

# Study on New Combined Asphalt Pavement Structure

Yichen Fang\*

*School of Civil Engineering, Shandong University of Construction, Shandong Province, China 250101*

*\*Corresponding author. Email: 2506281851@qq.com*

## ABSTRACT

In modern times, new asphalt pavement structures have become a hot topic of concern in the road and urban road construction industry. If the new asphalt combined structure can be used in road construction, it will provide key help to improve the performance of the pavement and guarantee the quality of the pavement. In this paper, the excellent high-temperature stability and good compressive and tensile properties are obtained by combining the results of numerical simulations with finite element software from previous papers on new pavement structures combined with corresponding asphalt materials, followed by an analysis of the current situation of new combined asphalt pavement applications in China. Finally, it presents the research content that is not covered in the relevant papers at this stage, and proposes to reduce the vertical displacement of the new combined asphalt to meet its overall optimisation as the future direction that can be developed.

**Keywords:** *New combined asphalt; Pavement structure; Development prospect*

## 1. INTRODUCTION

With the progress of the times, China's highway and urban road construction business are developing rapidly. However, the quality of road construction and construction technology and other aspects are still some shortcomings, especially China's widespread use of semi-rigid asphalt pavement, whose service life generally does not reach the design life. And maintenance, not only repair the asphalt surface layer, but also must be repaired at the same time the grass-roots level and even the sub-base, this major repair not only high cost, but also cause adverse social impact. And for China's highway "big traffic" "high axle load" traffic conditions, ordinary flexible base pavement structure resistance rutting ability is poor [1]. Therefore, we urgently need a durable and excellent pavement structure and material. The flexible subgrade asphalt pavement structure can effectively delay the development of cracks and other diseases, and extend the life of the subgrade. At the same time, the new combined sub-base asphalt pavement structure has good resistance to compression and tensile deformation. Therefore, it is important to find out the applicability of the new combined sub-base asphalt pavement structure in China, and if it can be proven to be suitable for road construction in China, then the above disadvantages can be greatly improved. The main objective of this paper is to synthesise the advantages of the new combined asphalt road structure at this stage and compare it with the

traditional semi-rigid structure of asphalt roads in China to verify its suitability for road construction in China.

## 2. RESEARCH STATUS

### 2.1. summary of research results

Tang analyzed the application of new pavement structures and high-performance pavement materials[2]. This paper introduces the design points and advantages and disadvantages of lean concrete base pavement, permanent pavement, and multi-void drainage pavement in asphalt concrete pavement, reinforced concrete pavement in cement concrete pavement, and different pavement types in steel fiber concrete pavement, and extends the corresponding development direction, based on external factors and geographical environment factors. This paper focuses on the analysis of modified asphalt in high-performance pavement materials, the different treatment methods of physical and chemical modification, the growth of high-quality performance after modification, and what kinds of road practical problems have been solved. The opportunity points to change the quality of pavement are summarized, which can be improved by the construction structure and the reasonable selection of pavement materials. Choosing the appropriate pavement structure and high-performance pavement materials for different pavements can not only

ensure the quality of pavement, but also improve the safety factor of road driving.

Zheng Hezhang et al. demonstrated the applicability of the new combined base asphalt pavement structure in the construction of an expressway in Jiangsu Province [3]. According to the theoretical method, the control standard for bottom tensile strain of asphalt layer is determined as follows: the bottom tensile strain of modified asphalt layer is less than  $100 \mu \varepsilon$  [4-5]. The tensile strain standard at the bottom of heavy asphalt layer is less than  $70 \mu \varepsilon$ . Combined with the pavement structure, the corresponding mechanical model is established for analysis and calculation. The main conclusions are as follows: the new combined base asphalt pavement structure is modified asphalt SMA13 + Modified Asphalt sup20+

Road petroleum asphalt lsm25 + water stabilized base; The dynamic stability of asphalt macadam base lsm25 can reach 2676 times / mm at  $60^\circ\text{C}$ , and has good compressive performance and tensile deformation resistance; The "fatigue limit" of the LSM mixture layer is about  $70 \mu \varepsilon$ .

