

Research on the Integration of Structural Design and Material Parameters of Long-life Asphalt Pavement

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Abstract: In order to reduce the disease risk stemming from asphalt concrete pavement and ensure the safety of road operation, we should pay attention to the structural design of long-life asphalt pavement, strengthen the selection of long-term pavement materials, scientifically set the pavement mechanical performance indexes based on the calculation results of pavement structure thickness combination and modulus combination, and ensure the stability and durability of road pavement structure through the real-time establishment of three-dimensional finite element calculation model, as well as the integrated design that takes into consideration the aspects of road subgrade, semi-rigid base and asphalt layer.

Keywords: Long life asphalt pavement; Modulus combination; Thickness combination; Structural design

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1. Introduction

In the environment of accelerating socialist economic development, the stability and durability of road engineering pavement structure will have a direct impact on national production efficiency. In recent years, the economic and trade exchanges between cities have become more frequent, and the number of road traffic running vehicles and the road load pressure have increased, resulting in the frequent occurrence of road pavement diseases and serious potential safety hazards for the safety of travelers. Therefore, it is of great significance to explore the scientific methods of long-life pavement structure design and construction. In fact, long-life asphalt pavement is to improve the durability of road pavement structure through the scientific selection of construction materials as well as the reasonable design of mixed materials and pavement structure. This study adopts the design of semi-rigid base asphalt pavement to realize the construction of long-life pavement, makes a scientific analysis on the structural design of each layer of pavement and the selection of pavement materials, and provides technical guidance for the efficient construction of similar projects.

2. Overview of long-life asphalt pavement

Long-life asphalt pavement refers to an innovative pavement with a theoretical service life of more than 40 years. During the design and construction of long-life road pavement, attention should be paid to its outstanding flexibility and durability characteristics, so as to avoid rutting, cracks, and other diseases under the influence of vehicle load and external stimulation factors^[1]. Therefore, relevant construction units and designers should fully understand the design connotation of long-life asphalt pavement, accurately calculate

the thickness combination and modulus combination of asphalt pavement structure, and then apply scientific construction technology to realize the scientific control of road pavement structure diseases.

3. Selection of mechanical performance indexes of long-life asphalt pavement structure

The release of the code for design of highway asphalt pavement (JTGD50-2017) puts forward new requirements for the mechanical performance indexes of asphalt pavement. It requires designers to take into consideration the tensile stress at the bottom of asphalt layer, surface deflection and surface shear stress as the main indexes for the design of new road asphalt pavement in order to control the fatigue damage of pavement and improve the overall stiffness of pavement.

In fact, the fatigue life of asphalt layer is mainly affected by tensile stress. Therefore, the fatigue characteristics of asphalt layer can be accurately reflected by using tensile strain instead of tensile stress. In terms of ensuring the overall stiffness of the pavement, we should not only pay attention to the deflection design of the road surface, but also pay attention to the stress design of the stress surface. Through systematic research, Bi ^[2] found that the maximum shear stress of asphalt pavement in road engineering plays a decisive role in the early longitudinal crack shear damage of rutting and wheel track belt. Therefore, in this study, the pavement surface deflection, the tensile strain at the bottom of the asphalt layer, the compressive strain at the top of the foundation, and the maximum shear stress of the surface layer are used as the mechanical analysis indexes of the pavement structure.

4. Design of structural surface course of long-life asphalt pavement

In the structural design of long-life asphalt pavement surface, the main consideration should be the protection of pavement base crack and dry crack. Designers should effectively control the subgrade design, semi-rigid design and asphalt layer thickness design, so that the semi-rigid base that has not been cracked can be scientifically protected, so as to improve its overall durability and ensure that the service life of the pavement can be moderately extended.

4.1. Roadbed design

Under the action of vehicle load, the asphalt pavement structure will deform, and the bottom surface of the surface course will produce the phenomenon of joint strain, which will seriously affect the safety of the road pavement, which will not only bring inconvenience to the driving comfort, but also further damage the pavement fatigue. Based on this, designers should focus on controlling the permanent deformation of pavement structure in the process of road pavement design. One way is to accurately analyze the permanent strain inside by constructing the prediction model, and determine the design conditions and actual deformation by calculating the cumulative deformation ^[3]. The other way is to limit the profitability of subgrade soil and reduce shear failure, so that the permanent deformation of pavement under repeated load is always in a stable state, so as to avoid diseases such as car river and crack during road operation.

