Development of a new design method for composite pavement structure

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Abstract. HMA/PCC composite pavement is a new type of durable pavement structure which is a rigid-flexible combination. The composite pavement structure with excellent design has better durability. However, due to less domestic use, there is no effective structural combination design method in China. In this paper, a new structural design method of HMA/PCC composite pavement is put forward, in which the maximum thickness of asphalt concrete is designed according to the allowable permanent deformation, and the lower limit of the thickness of asphalt concrete is designed with the allowable shear stress of bond layer as the index. The composite slab model was used to design the thickness of concrete layer.

1. Introduction
HMA/PCC composite pavement is a type of pavement structure with rigid-flexible combination. The cement concrete layer is below. Asphalt concrete layer on top can buffer the impact of traffic load and climatic factors on the cement concrete slab. Because of the protection from asphalt concrete layer, diseases on cement concrete layer, such as erosion, creeping mud, emptying, broken slab and staggered platform can be greatly reduced.

In HMA/PCC composite pavement structure, cement concrete slab is the main bearing structure, which requires the layer to resist fatigue cracking and durability, the asphalt pavement layer is the functional layer, and at the same time protect the cement concrete slab, which requires better road surface performance and safety[1-3]. The typical structure of HMA/PCC composite pavement as shown in figure 1. Structure system for paving asphalt concrete is on newly cast cement concrete slabs [4].
The characteristics of HMA/PCC composite pavement structure are as follows:
1) HMA layer as the surface function layer is good smoothness, low noise, anti-rut deformation and durability.
2) Maintenance is convenient and fast. After the HMA layer is damaged by traffic load and aging environment, the new asphalt surface layer can be quickly milled and planed.
3) The PCC layer has a long design life and can be used for up to 30 years.
4) The typical damage of conventional asphalt pavement is less.
5) Life cycle cost advantage is significant. Initial construction of PCC layer can use old road recycling material, saving raw material cost, less road damage, lower maintenance cost, low future road overhaul cost (PCC layer can be used for 30 years, HMA layer refurbished every 10 years 15 years)
6) Sustainable development. The PCC layer can be 100% recycled pavement materials, the local cheap and slightly inferior aggregate can be used in the PCC layer, fly ash and other industrial waste can be used in a large number of substitutes for cement, saving costs[5].
7) HMA has the effect of insulation and moisture insulation on the PCC layer, which protects the PCC layer [6].

However, due to less domestic use, there is no effective structural combination design method in china. A new structural design method of HMA/PCC composite pavement is put forward, in which the maximum thickness of asphalt concrete is designed according to the allowable permanent deformation, and the lower limit of the thickness of asphalt concrete is designed with the allowable shear stress of bond layer as the index. The composite slab model is used to design the thickness of concrete layer.

2. Design method for composite pavement
According to the application practice of HMA/PCC composite pavement at home and abroad, rut deformation and reflection crack are the main diseases of HMA layer. Because of the protective effect of HMA layer, the diseases of PCC layer are less. Based on the design idea of preventing rut deformation and reflection crack, the composite plate model is used to analyze the pavement structure, and a new design method for HMA/PCC composite pavement structure is put forward, which includes three parts: one is the material and thickness design of HMA layer, the other is the design of the material and thickness of the pavement layers, another is selection of prevention and control measures for reflective cracks in Surface layer. For anti-rut deformation and anti-crack function, the material, thickness and size of PCC layer are designed to prevent the cracking of concrete slab under the action of traffic load and temperature fatigue, and the interlayer treatment measures are designed to restrain the reflection of the joint of PCC layer to the upper layer of HMA. The main design process is shown in figure 5.2. Temperat Measure Load and temperature fatigue stress checking calculation.
The main contents are as follows:

(1) According to the requirements of "specifications for Design of Highway Asphalt Pavement ", other influencing factors, such as traffic parameters, subgrade soil quality and equivalent modulus of resilience on top surface, humidity and temperature conditions are investigated and obtained.

(2) The design parameters of HMA layer and PCC layer, such as material property requirement and layer thickness, are preliminarily worked out.

(3) Stress analysis is carried out according to the composite slab model in the Specifications for Design of Highway cement concrete pavement.

(4) Calculating the bending stiffness and equivalent thickness of the composite plate.