Li and Bai et al. studied the nonlinear research method of a new flexible pavement structure [6]. The Dun can chang constitutive model is selected to simulate the nonlinear elastic mechanical characteristics of foundation soil, and the flexible pavement structure is simplified into a membrane beam element mechanical model [7]. Considering the large deformation of pavement structure under load and the contact nonlinearity between foundation and pavement, the nonlinear analysis model of flexible pavement structure is established by using the finite element analysis software ABAQUS, and the results of deformation and internal force response of pavement structure under load are obtained. The accuracy of numerical analysis results is verified by real load test. Finally, it is concluded that the Dun can Chang model is utilized for the modeling of flexible pavement on soft soil foundation, and the loading form of flexible pavement is simulated by membrane beam element composite. The analysis results are consistent with the pavement test results, and the coincidence degree is more than 80%. The woven body is melted into TPU with outstanding wear resistance, so that the pavement has better wear resistance; The reinforcing rod and thermoplastic polyurethane sheet are heat bonded as a whole, which can better bear the effect of high-grade load. However, the analysis method is static load analysis, and phenomena such as liquefaction or softening of beach foundation soil under continuous dynamic load are not considered in the analysis process. Therefore, in order to more accurately simulate the actual stress conditions of flexible pavement, we can consider carrying out a dynamic response analysis of flexible pavement.

Fan analyzed the main damage to the pavement, and then simulated the pavement structure through ANSYS finite element analysis [8]. It was concluded that the shear stress of the asphalt pavement was the largest at 5cm. At the same time, according to the rutting formation mechanism, the outlet surface course was the main anti rutting effect. Secondly, the pavement structure layer is optimized. Through the finite element analysis of each layer of the combined base asphalt pavement under different thicknesses, the design and modulus requirements of the combined base asphalt pavement structure layer are put forward.

The layer function of cement stabilized macadam layer is based on the comprehensive design of the crack resistance of cement stabilized macadam base according to the three indexes of unconfined compressive strength, splitting strength and maximum dry shrinkage strain. Finally, compared with the semi-rigid base, it is found that it can greatly improve the problem of pavement cracks, and it is concluded that the combined base has a certain application value. And the analysis of the economic and social benefits of using a semi-rigid base versus a combined base has obvious advantages in terms of daily maintenance after construction. For example, the semi-rigid base layer will crack as the pavement is used for a longer period of time. However, the use of graded aggregates as an intermediate layer underneath the asphalt layer can effectively reduce or delay the cracking of the asphalt pavement, thus extending the service life of the pavement. For later pavement maintenance, the frequency of repairs can be reduced and maintenance costs reduced.

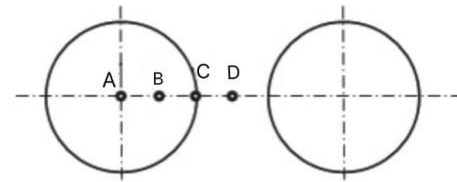
S compared and analyzed the characteristics of semi-rigid base asphalt pavement in China and long-life asphalt pavement in foreign countries, put forward the rationality of using a combined base for asphalt pavement in China, and expounded the research status of long-life durability asphalt pavement at home and abroad [9]. The application of combined base asphalt pavement on the Shao Gan expressway is introduced. Through the investigation and analysis of the asphalt pavement condition, it is found that the combined base asphalt pavement is in good condition, and the rationality of the application of the asphalt pavement form in China is affirmed. The simulated data of vertical displacement, vertical dynamic stress, horizontal dynamic stress, shear stress and compressive strain of semi-rigid subgrade and combined subgrade asphalt pavement under moving load were compared and analysed using ANSYS method. This has guiding significance for the design and construction of combined base asphalt pavement in the future. The structural characteristics of combined base asphalt pavement are obtained, the structural design indexes of this kind of asphalt pavement are determined, and the influence of various indexes on relevant factors is analyzed. It provides a certain reference and guiding significance for the design, construction and maintenance of combined

base asphalt pavement in China, and has a certain practical application value.

