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Research Paper

# Research on Design Method of Long-life Asphalt Pavement

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In recent years, the problem of early damage of asphalt pavement has been basically solved, and the service performance has been improved, but there are still some deficiencies in design life and service life. This paper investigates the long-life asphalt pavement structure, analyzes the design method of asphalt mixture, and summarizes the pavement design theory and related software. The long-life asphalt pavement with semi-rigid base, flexible base and combined base structure has been designed by four method, including typical load, Per-Road, D50-2006 and D50-2017. Four methods were compared by designing long-life pavements with semi-rigid base and flexible base. The results show that the proposed asphalt pavement structure can meet the requirements of Per-Road, typical load design and D50-2006. However, D50-2017 has higher requirements for the bending and tensile fatigue life of the base layer and requires a thicker base layer. When d50-2017 is used to design flexible base pavement, the fatigue life of asphalt layer should be the main control index, and the fatigue life of sub base course should be the main control index in other pavement de-sign. It remains to be seen whether the proposed highway structure can achieve the design goal of long-life asphalt pavement.

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## 1 Introduction

Asphalt has become one of the most important pavement for its construction continuity and other characteristics. At the same time, asphalt pavement has high-temperature stability and low-temperature crack resistance, which greatly improves the safety of the road, making people travel more efficient and comfortable.However, due to the effect of traffic load and

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natural oxidation, asphalt pavement is easy to damage and aging, and this will shorten its life. The design life of asphalt pavement in various countries in the world is shown in Table 1.According to the investigation, the service life of the current asphalt pavement is about 7 or 8 years. If major or medium repairs are not carried out, it will not meet the service performance. However, frequent repairs will consume a lot of manpower and financial resources. And frequent construction of roads will also reduce the capacity of the highway.Therefore, designing a long-life asphalt pavement has become an urgent research issue.

**Table 1. Design life of asphalt pavement in various countries**

| Country | China | US | Germany | UK | France | Japan | Canada |
|---|---|---|---|---|---|---|---|
| **Design life (year)** | 15 | 20~40 | 30~40 | 40 | 30~40 | 20~40 | 30~40 |

In 20th century, long life pavement has become a popular research issue in the world [1-5]. European Long-Life Pavements Group (ELLPAG) has conducted a number of studies on long-life pavements and achieved good results [3]. In June 2004, ISAP (international Society for Asphalt Pavements) organized the "First International Conference on Long-Life Pavements" at Auburn University in the United States. The conference mainly introduced the use of long-life pavements in developed countries. In 2016, the International Symposium on permanent pavement was held in Jinan, China. The conference discussed the development feasibility of permanent pavement under heavy traffic conditions, and summarized and exchanged the development, application and performance of long-life pavement.

This paper investigated the current long-life pavement structures. compare different design software, different pavement structures were designed by four methods. This paper can provide reference to related research of long-life pavement.

## 2 Long-life asphalt pavement structure

By investigating the long-life asphalt pavements that have been built in China, three pavement structures including semi-rigid base, flexible base and combined base, have been obtained in Table 2.

**Table 2. Three pavement structures for long-life asphalt pavement**

| | Semi-rigid base | | Flexible base | | Combined base | |
|---|---|---|---|---|---|---|
| **Structure combination** | Mixture type | thickness (cm) | Mixture type | thickness (cm) | Mixture type | thickness (cm) |
| **Surface** | Modified asphalt SMA-13 | 6 | Modified asphalt SMA-13 | 4 | Modified asphalt SMA-13 | 4 |
| | Continuously reinforced cement concrete | 24 | Modified asphalt Sup-20 | 6 | Modified asphalt AC-20 | 6 |
| | | | Ordinary asphalt Sup-25 | 8 | | |
| **Base** | Cement stabilized macadam | 26 | Ordinary asphalt ATB-25 | 20 | Asphalt Macadam LSM-25 | 18 |
| | | | Graded gravel | 20 | Low-dose cement stabilized gravel | 20 |
| **Sub-base** | Lime soil | 20 | Low-dose water stabilized gravel | 20 | Lime soil | 24 |

## 3 Theoretical method of long-life asphalt pavement design

### *3.1 Long-life pavement design software*

The design software of long-life pavement includes FPS 21 of TxDOT (Texas Department of Transportation), TxME of TTI (Texas Transportation Institute), PerRoad of NCAT (National Center for Asphalt Technology), the permanent pavement design software of Shandong Provincial Transportation Research Institute. The mechanics calculation model of all the above software is the same as the traditional road design method, which is based on the elastic layered system design, but they have some differences in the value standard of the design index. The comparison results of different design methods are shown in Table 3.

