Applicability and Mechanical Response of Concrete Pavement Panel Thickness of Road Network Highway

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Abstract: Concrete pavement has been widely used in highway builders of Guangxi road network because of its outstanding characteristics such as high strength, low energy consumption, good economic and social benefits, and long service life. It has nearly 8000 km of application mileage. However, with the continuous development of heavy-duty traffic, the problems of impact resistance, fatigue resistance, comfort performance, and inconvenient maintenance of cement pavement have gradually become prominent. The use of cement pavement is restricted by broken plates, staggered platforms, large driving noise, and discomfort. In this paper, aiming at the problems of uneven bearing capacity and different damage degree of cement pavement, combined with the actual field investigation, the mechanical response calculation of different surface thickness of cement pavement is carried out, and the influence of different surface thickness on the overall use of cement pavement is obtained. This paper can provide scientific data and technical reference for the selection and design of cement pavement structure.

1 INTRODUCTION

Concrete pavement is one of the important forms of road pavement structure (JTG D40-2011, 2011). Cement pavement has good applicability in road network highways, especially in heavy-duty traffic sections. Most of the cement pavements have a service life of up to 10 years and good road conditions. However, due to heavy-duty traffic loads, bearing capacity of subgrade and base, more precipitation, more voids at the edge of slab corners, material composition and other unfavorable factors, with the increase of its operating time, some road sections will have different degrees of pavement damage such as slab corner fracture, broken slab or broken slab, and joint damage during use (JTJ 073.1-2001, 2001; Wang et al., 2021; Wang et al., 2021).

In this paper, the cement pavement with different surface thickness of G207 and G209 lines is taken as the research object, and the investigation and analysis of the use of cement pavement in road network highway are carried out. Based on the field test results, the mechanical calculation of cement pavement with different surface thickness is carried out, and the surface thickness suitable for cement pavement of road network highway is analyzed and studied, which provides strong data support for the selection and design of cement pavement structure of road network highway.

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2 INVESTIGATION ON THE USE OF CEMENT PAVEMENT WITH DIFFERENT SURFACE THICKNESS

With the increase of its operation time, concrete pavement is affected by unfavorable factors such as heavy traffic load, bearing capacity of subgrade and base, more precipitation, more voids at the edge of slab corner, and material composition. In the process of use, some sections will have different degrees of pavement damage, such as slab corner fracture, broken slab or broken slab, joint damage and so on. In order to understand the use of concrete pavement structure with different panel thickness, this paper investigates and studies the daily traffic volume, heavy vehicle traffic ratio, service life and road condition of concrete pavement with panel thickness of 20, 24 and 26cm respectively. The FWD deflection test vehicle is used to test the angular deflection value of the plate and calculate the load transfer coefficient. The comprehensive information above each road section is shown in Table 1, and the on-site road conditions and on-site drilling core samples are shown in Figure 1.

Table 1: Three different panel thickness of concrete pavement structure road condition questionnaire.

serial number	Section number	pavement structure types	Daily traffic volume (vehicles)	Percentage of heavy traffic	in the years already spent	Plate corner deflection value （μm）	load transfer coefficient	Road conditions
1	G209	20cm cement concrete panel+20cm cement stabilized gravel+ 18cm graded crushed stone	7276	70%	9 年	79.6	87.3%	Longitudinal and transverse cracks
2	G209	24cm cement concrete panel+20cm cement stabilized gravel+ 18cm graded crushed stone	7276	70%	9 年	88.7	93.8%	Longitudinal and transverse cracks
3	G207	26cm cement concrete panel+20cm cement stabilized gravel+ 18cm graded crushed stone	24882	23%	12 年	75.2	94.3%	good

G209 20cm cement concrete panel road map

G209 24cm cement concrete panel road map

Figure 1: Three different thickness of concrete pavement structure field survey road map.

The concrete pavement structure of the three road network highways shown in Table 1 represents the typical structure of concrete pavement in Guangxi. The concrete pavement (panel thickness 20cm) of a section of G209 has been used for 9 years, and there have been longitudinal and transverse cracks and other diseases. The load transfer capacity between the slabs is the worst; the concrete pavement (panel thickness 24cm) of a section of G209 has been used for 9 years, and there have been longitudinal and transverse cracks and other diseases, and the load transfer capacity between the plates is in the middle. The concrete pavement (panel thickness 26 cm) of a section of G207 has been used for 12 years, and the traffic volume has reached more than 20,000. However, the road condition is good, there are no cracks and other diseases, and the load transfer capacity between slabs is the best.