4.2. Semi rigid base course

In the practice of structural design of long-life asphalt pavement, the construction unit shall mainly design the semi-rigid base course with rigid materials, which have high quality and high compressive strength for the overall structure. Even under the load of heavy-duty trucks, the compressive stress can reach 1 MPa, and the stress transmitted to the surface of the base course is smaller, meeting the durability requirements of road pavement ^[4].

4.3. Asphalt layer

In order to ensure that the asphalt pavement has been operated for 40 years without fatigue damage, the

concept of long-life construction should be scientifically integrated into the pavement structure design, and all details should be strictly controlled. For example, in the selection of asphalt materials, it is necessary to check the pavement fatigue during the road design life, and then formulate a scientific construction scheme based on the road design standard. Meanwhile, it is required to strictly follow the established scheme in the subsequent construction to ensure that the quality of the road pavement structure meets the long-life application standard [5].

5. Calculation and analysis of pavement structure thickness combination

5.1. Structure thickness combination and material parameters

In order to control the pavement elevation scientifically, the total thickness of pavement structure should be kept unchanged during calculation, and the flexible base course should be replaced by asphalt surface course. The thickness of the surface course should be strictly controlled, and the thickness of the corresponding base course should also be controlled within the allowable variation range, generally 10 – 40 cm. High-quality asphalt mixing beam should be adopted for each layer of asphalt, the modulus should reach 1400 MPa, and the Poisson's ratio should be set to 0.35. The base modulus is set to 400 MPa and the Poisson's ratio is set to 0.35. The modulus of soil foundation is 45 MPa and the Poisson's ratio is 0.40 [6]. The calculation and parameters of pavement structure are shown in **Table 1**.

Table 1. Pavement structure and parameters with varying thickness of structural layer

Pavement structure	Thickness (cm)	Modulus (MPa)	Poisson's ratio
Asphalt surface course	32-62	1400	0.35
Basic level	42	400	0.35
Soil base		45	0.40

5.2. Result analysis

Various parameters are input into the general finite element calculation program for calculation, and the obtained mechanical indexes are shown in **Table 2**. Reading **Table 2**, we can draw the following conclusions:

- (i) The flexural tensile strain of asphalt pavement structure will increase with the increase of asphalt layer thickness, while the flexibility will gradually decrease with the increase of asphalt layer thickness. The maximum shear stress also showed an insignificant growth trend.
- (ii) With the increase of the thickness of base course, the total deflection of asphalt pavement will decrease obviously.

Through the combination calculation of asphalt layer and flexible base course with different thickness, it is found that the deflection value for testing the overall deformation capacity of pavement structure changes greatly, while the maximum shear stress value affecting the local shear failure of surface layer and the maximum flexural tensile strain of fatigue crack of asphalt layer are not obvious [7].

Relevant research results show that the construction of thick asphalt surface on semi-rigid foundation can significantly reduce the maximum shear stress and bending tensile stress at the bottom of the layer, while the construction of thick asphalt surface on flexible base will not significantly change the maximum shear stress and bending tensile strain, indicating that without considering the nature of the base, blindly increasing the thickness of asphalt surface may lead to a significant increase in the shear failure ability of pavement structure and the overall failure ability of pavement. Therefore, designers should fully consider the adverse impact of base course properties on pavement structure when implementing the thickness combination design of pavement structure [8].

Table 2. Mechanical indexes calculated when the thickness of structural layer changes

Surface thickness (cm)	Base course thickness (cm)	Maximum shear strain (Ma)	Maximum bending tensile strain ($\mu \mathcal{E}$)	Deflection / 0.01 mm
32	40	1.93E+05	25.72	29.82
34	38	1.95E+05	32.35	29.80
36	36	2.69E+05	41.05	29.82
38	34	2.04E+05	25.61	29.84
40	32	1.78E+05	32.99	29.59
42	30	2.42E+05	68.74	28.42
44	28	2.70E+05	29.99	29.09
46	26	2.38E+05	21.98	28.75
48	24	2.16E+05	30.01	28.32
50	22	2.61E+05	39.20	27.97
52	20	2.23E+05	41.64	27.32
54	18	2.19E+05	52.78	27.37
56	16	2.05E+05	54.75	27.04
58	14	2.37E+05	45.85	26.52
60	12	2.51E+05	68.49	25.87
62	10	2.80E+05	43.01	16.13