## 2.2. introduction to some data results, curves and formulas

Zheng Hezhang et al. adopted an elastic layered system to calculate the mechanical model of the three schemes [3]. Each layer is assumed to be in a continuous state, and the design axle load is bzz-100, the standard axle load of China's asphalt pavement design code. The plane position of the calculation points is shown in Figure

1, and the calculation result is the one with the largest index value among the four points.



**Figure 1** Calculation points

The corresponding modulus of resilience results are obtained. Table 1

**Table 1:** resilient modulus test results (20° C)

Mix type	Oil to stone ratio %	Modulus of rebound/Mpa							
		1	2	3	4	5	6	Average	Requirements
LSM25	3.8	128	109	14	98	12	13	1224	> 800
		0	2	62	0	30	00		

In order to test the high-temperature stability of large particle size asphalt macadam mixture (LSM) utilized in the test road, the high-temperature rutting test is

employed to evaluate the high-temperature stability of LSM mixture, and the rutting test results are shown in Table 2:

**Table 2:** rutting test results of LSM mixture

Mix type	Oil to stone ratio %	Dynamic stability/(times*mm <sup>-1</sup> )			
		1	2	3	Average
LSM mixes	3.8	2890	2460	2680	2676

The rutting test results show that the dynamic stability of LSM mixture has reached 2676 times / mm, which exceeds the requirement that the dynamic stability of middle and lower layer heavy duty asphalt mixture is greater than 800 times / mm. It also shows that the high temperature stability of LSM is good.

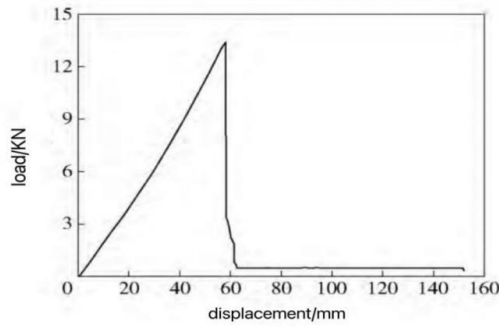
Li Hebai et al. in order to accurately analyze the mechanical behavior of flexible structure bearing, the Duncan Chang nonlinear elastic foundation model, which is closer to the actual mechanical properties of soil, is selected as the foundation constitutive model, which can reflect the nonlinear, compressive and strain strengthening characteristics of the foundation under the pavement [6].

The constitutive relation of the model (1) is briefly described as

$$E_t = \left[ 1 - \frac{R_t(\sigma_1 - \sigma_3)(1 - \sin \varphi)}{2c \cos \varphi + 2\sigma_3 \sin \varphi} \right]^2, \quad (1)$$

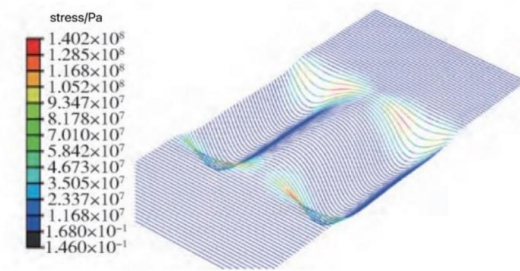
The finite element model of flexible pavement is established, and the geometric dimension is 4.5 mm wide by 2 m, with a full load length of 12 M. the flexible pavement layer is discretized by S4 element (4-node quadrilateral membrane strain linear integral element), which is divided into 4000 elements in total; B31 element (linear beam element) is selected as the stiffening rod, which is divided into 4040 elements. The reinforcing rod, flexible layer and other materials are tested by MTS810 material testing machine produced by MTS company in the United States.