3 STUDY ON MECHANICAL RESPONSE OF CONCRETE PAVEMENT STRUCTURE WITH DIFFERENT PANEL THICKNESS

3.1 Construction of Finite Element Calculation Model of Concrete Pavement Structure with Different Panel Thickness

In order to grasp the mechanical properties of concrete pavement structure with different panel thickness, this paper constructs the finite element model of concrete pavement structure with cement panel thickness of 20,24 and 26cm based on ABAQUS finite element software, as shown in Figure 2. In order to grasp the mechanical properties of cement pavement structure with different panel thickness, this paper constructs the finite element model of cement pavement structure with cement panel thickness of 20,24 and 26cm based on ABAQUS finite element software, as shown in Figure 2. In order to analyze the mechanical properties of three different cement pavement structures, this paper builds a three-dimensional calculation model based on ABAQUS software. The relevant calculation parameters are shown in Table 2. The first structure is G207 section (panel thickness 26cm), the second structure is G209 section (panel thickness 24cm), and the third structure is G2094section (panel thickness 20cm). As shown in Figure 2, the model size is proposed to be 5m × 5m × 5m, and the mesh is divided by C3D8R (three-dimensional hexahedron eight-node linear reduced integral isoparametric element) unit (AZAD et al., 2020; FEI et al., 2024; Wang et al., 2022). The equivalent diameter D = 30.2cm, and the load uniform pressure P = 0.7MPa.

Table 2: Parameter model parameters of structural mechanics calculation of concrete pavement with different panel thickness.

structure one	structure two	structure three	layer thickness（cm）	Elastic modulus (MPa)	poisson ratio
cement concrete slab	cement concrete slab	cement concrete slab	(20,24,26)	30000	0.2
cement stabilized macadam	cement stabilized macadam	cement stabilized macadam	20	2000	0.25
graded broken stone	graded broken stone	graded broken stone	18	600	0.35
earth base	earth base	earth base	/	35	0.35

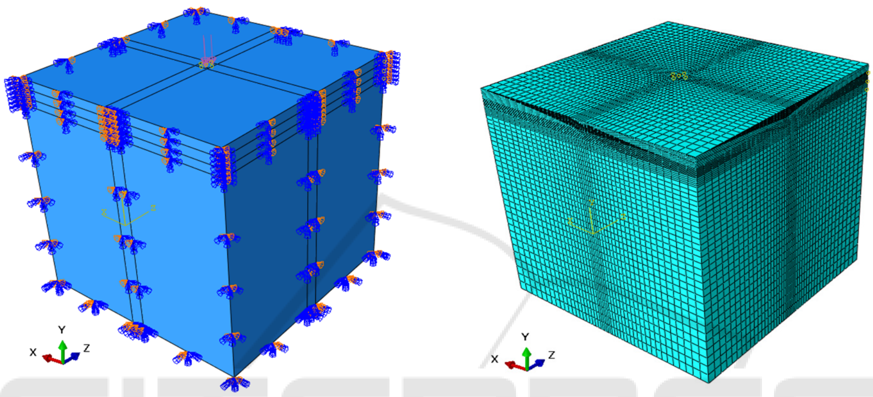

Figure 2: Pavement structure finite element model diagram.

3.2 Finite Element Calculation and Analysis of Concrete Pavement Structure with Different Panel Thickness

(1) concrete pavement surface deflection

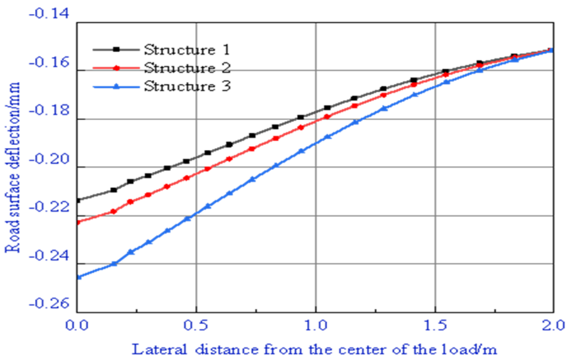

Figure 3: The road surface deflection comparison diagram of the three structures.

From Figure 3, it can be seen that the road surface deflection of structure one is the smallest, and the road surface deflection of structure two and three gradually increases. With the decrease of the thickness of the cement pavement surface layer, the road surface deflection becomes larger and larger. The thickness of the cement pavement surface layer of structure two and structure three is reduced by 7.69 % and 23.08 % respectively, while the road surface deflection of the load center is increased by 4.25 % and 14.92 % compared with the structure one. This shows that the vertical deformation of the cement pavement surface layer is closely related to its thickness. As the thickness of the cement pavement surface layer increases, its flexural strength increases, while its surface deflection decreases relatively.

(2) The influence of concrete pavement panel thickness on the internal stress of the structural layer

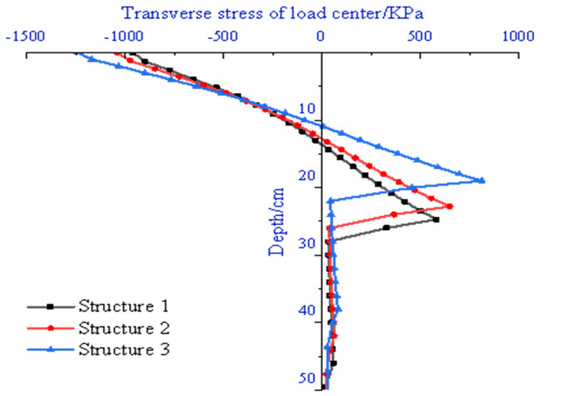

Figure 4: The transverse stress comparison diagram of the load center of the three structures.