**Table 3. Comparison of different design methods**

| project | FPS 21 | TxME | PerRoad 4.4 | Shandong Research Institute |
|---|---|---|---|---|
| **Design method** | Linear elastic analysis | Linear elastic analysis | Linear elastic analysis | Linear elastic analysis |
| **Reliability analysis** | No | Yes | Yes | No |
| **operation hours** | Short (<10s) | Medium (<2min) | Long | medium |
| **Maximum design level** | 7 | 7 | 5 | / |
| **Output** | Suggested design choices | Monthly disease or performance forecast | Number of years required to produce specific diseases | Suggested design choices |
| **Analysis cycle** | ＞20 years | ＞20 years | ＞20 years | ＞20 years |
| **Fatigue limit** | No | Determine single value strain | Compare and determine strain distribution and user input | Yes |
| **Permanent pavement structure** | Needs correction | Needs correction | Needs correction | No |
| **Software modifiable** | Yes | Yes | No | No |

### *3.2 Comparison of different design software*

Referring to the investigated long-life asphalt pavement structure, the long-life pavements of three types including semi-rigid base, flexible base, combined base are designed respectively using the environment of a certain highway. The design methods used are Typical Load, PerRoad, Specification for Design of Highway Asphalt Pavement (JTG D50-2006) and Specification for Design of Highway Asphalt Pavement (JTG D50-2017). The design diagram is shown in Figure. 1.

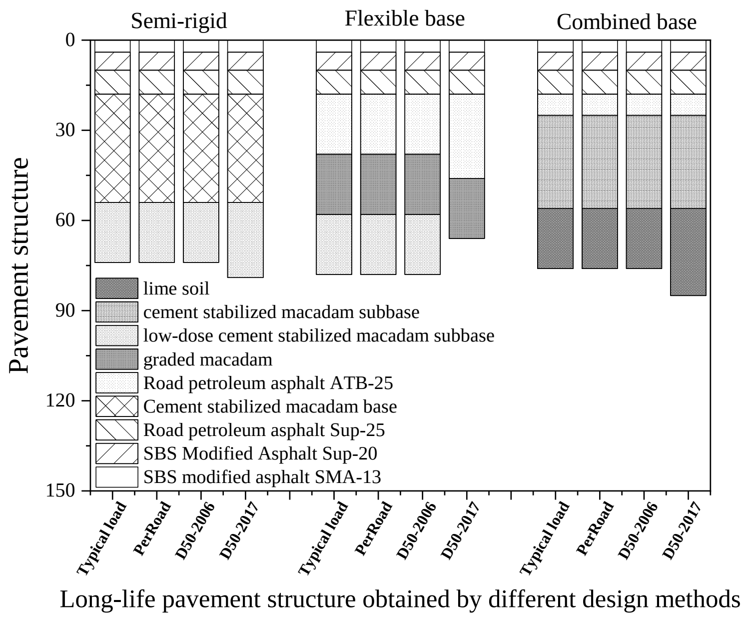



***Fig. 1. Pavement structure drawings of different design methods/software***

### *3.2.1 Semi-rigid base long-life pavement structure*

In the design of PerRoad and typical load (overload 40%), the vertical compressive strain of the top of the soil foundation and the tensile strain at the bottom of the asphalt layer is far below the fatigue limit standard, which means the existing structure can meet the requirements of long-life asphalt pavement.

D50-2017 design method mainly adopts the concept of cumulative damage. Com-pared with the typical structure of Expressway, 6cm low dose Cement Stabilized Macadam Subbase is added to ensure that the bending fatigue life of low-dose cement stabilized Macadam Subbase meets the requirements of the specification as shown in Figure. 2. The existing structure designed according to D50-2006 meets the requirements, that is, D50-2017 design method has higher requirements for the base layer.