The tensile curve of a typical sample of flexible layer is shown in Figure 2.

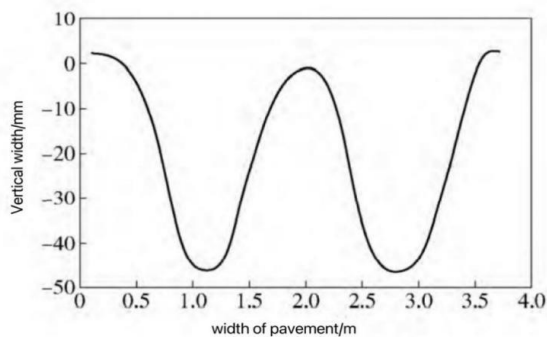


**Fig.2** Typical tensile curve of flexible layer

Fig. 3 and Fig. 4 are respectively the nephogram of bending stress of stiffener and the deformation curve of single stiffener along 4m long axis



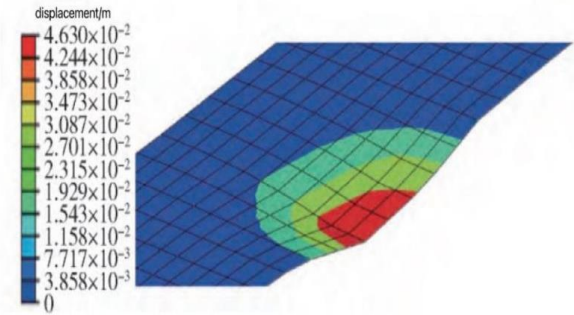
**Fig.3** Bending stress nephogram of enhanced rods



**Fig.4** Deformation curve of single enhanced rod along 4 m long axis

It can be seen that after the pavement is loaded, the middle part is raised, the loading positions on both sides are concave, and the deformation is in a "W" shape, which is consistent with the phenomenon that the foundation soil is squeezed from both sides to the middle after the pavement is loaded in the actual test process, resulting in the arching of the middle of the pavement slab.

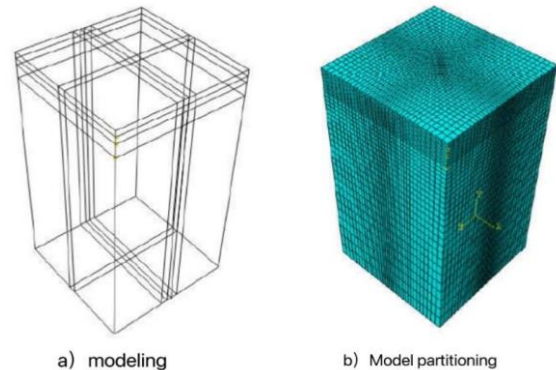
The cloud diagram in Figure 5 is the cloud diagram of the longitudinal section deformation of the flexible layer under the action of a single wheel.



**Fig.5** Deformation nephogram of load bearing location

It can be observed from the figure that the numerical analysis results have good continuity. The pit formed by the flexible layer at the wheel load position shown in the figure is also consistent with the deformation mode of the flexible layer in the actual working condition.

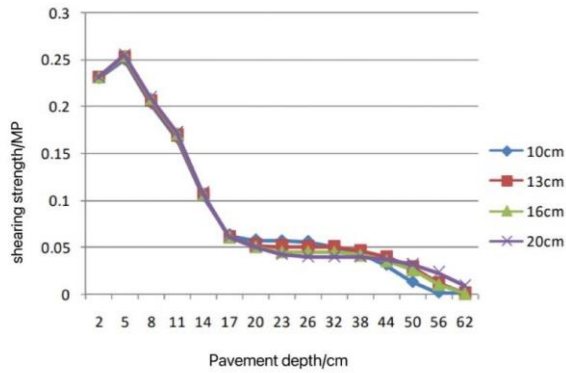
When the fan established the finite element model, the grid size was 0.02M [8]. At the same time, he densified the grid of cement stabilized gravel layer, graded gravel layer and asphalt surface layer along the pavement thickness. 8-node isoparametric element is adopted. The boundary conditions are assumed as follows: there is no X-direction displacement in the front and rear directions, no Y-direction displacement on the bottom, no Z-direction displacement in the left and right directions, and the layers are completely continuous. As shown in Figure 6.