From Figure 4, it can be seen that the peak value of transverse stress tension and compression of structure one is the smallest, the peak value of transverse stress tension and compression of structure two and three increases in turn, and the peak value of transverse stress tension and compression of structure two and three increases by 11.75 % and 40.07 % respectively. The peak transverse compressive stress of the second and third structures increased by 8.08 % and 28.96 %, respectively. This shows that as the thickness of the cement pavement surface layer increases, the peak value of the transverse stress tension and compression inside the pavement structure decreases accordingly, and the depth of the position where tension and compression alternate will increase.

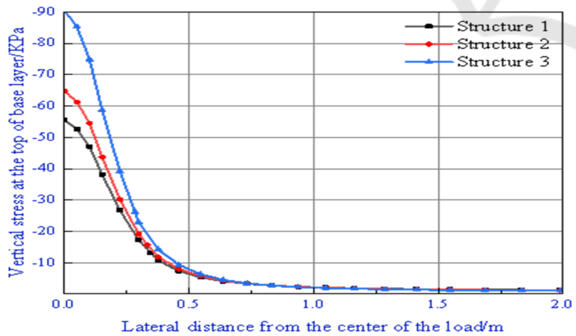

Figure 5: Comparison of vertical stress at the top of the base layer of three structures.

According to Figure 5, the peak vertical stress of the top of the first, second and third base layers of the structure is-55.533 MPa, -64.771 MPa and-90.499 MPa, respectively. The vertical stress of the load center of the second and third structures is increased by 16.64 % and 62.96 % respectively compared with the first structure. This shows that the increase of the thickness of the cement pavement surface layer will lead to a significant increase in the peak value of the vertical stress at the top of the base layer.

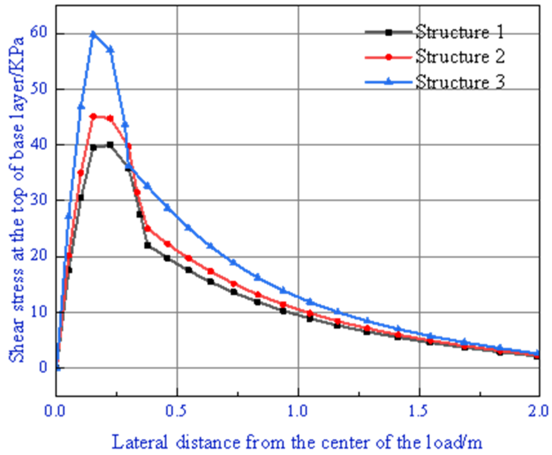

Figure 6: Comparison of shear stress at the top of the base layer of three structures.

From Figure 6 that the shear stress at the top of the cement pavement base layer increases first and then decreases, reaching a peak at the edge of the single wheel load. With the increase of the thickness of the cement pavement surface layer, the shear stress of the structure one, two and three decreases in turn, and the peak values are 39.944 KPa, 44.784 KPa and 57.015 KPa, respectively, and the peak values of the shear stress of the structure two and three are increased by 10.81 % and 29.94 % respectively compared with the structure one.

In summary, the thickness of the cement pavement surface layer of the second and third structures is reduced by 7.69 % and 23.08 % compared with the first structure, while the peak deflection of the road surface is increased by 4.25 % and 14.92 % ; the peak value of transverse tensile stress increased by 11.75 % and 40.07 %. The peak value of transverse compressive stress is increased by 8.08 % and 28.96 %. The peak value of vertical stress increased by 16.64 % and 62.96 %. The peak shear stress increased by 10.81 % and 29.94 %.

4 CONCLUSION AND SUGGESTION

(1) In this paper, aiming at the problems of uneven bearing capacity and different degrees of damage of cement pavement, combined with the actual investigation, it is found that the use of cement pavement in road network highway is

proportional to the thickness of its surface layer. The thicker the surface layer, the better the use condition, but the smaller the deflection value of the plate angle, the larger the load transfer coefficient between the plates, and the best overall applicability.

(2) In this paper, the simulation results show that : 1 The vertical deformation of cement pavement surface layer is closely related to its thickness. The thicker the cement pavement surface layer is, the higher the flexural strength will be, but the deflection of the road surface will decrease. The peak value of the transverse stress of the first structure is the smallest, and the second and third structures increase in turn. The increase of the thickness of the cement pavement surface layer will lead to the decrease of the internal transverse stress. 3 The increase of the thickness of the cement pavement surface layer will make it produce smaller vertical stress at the top of the base layer. In order to ensure the overall stability and bearing capacity of the cement pavement structure and improve its comprehensive service life, it is recommended to increase the thickness of the cement pavement surface layer when construction and economic conditions permit.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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