(5) Selecting the appropriate treatment measures for reflective cracks according to the design requirements.

(6) Initially simulating the HMA/PCC pavement structure combination.

(7) Selecting the appropriate treatment measures for the reflective cracks according to the design requirements. Using the equivalent thickness of composite plate and the bending stiffness of cross-section, under the combined action of load and temperature gradient in the design base period, the fatigue

Figure 2. Design process of HMA/PCC pavement design
fracture of PC plate is not taken as the design criterion. Under the combined action of maximum axial load and maximum temperature gradient during the design base period, the limit cracking of PC plate is not considered as the checking standard.

(8) Checking whether the permanent deformation of HMA layer meets the requirements of the specifications.

(9) Checking whether the fatigue cracking life of HMA layer meets the requirements of the specifications.

(10) Either of the above (7), (8) and (9) fails to meet the specification requirements, and the process steps return (6) to re-setting the material parameters, the thickness of the structural layer, or changing the interlayer treatment measures.

(11) The HMA/PCC pavement structure is determined by the technical and economic comparison of the design scheme of pavement structure, which meets the requirement of checking calculation.

3. Case study
On the basis of the natural division of the highway and the design of the pavement structure of a first class highway, the HMA/PCC pavement structure combination design is studied by adopting the design process of the pavement structure mentioned above.

The natural division of highway is to build a new class one highway with HMA/PCC pavement and PC layer respectively using ordinary concrete. The roadbed soil is low liquid limit silt, and the road bed top is 1.5 m away from the groundwater level. According to the traffic investigation, the designed axle load is 100 KN. And the heaviest axle load is 200 KN. At the beginning, the number of daily action of the standard axle load is 2223, and the average traffic growth rate is 5%.

The proposed pavement structure and parameters can meet the requirements of checking the limit state of the structure. The thickness of PCC layer 250mm is the ultimate thickness under this traffic condition, and the thickness of PCC layer is 260 mm. Thus, the pavement structure diagram of ordinary concrete of the class one highway can be obtained. The design results are shown in Figure 3.

| 40mm Fine-grained asphalt concrete |
|-----------------------------------|
| 60mm Medium-sized asphalt concrete |
| Modified asphalt waterproof adhesive layer |
| 260mm normal concrete |
| 200mm Graded macadam base |
| Soil base |

Figure 3. HMA/PCC pavement structure

4. Conclusion
One new structural design method of HMA/PCC composite pavement is put forward, in which the maximum thickness of asphalt concrete is designed according to the allowable permanent deformation, and the lower limit of the thickness of asphalt concrete is designed with the allowable shear stress of bond layer as the index. The composite slab model was used to design the thickness of concrete layer. The example shows that the design method can meet the requirements of specification and pavement performance.

References
[1] Lytton, R. L., F. L. Tsai, S. Lee, R. Luo, S. Hu, and F. Zhou. NCHRP Report 669: Models for Predicting Reflection Cracking for Hot-Mix Asphalt Overlays. Transportation Research Board of the National Academies, Washington, D.C., 2011.
[2] Choubane, B., and M. Tia. Nonlinear Temperature Gradient Effect on aximum Warping Stresses in Rigid Pavements. In Transportation esearch Record 1370, TRB, National Research Council, Washington, D.C., 1992, pp. 11–19.
[3] Ioannides, A. M., and L. Khazanovich. Nonlinear Temperature Effects in Multilayered Concrete Pavements. ASCE Journal of Transportation Engineering, Vol. 124, No. 2, 1998, pp. 128–136.

[4] Hassan, K. E., J. C. Nicholls, H. M. Harding, and M. E. Nunn. Durability of Continuously Reinforced Concrete Surfaced with Asphalt. In Transport Research Laboratory Report TRL666, United Kingdom, 2008.

[5] Hallin, J., S. Sadasivam, J. Mallela, D. Hein, M. Darter, and H. Von Quintus. NCHRP Report 703: Guide for Pavement-Type Selection. Transportation Research Board of the National Academies, Washington,D.C., 2011.

[6] Yu, H. T., K. D. Smith, M. I. Darter, J. Jiang, and L. Khazanovich. Performance of Concrete Pavements Volume III: Improving Concrete Pavement Performance, Final Report. Report FHWA-RD-95-111. FHWA, U.S. Department of Transportation, 1998.