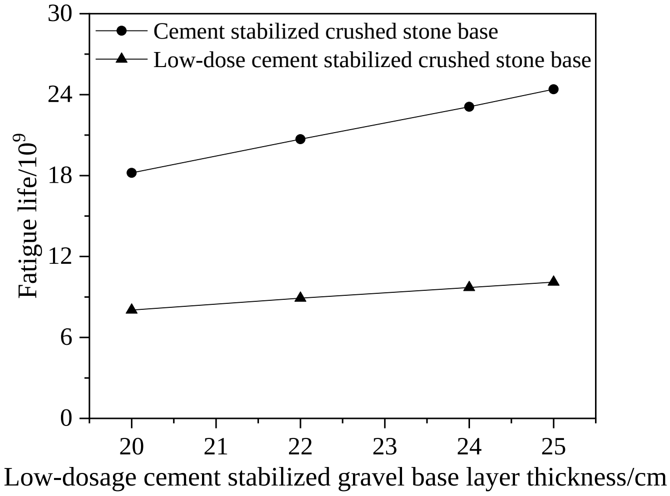


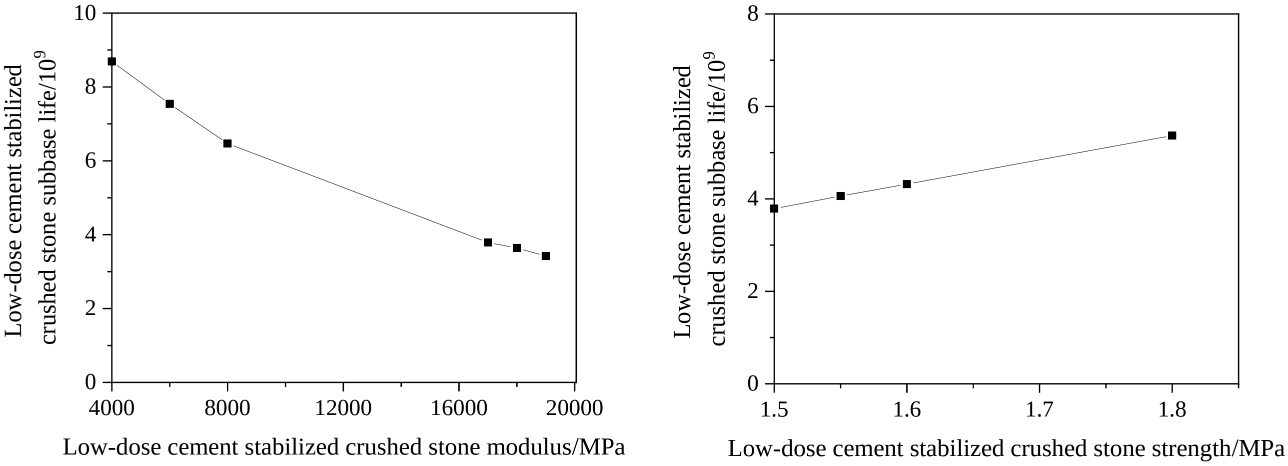

***Fig. 2. Relationship between fatigue life and subbase thickness of inorganic binder stabilized material layer***

### *3.2.2 Flexible base long-life pavement structure*

In the design of PerRoad and typical load (overload 40%), the vertical compressive strain of the top of the soil foundation and the tensile strain at the bottom of the asphalt layer is far below the fatigue limit standard, which means the existing structure can meet the requirements of long-life asphalt pavement.

When adopting the D50-2017, the fatigue life of the low-dose cement stabilized macadam was $3.79\times10^9$, while the design standard is $9.87\times10^9$, and the fatigue life of the low-dose cement stabilized macadam couldn't meet the requirements. In order to optimize the structure, some attempts were adopted including increasing the thickness, reducing the modulus and increasing the strength. The results show that when the thickness of the base was increased to 50 cm, the fatigue life of the low-dose cement stabilized macadam was able to meet the requirements. At this time, the thickness was increased by 150% relative to the original structure. The increase in modulus will further reduce its fatigue life, which means the improvement of strength will be limited in Figure. 3. The increase in strength will lead to an increase in modulus, but the effect of them is contrary to the road life.

