Applicability of Recycled Overlay Structure of Old Cement Pavement in Road Network

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Keywords: Old Cement Pavement; Regeneration Overlay; Green Economy Is Applicable; Applicability.

Abstract: The degree of damage of the old cement pavement is different, and the way of comprehensive utilization and treatment of the old road will be very different. In this paper, aiming at the problems of insufficient bearing capacity, uneven strength and reflection cracks after regeneration of old cement pavement, combined with the actual engineering application investigation, two types of post-regeneration overlay structure of cement pavement in road network are investigated and studied. The mechanical response of two different structural types is calculated by finite element simulation, and the mechanical response characteristics of different structures are compared. The rationality and applicability of the overlay structure of the old cement pavement are verified, and the green and economical applicable structure of the old cement pavement is recommended. It can provide a favorable technical reference for the selection of recycled overlay structure of old cement pavement.

1 INTRODUCTION

Cement concrete pavement is one of the important forms of highway pavement structure (JTG D40-2011, 2011). There will be different degrees of damage in the use of cement pavement. It is urgent to discuss and study the recycled overlay structure of green and economical old cement pavement. The old cement pavement recycling overlay technology is a kind of green environmental protection and economical recycling technology. However, the irregular cracks in the rubblized structure layer of the old cement pavement will directly affect the durability and comprehensive performance of the overlay structure. The overlay structure layer is one of the key considerations to prevent crack reflection. Therefore, how to choose a green and economical recycling overlay structure to treat the damage of the old cement pavement is particularly important (JTJ

2 INVESTIGATION AND RESEARCH ON THE USE OF RECYCLED OVERLAY STRUCTURE OF CEMENT PAVEMENT

In order to deeply understand the effect of various treatment methods of recycled overlay after rubblization of old cement pavement, this paper selects two different overlay structure sections of a representative road network highway for comprehensive information and road condition investigation. The comprehensive information of different overlay structure sections is shown in Table 1, and the on-site road conditions are shown in Figure 1. Combined with the comprehensive information of

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Chen, G., Huang, H., Huang and G.
Applicability of Recycled Overlay Structure of Old Cement Pavement in Road Network.
DOI: 10.5220/0013627200004671
In *Proceedings of the 7th International Conference on Environmental Science and Civil Engineering (ICESCE 2024)*, pages 189-195
ISBN: 978-989-758-764-1; ISSN: 3051-701X

the road section and the on-site road conditions, it can be seen that the application effect of the asphalt pavement structure of the old cement pavement rubblization overlay ATB asphalt macadam base is good, but the asphalt pavement structure of the old cement concrete pavement rubblization overlay lime aggregate base has appeared rutting, longitudinal cracks, oil and other diseases.

Table 1: Two different overlay structure section comprehensive information questionnaire.

serial number	Section number	pavement structure types	Daily traffic volume (vehicles)	Percentage of heavy traffic (%)	in the years already spent (years)	Plate corner deflection value （μm）	load transfer coefficient(%)	Road conditions
1	G324	8cm asphalt concrete + 7cm asphalt concrete ATB-25 + 1cm lower seal layer + rubblized layer of old cement pavement + 17cm lime-fly ash stabilized crushed stone + 17cm graded crushed stone	14407	52	6	79.6	82.7	good
2	G324	7cm asphalt concrete + 20cm lime stabilized aggregate + 1cm sealing oil layer + old cement pavement rubblization layer + 20cm cement stabilized gravel + 20cm graded gravel	6340	30	5	88.7	79.2	Rutting, longitudinal joints and oiling

Figure 1: Two different overlay structure field survey road map.

3 COMPARATIVE CALCULATION STUDY ON RECYCLED OVERLAY STRUCTURE OF CEMENT PAVEMENT

3.1 The Finite Element Calculation Method of Recycled Overlay Structure of Cement Pavement

In order to grasp the mechanical properties of the recycled overlay structure of cement pavement, this paper establishes a three-dimensional pavement structure model by ABAQUS finite element software based on the structure of the above two on-site investigation sections, as shown in Figure 2. The first structure is paved with 8cm asphalt concrete + 7cmATB-25. Structure 2 is paved with 7 cm asphalt concrete + 20cm lime stabilized aggregate. The simulation parameters are shown in Table 2 and 3 (Xu et al., 2009; Cao et al, 2010; BEREBJI et al., 2022).

