical Properties of the Pavement Layer Will Be Reduced, and the Relative Displacement in the Horizontal Direction Will Easily Lead to Shear Damage and Diseases Such as Displacement and Wrapping Will Occur [2]. the Service Life of the Overlay is Far Less Than the Design Period. the Overlay Often Suffers from Various Damages after Several Years of Use (Far Less Than the Design Period). Asphalt Concrete Overlay Must Be Carried out Again without Stopping Navigation. Even Some Large Airport Runways Have Undergone More Than Four Asphalt Concrete Overlays. Then, According to the Thickness of Asphalt Concrete Overlay, It is Equivalent to a Single Rigid or Flexible Pavement to Analyze Its Bearing Performance Such as Structural Performance Parameters Such as Pcn Value of Pavement [3]. Research Shows That the Contact State between Layers Has a Significant Effect on the Mechanical Response of the Cement Concrete Pavement Overlay Structure System [4]. Therefore, in the Process of Structural Modeling and Analysis of Epoxy Asphalt Concrete Composite Pavement At the Airport, the Influence of Interlayer Contact State is Considered in This Experiment, and the Stress State of Composite Pavement is Studied, Which Provides Basis for Structural Design and Construction of Epoxy Asphalt Concrete Composite Pavement.

2. Calculation Model and Parameters

Firstly, a Three-Dimensional Structural Model Composed of Epoxy Asphalt Concrete Overlay, Old Cement Concrete Pavement Slab with Joints and Foundation is Established by Ansys. in Order to Ensure Accuracy and Save Calculation Time, Three-Dimensional Eight-Node Isotropic Solid Element Solid 45 is Selected for Each Structural Layer, Three-Dimensional Surface-to-Surface Contact Elements Targe 170 and Conta173 Are Selected for Interlayer Contact Model, and Combin

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14 Element is Used for Joint Load Transfer Model. Because the Properties of the Asphalt Concrete and the Original Cement Concrete Are Quite Different, the Contact Analysis is the Contact Condition between the Asphalt Surface Layer and the Cement Concrete Layer, and the Other Layers Are Continuously Combined. the Mechanical Properties of Cement Concrete Base and Asphalt Surface Will Change Greatly after Paving [5]. Therefore, in the Design of Pavement Structure, We Can Neither Assume That All Layers of Pavement Are Completely Continuous, Nor Can We Completely Separate Hydraulic Concrete Base and Asphalt Concrete Surface. a Contact Unit is Arranged between the Asphalt Surface Layer and the Cement Concrete Layer, and the Interlayer Bonding Coefficient K is Used to Characterize the Interlayer Bonding Condition. the Value of K Indicates the Degree of Interlayer Bonding, Thus It Can Be Seen That Interlayer Bonding Coefficient K is a Very Important Parameter.

The Elastic Modulus and Poisson's Ratio of Foundation and Old Cement Concrete Pavement Slab Shall Be Determined According to the Technical Specifications [6], as Shown in Table 1. the Foundation Refers to the Comprehensive Support System Composed of Various Structural Layers Below the Old Cement Concrete Pavement Slab, and Its Modulus Value is the Equivalent Rebound Modulus Value of the Comprehensive Support System.

Table 1 Basic Parameters Of Epoxy Asphalt Concrete Composite Pavement Structural Materials

Material parameters	Epoxy asphalt concrete	Old cement concrete pavement	Basis
Modulus of elasticity / MPa	2000	32000	200
Poisson's ratio	0.21	0.17	0.33
Thickness/m	0.07	0.34	6