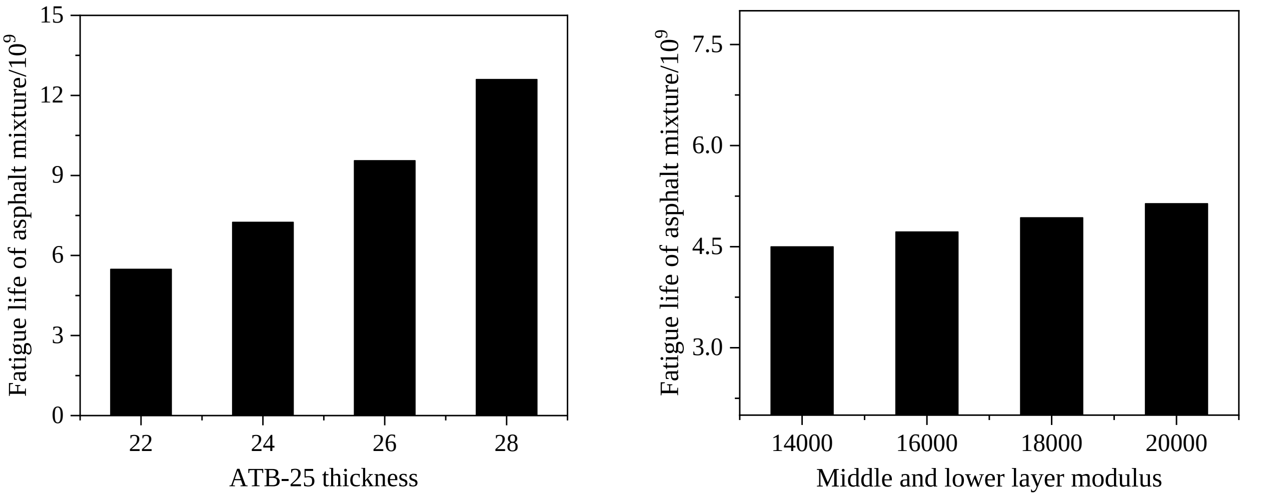
Considering the impact of increase in the thickness on the road surface elevation and cost, an attempt was made to adopt a fully flexible asphalt pavement, that is no low-dose cement stabilized macadam subbase was set. Set the initial pavement structure to 4cm SBS modified asphalt SMA-13+6cm SBS modified asphalt Sup-20+8cm road petroleum asphalt Sup-25+20cm road petroleum asphalt ATB-25+20cm graded macadam. At this time, the fatigue life of the asphalt layer was $4.19\times10^7$, and the design standard is $1.23\times10^8$, which means it couldn't meet the requirements. Therefore, consider increasing the thickness of the ATB-25 base layer or increasing the modulus of the middle and lower layers. According to the relationship between the fatigue life of the asphalt mixture and the thickness of the ATB-25 base layer and the modulus of the middle and lower layers of the asphalt mixture in Figure. 4, the design of the pavement structure scheme is 4cm SBS modified asphalt SMA-13+6cm SBS modified asphalt Sup-20+8cm road petroleum asphalt ATB-25+28cm road petroleum asphalt ATB-25+20cm graded macadam.




a. The relationship between fatigue life and modulus

b. The relationship between fatigue life and thickness

***Fig. 3. Fatigue life relationship diagram of low-dosage cement stabilized macadam subbase***




a. The relationship between fatigue life and ATB-25 thickness

b. The relationship between fatigue life and modulus of middle and lower layers

***Fig. 4. Diagram of fatigue life of asphalt mixture***

### *3.2.3 Combined base long-life pavement structure*

In the design of PerRoad and typical load (overload 40%), The tensile strain at the bottom of the asphalt layer is far below the fatigue limit standard, which means it can meet the design requirements of long-life asphalt pavement.

When the D50-2017 design is adopted, the fatigue life of the water-stable gravel sub-base in the combined base test road of the expressway along the Yangtze River is $6.51\times10^9$, the fatigue life of lime-lime soil is $8.19\times10^9$, and the design standard is $9.87\times10^9$, which means the fatigue life of lime-lime soil couldn’t meet the requirement. In order to meet the requirements, the asphalt pavement structure designed added 9cm of lime-lime soil base in Figure. 5.

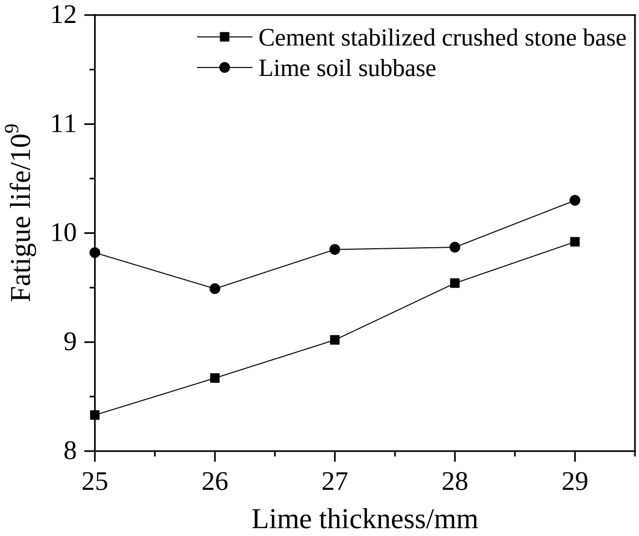



***Fig. 5. The relationship between the fatigue life of inorganic binder stabilized material layer and the thickness of limestone***

## 4 Conclusions

Summarized the current long-life pavement structure, long-life pavement design theory and method, compared four design methods, and reached the following conclusions:

- According to the different base materials, the long-life asphalt pavement can be divided into three types: semi-rigid pavement structure, flexible pavement structure and combined pavement structure.
- The mechanical index of long-life pavement design is mainly based on the calculation of linear elastic system, and the concept of fatigue limit is the mainstream concept of long-life pavement design.
- Long-life pavement mainly includes PerRoad software, D50-2017, typical load and D50-2006 four design methods. When D50-2017 is used to design semi-rigid base pavement structure or combined base pavement structure, for semi-rigid base or semi-rigid base, the fatigue life requirements are higher.

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