Table 2: Structure-pavement material and its calculation parameters.

name of the material		Thickness /cm	elastic Modulus /MPa	poisson ratio
New overlay structure layer	bituminous concrete facing membrane	8	1600	0.25
	ATB-25	7	1500	0.25
Old cement pavement structure	Rubblization layer of old cement pavement	24	1200	0.25
	lime-fly ash stabilized-crushed-stone foundation	17	1000	0.25
	gravel-sorted subbase	17	500	0.35
	earth base	/	60	0.35

Table 3: Structural two-surface material and its calculation parameters.

name of the material		Thickness /cm	elastic Modulus /MPa	poisson ratio
New overlay structure layer	bituminous concrete facing membrane	7	1000	0.25
	Lime stabilized granular layer	20	600	0.25
Old cement pavement structure	Rubblization layer of old cement pavement	24	1200	0.25
	cement stabilized macadam base	20	2400	0.25
	gravel-sorted subbase	20	500	0.35
	earth base	/	60	0.35

In order to simplify the calculation, the model size is proposed to be 5m × 5m × 5m. The following assumptions are made for each structural layer: (1) each structural layer is a uniform, continuous and isotropic linear elastic body; (2) The layers of each structure are continuous; (3) The bottom of the foundation adopts fixed constraint, the displacement is zero, the side adopts horizontal constraint, the horizontal displacement is zero; (4) The load is a single wheel load, the wheel pressure is 0.7 MPa, and the diameter of the load area is 30.2 cm;(5) The finite element model mesh is divided by C3D8R (three-dimensional hexahedron eight-node linear reduced integral isoparametric element) element, and the seed treatment is encrypted near the load area (AZAD et al., 2020; FEI et al., 2024).

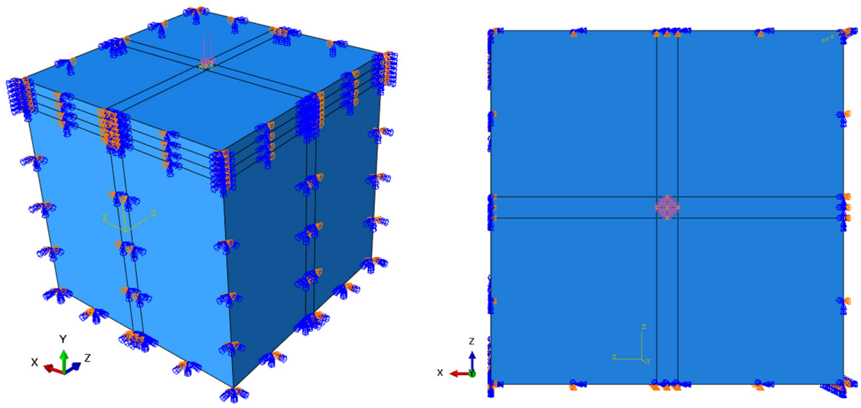

Figure 2: Pavement structure finite element model diagram.

3.2 Comparative Analysis of Finite Element Calculation of Recycled Overlay Structure of Cement Pavement

(1) Deflection

Deflection can reflect the overall bearing capacity of the pavement. In this paper, the surface deflection of two different asphalt overlay structures and the bottom deflection of asphalt overlay are calculated respectively. The results are shown in Figure 3.

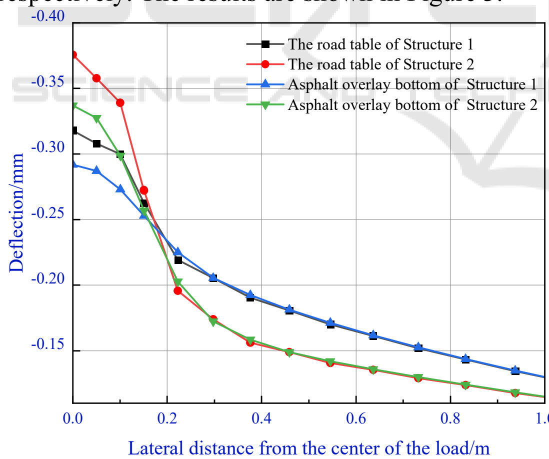

Figure 3: Deflection comparison diagram of the two structures.

