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Application of Elastic Layered System in the Design of Road

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ABSTRACT
Elastic layered system is widely used in road design because of its reasonable assumptions, simple calculation model and typical represent activeness. Although the hypothesis is partly different from the actual structure, it is irreplaceable and worthy of further study in the current level of science and technology. This paper lists and briefly describes the application of elastic layered system theory in the calculation of asphalt pavement thickness and subgrade the stress analysis of cement concrete pavement and porous concrete base load to illustrate the generalizability of application of elastic layered system and look to the future road.
Keywords **-** Elastic layered system; Calculations icon; Stress analysis; subgrade bed; pavement

I. INTRODUCTION

Elastic layer theory is specializing in stress and displacement generated in the circular loads within the elastic layered system.[1]The elastic layer theory is mainly used for asphalt pavement thickness design in our country's road design, and it has the following basic assumptions：（1）Every layer is made of homogeneous isotropic linear elastic material composition；（2）Assume soil base in the horizontal direction and downward depth direction are infinite, and thickness of pavement layers on is limited, but their horizontal direction is unlimited；（3）Assume there are vertical loads on the upper surface of the pavement, and the contact surface of loads and the pavement is a circle, on which the pressure is evenly distributed；（4）The contact surface between each layer is assumed to be fully continuous（Sufficient frictional resistance）or partially continuous or completely smooth (no friction resistance).[2-6]The assumptions and the actual circumstances of the subgrade and pavement structure system have some differences. However, it is simple and clear and can generally indicate the actual stress situation of the road.[7-8]So it has been widely used, and is especially promoted by the application of modern computer technology. This theory can be used in the aspects below: calculation of asphalt pavement thickness, calculation of roadbed, cement concrete pavement stress analysis, calculation of porous concrete base load stress and so on.

II. ELASTIC LAYERED SYSTEM THEORY IN ASPHALT PAVEMENT

2.1 ELASTIC LAYERED SYSTEM THEORY IN THE CALCULATION OF THICKNESS

The specified design method of asphalt pavement thickness in the »Specifications for Design of Highway Asphalt Pavement» of China is elastic layer theory, which is assuming that between the layers it is completely smooth and frictionless and regards the surface deflection of the road and the bottom tensile stress of asphalt surface or semi-rigid base course as a design standard. Load of BZZ-100 dual circular uniformly distributed load. The calculation illustrated as Figure 1,In the figure A is the calculated point of deflection（the center of the wheel）,B,C,D,E are the checking points of stress.

After the material parameters of each layer are determined, BISAR procedures can be used to calculate the deflection of point A and the bending tensile stress of point B C D E, then to determine the thickness of the asphalt pavement.

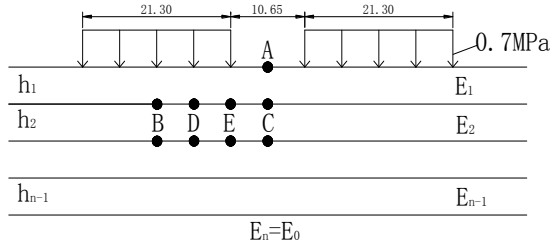

Figure 1 BZZ-100 dual circular uniformly distributed load

FEM Simulation asphalt pavement elastic layered system of analysis

2.2.1 ANSYS modeling

Analysis of Multi pavement structure, provided that the material has a linear elastic properties. Finite element analysis modeling in software ANSYS8.0, Unit adopts three-dimensional hexahedral 8-node isoparametric element. Size of the road surface model （X、Y、Z） is 2.65m*2.5m*2.65m.Boundary condition is assumed to be：Bottom surface UY=0, Left and right side of the bilaterally symmetrical boundary conditions Symmetry B.C, one side UX=0 Front and rear sides UZ=0. Interlayer is completely continuous exposure. Loads using the Huanghe JN-100 standard models,axle is 100kN, wheel pressure is 0.7MPa, The wheel load will reduced to the equivalent of a circular uniform load in engineering design,Each circle having a diameter of 21.3cm,Area 356.33cm ². We can analyzed the desirability of which half because the model and load symmetry.

2.2.2 Simulation pavement under wheel loads Deflection

In Fig.1, according to the example of a combination to modeling, load, and solving,then draw the vertical displacement contours,as figure 2.As shown in Figure 3 uniform load is half entity from the middle of a cut-away round. It can be more intuitive to see the distribution of Deflection. Figure 3 and 4 corresponding to figure 2 pavement deflection deformation maps and contour maps.We can see in the figure the center of the wheel is not the biggest gap, The maximum deflection of the axis of the wheel carrier, but the difference between the two is very small, which is consistent with the actual situation.