6. Calculation and analysis of pavement structure modulus combination

6.1. Structural modulus combination and material parameters

The main feature of long-life pavement structure is that the surface layer and intermediate layer can diffuse the load and prevent pavement damage. The main function of the base course is to eliminate fatigue damage. Pavement foundation plays a positive role in promoting pavement deformation and frost resistance. Therefore, the surface course adopts high-quality asphalt mixture, the base course adopts low modulus flexible material, and the soil foundation adopts stable soil material. In order to find out the important influence of asphalt mixture surface course and low modulus base course on pavement structure, it is necessary to accurately calculate the modulus combination of pavement structure ^[9-12]. The specific performance is as follows: The thickness of each surface course remains unchanged, and the modulus of asphalt layer is controlled in the range of 1200 – 1600 MPa. The low modulus base course should be controlled at 1000 – 200 MPa. The modulus of soil foundation is 45 MPa. The pavement structure and parameters are shown in **Table 3**.

Table 3. Pavement structure and parameters with varying structural layer modulus

Pavement structure	Thickness (cm)	Modulus (MPa)	Poisson's ratio
Asphalt surface course	32	1200 – 1600	0.35
Basic level	40	1000 – 200	0.35
Soil base	N/A	45	0.40

6.2. Result analysis

By inputting the parameters into the finite element program, the mechanical indexes can be obtained. The results are shown in **Tables 4, 5 and 6**.

Table 4. Maximum flexural tensile strain when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	23.32	19.63	16.59	14.13	12.01
	400	33.74	29.44	25.73	22.70	19.96
	600	41.10	35.52	31.43	27.98	25.14
	800	48.11	42.09	37.11	32.90	29.20
	1000	43.43	47.13	41.88	36.37	33.64

Unit: $\mu\epsilon$ **Table 5.** Maximum shear stress when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	194811	194917	194992	195069	195152
	400	194.79	194183	194279	194361	194443
	600	193621	193722	193818	193903	193979
	800	193309	193403	193485	193579	193661
	1000	193082	191839	193249	193332	193409

Unit: Pa

Table 6. Maximum deflection value when the modulus of structural layer changes

Surface layer	MPa	1200	1300	1400	1500	1600
Base course (MPa)	200	35.53	34.38	33.52	32.63	31.87
	400	31.44	30.61	29.83	29.09	28.51
	600	29.12	28.40	27.74	27.14	26.48
	800	27.64	26.91	26.26	25.73	25.22
	1000	26.49	25.78	25.17	24.68	24.24

Unit: 0.01 mm

Through the analysis of relevant data in **Tables 4, 5** and **6**, the following changes can be found:

(i) The maximum shear stress of pavement structure increases with the increase of asphalt surface modulus. The maximum flexural tensile stress is inversely proportional to the completion value and the increase of surface modulus, that is, the modulus increases, and the maximum shear stress and deflection value gradually decrease.

(ii) The maximum strain of pavement structure will increase with the increase of flexible base modulus. The maximum shear stress and deflection decrease with the increase of flexible base modulus.

Relevant research results show that the application of flexible base material can help the rapid diffusion of road surface stress. However, the application of flexible base can significantly improve the maximum flexural tensile strain and deflection ^[13-16]. It is not advisable to increase the modulus of flexible base material. High-quality asphalt pavement can significantly reduce the maximum flexural tensile strain, enhance the fatigue cracking resistance of road pavement structure, and effectively improve the deformation resistance of pavement structure. It can be widely used in engineering design practice. It should be noted

that in the application practice of modulus flexible materials and asphalt surface materials, materials should be selected first, and the maximum shear stress and deflection of materials are required to meet the design standards [17,18].

7. Conclusion

In short, the long-life asphalt pavement structure is the inevitable trend of the construction and development of road pavement engineering in the future. Relevant personnel should apply high-quality thick asphalt pavement and high modulus flexible base material in the structural design and material selection of long-life asphalt pavement, and make use of its significant mechanical index advantages to continuously improve the stability and durability of road pavement structure and ensure the safety of road operation.

Disclosure statement

The author declares no conflict of interest.

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