It can be seen from Figure 3 that at the center of the load, the maximum deflection of the structure 2 is much larger than the maximum deflection of the structure 1, and the maximum deflection value is shown in Table 4. Compared with structure 1, the maximum deformation of surface deflection and bottom deflection of asphalt overlay of structure 2 increased by 18.22 % and 15.49 % respectively. This shows that the deflection is mainly determined by the modulus of the new overlay structure. The structure 1 with 8cm asphalt concrete + 7cmATB-25 has better pavement bearing capacity.

(2) Internal stress of structure

Figure 4: Load center transverse stress contrast diagram.

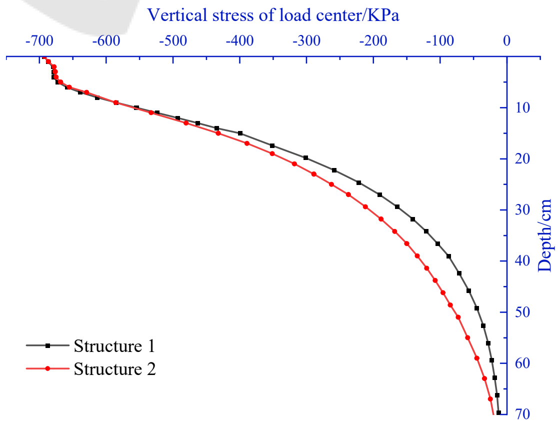

Figure 5: Vertical stress comparison diagram of load center.

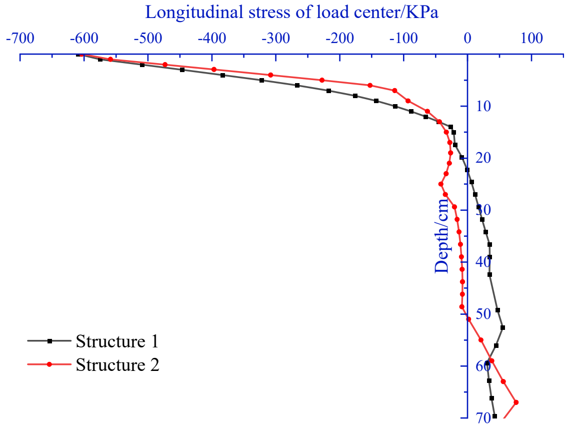

Figure 6: Longitudinal stress comparison diagram of load center.

(3) Internal strain of structure

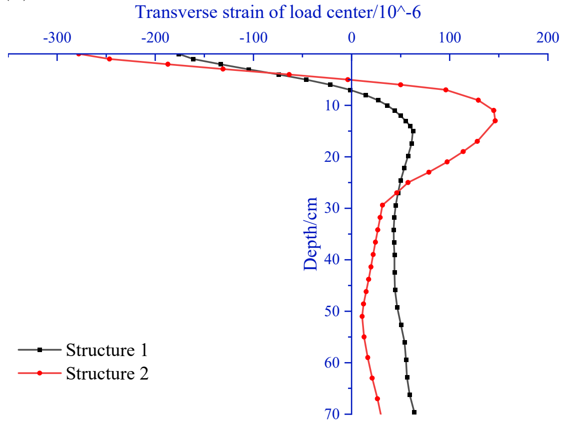

Figure 8: Load center transverse strain contrast diagram.

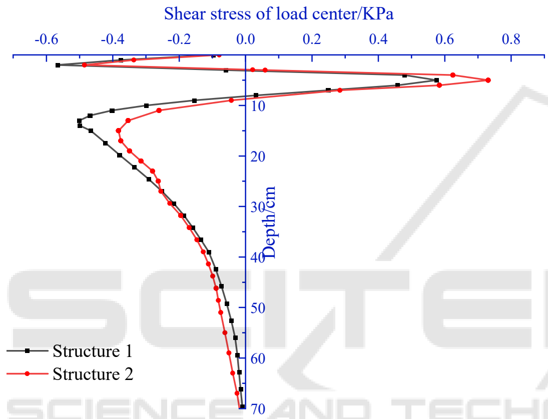

Figure 7: Load center shear stress comparison diagram.