Fig. 1. Asphalt Concrete Pavement Structure

E1=1400MPa	h1=4cm
E2=1200MPa	h2=5cm
E3=1000MPa	h3=6cm
E4=1500MPa	h4=25cm
E5=550MPa	h5=24.5cm
E0=40MPa	

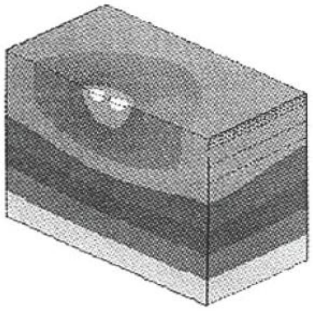

Figure 2 Pavement vertical displacement contours under wheel loads

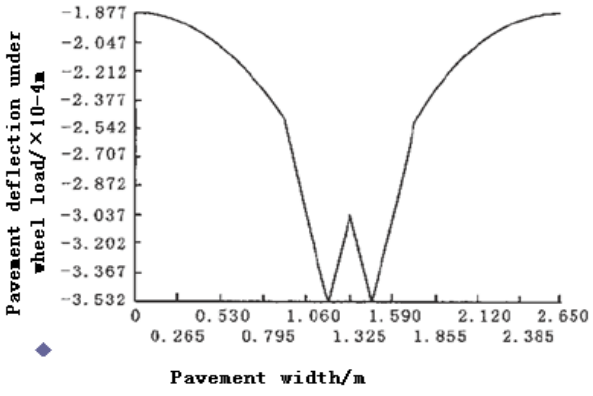

Figure 3 Pavement Deflection deformation under wheel loads

III. ELASTIC LAYERED SYSTEM THEORY IN THE CALCULATION OF ROADBED

Its principle of application in the subgrade is basically consistent with that in the asphalt pavement thickness calculation. It is assumed to be completely continuous between layers and interlayers and models are different. The calculation is illustrated as figure 5:

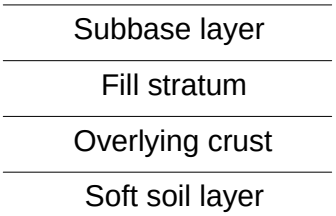

Figure 5 Interlayers and models

The modulus of each layer may be measured or based on experience. According to the elastic layer theory, the deflection value under double circular uniform load (BZZ-100) can be calculated, with which the thickness of each layer can be adjusted.

IV. Elastic layered system theory in the Stress Analysis of cement concrete pavement

In the stress analysis of cement concrete pavement, we usually use Winkler foundation model, which assumes that the subsidence of a certain point of foundation depends on the force of that point but does not have any relationship with the neighboring foundation then to calculate the stress and strain of rigid pavement. In fact, each point of the road is interrelated and will have association displacement. Unlike Winkler Foundation, Elastic layer system space board foundation model considerate horizontal linkages, which makes it better simulate the actual foundation. Thus, we can use this theory to analyses the stress condition of cement concrete pavement with a cushion. Its calculation illustrations and loads are consistent with those of asphalt pavement. The cement concrete pavement should be divided into several layers. And chosen stress calculation points are in the center of double circle and the intersection of the circle and the circumference. Then, we check the stress of each point by finite element software to control the thickness of the cement concrete pavement.

V. APPLICATION OF ELASTIC LAYERED SYSTEM IN BASE LOAD STRESS ANALYSIS OF POROUS CEMENT CONCRETE

Porous concrete is a rigid material, whose strength is between ordinary concrete and lean concrete between. When used in asphalt pavement base, it acts as the main force layer via composite Pavement Design Method, which means that asphalt layer is the functional layer. Concrete base is designed according to cement plate and cement pavement base is designed by double plate theory. Current cement concrete pavement design is based on the Winkler foundation theory. The main design parameter is the grass-roots equivalent modulus of elasticity of the top surface. However, since porous concrete and Portland cement concrete in material properties are different of, such as strength, elastic modulus and so on. At the same time, in order to highlight the sharing of load stress effect on the under-grassroots, bedding, and other layers of different materials, bedding, and subgrade and so on. It should be calculated using elastic layered system load stress.

5.1 MODEL SELECTION

In the in porous concrete composite structure of asphalt pavement, asphalt surface as a function of layer primarily has little inference on porous concrete base. Therefore, when calculating the load stress we may not consider the impact of the asphalt surface layer. Porous concrete base as the main load-bearing layer withstand wheel loads with the grassroots, cushion and subgrade. Taking into account the main function of the cushion is to improve subgrade moisture and temperature conditions, so it has little

inference on the load stress of concrete of porous base. Therefore, merging the layer and subgrade together and looking the layer of porous concrete layer as elastic panel, we calculate the equivalent modulus of elasticity in accordance with standard formula. As for the foundation, we adopt the double elastic layered system models. Because porous concrete has large friction, we adopt the fully continuous hypothesis, and the center of wheels and the center of double circle center and center connection with the circumferential intersection as the calculating point.

5.2 INTERLAYER CONTACT

Porous concrete material contains free or low fines. Coarse aggregate particles coated slurry, particles contact with each other, and adhere to each other to form a uniformly distributed pores honeycomb structure. After forming porous concrete paving, the pave form a uneven surface, with a large coefficient of friction. When the lower grass-roots level contacts with grass-roots level of porous concrete, there is a strong engagement of each other, and the interlayer has good binding properties. Therefore, we analysis the inter-layer's contact condition in accordance with completely continuity.

5.3 LOAD AND CRITICAL LOAD POSITION

The calculation point of Load model and stress is the same as the concrete pavement stress analysis, and the critical load position of porous cement concrete base is located in the center of longitudinal edges.

VI. CONCLUSION

The elastic layer theory is widely used in stress analysis of road embankment, especially in the application of computer technology, making the calculation make the calculation more precise.

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