In order to consider the load transfer capacity of the joints of the old cement concrete pavement slab, the influence between adjacent slabs and the phenomenon of wheel load span joints of the aircraft, the finite element model is set as a full-scale nine-piece system, assuming the pavement slab is 5m× 5m in size and 24 cm in thickness. The method of enlarging the size is adopted to reflect the characteristics of semi-infinite space foundation, and the calculation error analysis is carried out by taking different sizes of the foundation. after 1.0kg/m^2 of bonding material is coated on the cement concrete slab, SBS modified asphalt mixture (limestone aggregate) is paved for molding, and after curing, the SBS modified asphalt mixture is cut into 70mm×70mm×50mm specimens. The working state of the incompletely combined track panel is between the completely sliding and completely continuous working states. The upper and lower layers of the track panel each have a neutral layer, which moves up and down along with the combined state of the upper and lower layers. When the track panel slides from completely to completely continuous, the neutral plate gradually approaches the joint of the two plates [7]. The bonding state between asphalt surface layer and original cement concrete layer shall be considered according to “contact analysis”, and other layers shall be in complete contact.

3. Contact Analysis Model

At present, Goodman model is mostly used as a measure of interlayer bonding conditions. Goodman model is that when the relative horizontal displacement Δu occurs between the upper and lower layers, the interlayer shear stress can be expressed as follows [8]:

$$\tau = k\Delta u \quad (1)$$

Where: k is the interlayer bonding coefficient (MPa/m).

From equation (1), it can be seen that: when k = 0, the layers are completely sliding; when k = ∞, the layers are completely continuous; when 0 <k <∞, the layers are completely sliding The state of combination.

Three-dimensional model of composite pavement is established by ANSYS finite element program. The foundation adopts elastic foundation model. Usually the pavement structure can be regarded as a semi-infinite elastic multi-layer system, but when using finite element modeling, the soil foundation can only take a finite size. This is because of the viscoelastic effect of asphalt

mixture. When the load frequency is large, the asphalt mixture lacks the necessary strength "healing" time, leading to a reduction in fatigue performance. In the vicinity of the load center, the grid division is relatively dense, and in the distance from the load, the grid division is relatively sparse. Interlayer contact is simulated by contact unit. The design service life of the overlay is generally about 10 years, and the overlay will be carried out again when the service life is reached or early structural strength failure occurs.

Contact deformation satisfies equilibrium equation:

$$\left.\begin{aligned} F_N &= K_N \times \Delta_N \\ F_T &= F_T \times \Delta_T \end{aligned}\right\} \quad (2)$$

The transmission of tangential force by the contact model is essentially consistent with Goodman model. Jun Xiao et al. think Goodman model can reasonably describe the interlayer contact state of pavement structure through calculation [9].

4. Calculation Results and Analysis

4.1 Determination of Interlaminar Shear Modulus Range

There are two interlayer contact surfaces considered in the calculation: one is the interlayer interface between the epoxy asphalt overlay and the old cement concrete pavement, referred to as interface A, and the interlayer shear modulus is represented by KA; The interlayer interface between the old cement concrete pavement slab and the foundation is referred to as interface B, and the interlayer shear modulus is expressed in KB. The larger the interlayer adhesion coefficient, the smaller the corresponding deflection value. However, when k increases to a certain range, the road surface deflection is already very close to the deflection when the layers are completely continuous. Then, as k continues to increase, the road surface deflection value will change little. Reflective cracks generally act on the bottom surface of asphalt layer through stress concentration such as old cement pavement joints and cracks, and then gradually diffuse to the surface. If interlayer treatment technology is good, the possibility of upward diffusion of reflective cracks may be reduced. Therefore, it can be said that reflective cracks are sensitive to interlayer bonding conditions [10]. The SU-27 slab is selected for loading, and the load center positions corresponding to the top surface and bottom surface of epoxy asphalt overlay and the top surface and bottom surface of old cement concrete pavement slab are taken as calculation points. Through calculation, the interlayer shear modulus range suitable for studying epoxy asphalt concrete composite pavement structure is determined. The calculation results are shown in Figure 1.