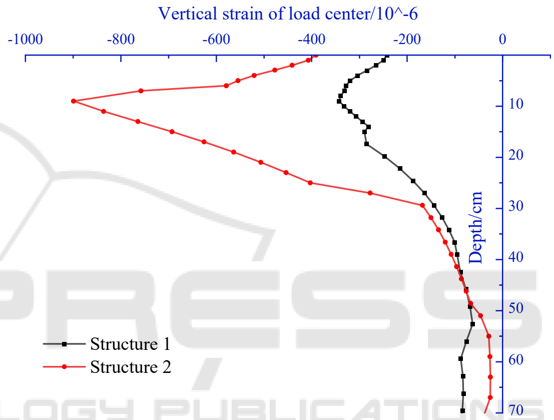

Figure 9: Vertical strain comparison diagram of load center.

It can be seen from Figure 4-6 that the first structure completes the tension and compression alternation in the rubblized layer of the old cement pavement, while the second structure only occurs in the cement stabilized gravel layer of the old pavement. It can be seen from Figure 5 that the vertical stress of structure 1 and structure 2 shows the same trend, and it is always under compression, but the vertical stress of structure 2 is greater than that of structure 1 at the same depth. It can be seen from Figure 7 that the maximum shear stress of the two structures appears at a depth of 5cm, which is located in the new asphalt overlay layer, and the maximum shear stress of the first and second structures is 0.575KPa and 0.731KPa, respectively. The analysis shows that the overall thickness of the pavement of the second structure is thicker, and the elastic modulus of the new overlay structure layer is smaller, which causes the internal vertical stress and shear stress of the second structure to be larger, which will increase the risk of pavement displacement, rutting and cracking.

It can be seen from Figure 8 to 9 that the transverse and longitudinal strains of structures 1 and 2 express to the peak of compressive strain in the road, and decrease with the increase of depth. Tension and compression alternate in the new pavement structure layer and begin to increase until the peak of tensile strain is reached at 15 cm, and then begin to decrease. Therefore, on the whole, the effect of setting 8cm asphalt concrete + 7cmATB-25 is better than that of setting 7cm asphalt concrete + 20 cm lime stabilized aggregate.

4 CONCLUSION AND SUGGESTION

In this paper, the use of two different overlay structures of ATB-25 layer and lime stabilized granular layer after the recycling of old cement pavement after rubblization is investigated and the structural mechanical response is calculated. The following conclusions are obtained :

(1) From the calculation and analysis of the failure mode and damage mechanism of the pavement structure, it is found that compared with the structure one, the maximum deformation of the surface deflection and the bottom deflection of the asphalt overlay layer of the structure two increased by 18.22 % and 15.49 % respectively. The structure one with 8cm asphalt concrete + 7cmATB-25 has better pavement bearing capacity. Due to the small elastic modulus of the new overlay structure layer of the second structure, the vertical stress and shear stress in the second structure are larger, which will increase the risk of pavement lapse, rutting and cracking. The maximum stress of the second structure in the transverse and longitudinal directions is greater than that of the first structure, which easily leads to a large stress concentration at the bottom of the base layer in the second structure, resulting in reflective cracks in the pavement. The vertical strain of structure one and structure two is always compressive strain, and it begins to decrease after reaching the peak of compressive strain at 10 cm. The peak strain of structure two is much larger than that of structure one, and the difference of transverse tensile strain peak is the largest, and the percentage of difference reaches 134.27 %. Therefore, on the whole, the effect of setting 8cm asphalt concrete + 7cmATB-25 is better than that of setting 7cm asphalt concrete + 20cm lime stabilized aggregate.

(2) Based on the actual engineering investigation and simulation analysis, it is found that considering the overall thickness and bearing capacity of the structure, the internal stress and strain changes of the structural layer, it is recommended to use the old cement pavement regeneration overlay structure of the road network, and adopt the ATB asphalt graded gravel base asphalt overlay structure with better flexibility and crack resistance. This paper can provide good theoretical and application support for the selection of overlay reconstruction structure after the regeneration of old cement pavement in road network.

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.

ACKNOWLEDGEMENTS

The research of this paper is supported by the ' Field Scientific Observation Station for Long-term Performance of Subgrade and Pavement in Guangxi Transportation Industry ' (Guijiaokejiaohan [2023 No.513) and ' Field Scientific Observation and Research on Long-term Performance of Large and Medium Repair Structure of National and Provincial Trunk Highways ' (Guijiaobianhan [2022] No.174).

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