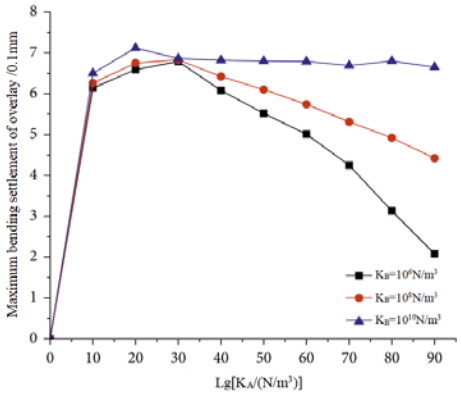

Fig.1 The Relationship between Interlayer Contact and Maximum Bending Settlement of Epoxy Asphalt Overlay

4.2 Influence of Interlayer Contact State on Pavement Deflection

Figure 2 is the result of the influence of interface A in different contact states on the maximum deflection of the epoxy asphalt overlay. It can be seen that when the interface contact state of one of

the layers is constant, the shear modulus of the other interface varies with Gradually increasing, the maximum deflection value of epoxy asphalt overlays has gradually decreased.

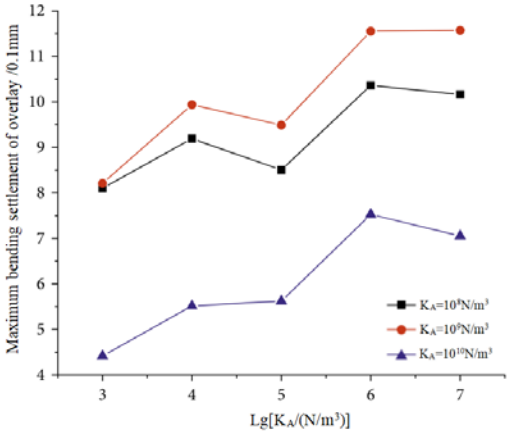

Fig.2 Influence of Interlayer Contact State on Maximum Bending Settlement of Epoxy Asphalt Overlay

The increase of the interlayer adhesion coefficient can promote the improvement of the overall stiffness of the pavement, so the road surface deflection decreases as the interlayer adhesion coefficient increases. When the layers are in a continuous state, the maximum road surface deflection is 0.2125mm. The maximum deflection in the fully sliding state is 2.4 times that in the continuous state. When the interface A is completely in smooth contact (that is, KA is 10^8 N / m^3), the maximum deflection of the epoxy asphalt overlay ranges from 0.5546 to 0.5734 mm; When the interface A is completely in continuous contact (ie, KA is taken at 10^9N / m^3), the maximum deflection of the epoxy asphalt overlay ranges from 0.5396 to 0.5582 mm. In most cases, the bonding state between the pavement layers is two. Between people. However, the design of the composite pavement at this stage is based on the layered system theory. It is assumed that the pavement layers are completely continuous, which is completely inconsistent with the actual working conditions of the pavement. Studies show that the stress and The change in strain is significant. The 12 test blocks are divided into three different situations. The surface of 4 blocks is extremely uneven. The height difference of concavity and convexity is about 5 ~ 1~5mm The surface of 4 blocks is relatively smooth after roughening treatment. The height difference of concavity and convexity is about 1 ~ 5 mm. The surface of 4 blocks is extremely smooth and smooth. You can hardly feel the fluctuation of concavity and convexity when touching with your hand. It can be seen from this that the overall stiffness of the continuous state model is much larger than that of the complete sliding state, and the continuous interlayer bonding state plays a great role in reducing road surface deflection.

4.3 Influence of Interlayer Contact State on Horizontal Stress

For the composite pavement structure under load, when the interlayer contact is in a completely continuous state, the top surface of the upper layer generates compressive strain, the bottom surface of the lower layer generates tensile strain, and the strain and displacement on the interlayer contact surface are continuous. When it is completely continuous, a deflection basin with relatively shallow middle and relatively deep two sides is formed. Deflection curves under other interlayer bonding conditions must be between completely smooth and completely continuous deflection curves. When the old pavement is paved with asphalt pavement, the shear stress between the original pavement layers decreases, but no matter how many times it is paved, the shear stress on the surface layer is the largest and increases with the increase of the number of additional layers. This shows that with the increase of the number of additional layers, the stress state of the surface layer of the additional layers has not improved, but the surface layer stress has increased under the action of interlayer bonding state and composite load, etc. Under the same conditions, several kinds of drawing strength all decrease with the increase of test temperature, and the higher the temperature, the faster the strength decreases. The main failure forms of cement concrete pavement are slab transverse fracture

and slab corner fracture, in which the slab transverse fracture is divided into top-down fracture and bottom-up fracture. The magnitude of the strain level directly reflects the degree of bending deformation of the specimen. For the actual pavement, the deformation degree of the pavement reflects the magnitude of wheel load acting force, and the deformation degree of the pavement under vehicle loading directly affects the fatigue life of the pavement. This not only shows that the vertical interconnection of the continuous model is stronger, but also points out that the quality of interlayer bonding can be preliminarily determined through deflection curves.

4.4 Influence of Interlayer Contact State on Maximum Shear Stress of Overlay

It can be seen from Figures 3 and 4 that the effect on the applied load in the smooth state is smaller than the continuous state in both longitudinal and lateral effects. The maximum deflection of the road surface between the continuous state and the fully sliding state between the layers is 0.3mm. This shows that the overall stiffness of the continuous model is greater than that of the contact model. The contact state between the old cement concrete pavement slab and the foundation has little influence on the maximum shear stress of the epoxy asphalt overlay, which can be ignored. The reason is that the cement concrete pavement slab is a rigid pavement with a large modulus and is not easy to bend and sink compared with the epoxy asphalt overlay.

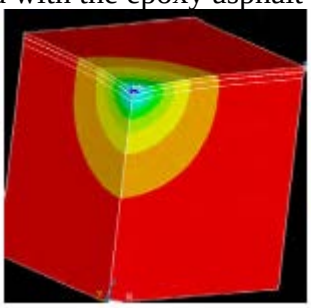

Fig.3 Vertical Displacement in Completely Smooth State

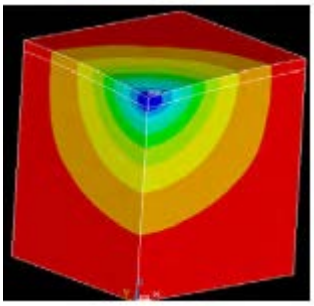

Fig.4 Vertical Displacement in Completely Continuous State

Because the fatigue strength of asphalt material is much less than that of steel bar, the fatigue damage of asphalt material should be taken as the index when studying the overall fatigue strength of composite pavement structure. Under the same conditions, the drawing strength of epoxy asphalt adhesive layer is higher than that of SBS and other waterproof materials. The magnitude of strain level should be controlled within a reasonable range. Excessive strain level will lead to short fatigue life, which is inconsistent with the fatigue failure behavior of the actual pavement. With the increase of shear modulus between the epoxy asphalt overlay and the old cement concrete pavement slab, the flexibility and rigidity of the overlay decrease, and the maximum shear stress of the epoxy asphalt overlay gradually decreases. When the shear modulus exceeds 1010 N/m3, the maximum shear stress slightly increases.

5. Conclusion

Cement concrete epoxy asphalt waterproof adhesive layer material has excellent mechanical properties, can improve the bonding between cement concrete bridge deck and asphalt mixture,

effectively resist the influence of road traffic, and improve the paving quality of the whole bridge deck. The quality of interlayer contact has great influence on deflection of composite pavement structure. In the detection of the airport composite pavement, the preliminary judgment of the interlayer bonding condition of the composite pavement structure can be carried out according to the measured deflection basin shape. In order to improve the service life of the overlay, the shear modulus between the old cement concrete pavement slab and the foundation shall be ensured to reach 1010 N/m3 during the design and construction. Improving the contact state between the epoxy asphalt overlay and the old cement concrete pavement slab can reduce the maximum shear stress of the epoxy asphalt overlay, but when the shear modulus exceeds 010 N/m3, the maximum shear stress rises slightly. The quantitative analysis of determining interlayer bonding condition by deflection basin shape needs to be based on a large number of experiments, and multiple nonlinear regression analysis needs to be used to explore the functional relationship between the two. This aspect needs further analysis.

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