**Figure 6** Finite element model

At the same time, the graded crushed stone layer is adopted as the transition layer to support the surface layer, so its modulus, thickness and other parameters need to be adjusted.

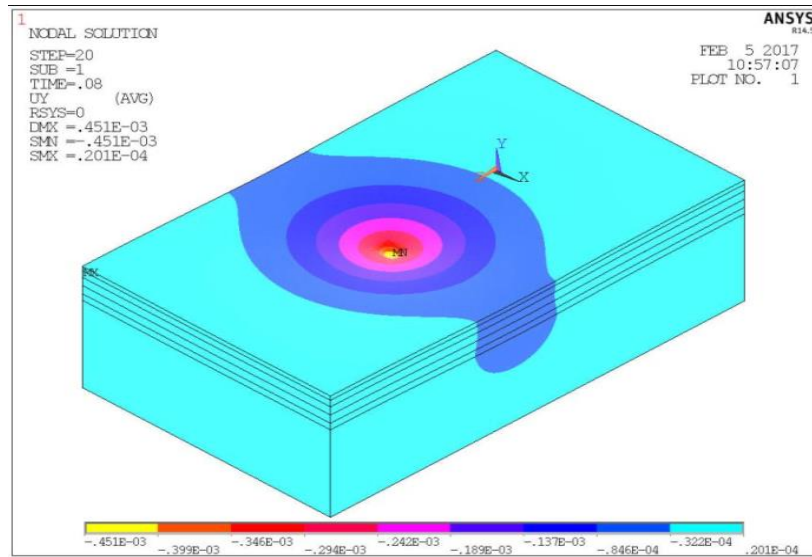
In order to reduce reflection cracks, 10cm, 13cm, 16cm and 20cm are used to determine the thickness and modulus of graded crushed stone, and other parameters of structural layer remain unchanged. Figure 7 is obtained through model calculation and analysis.



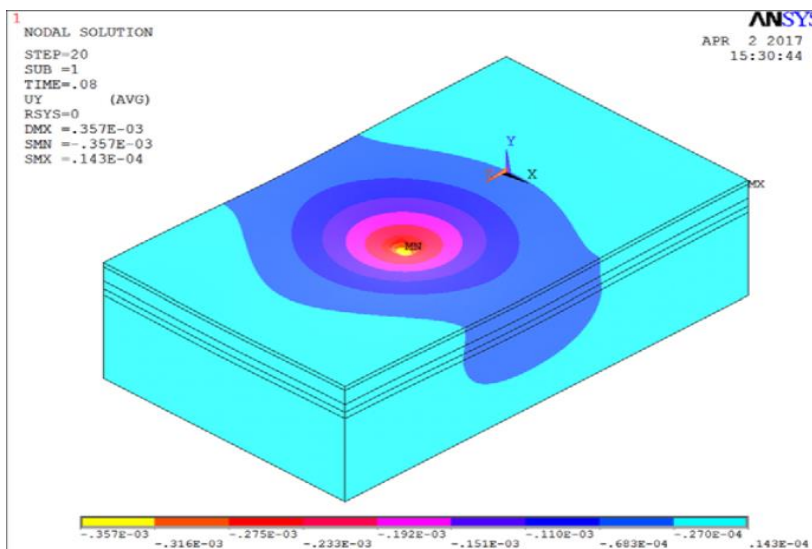
**Figure 7** Shear stress under different graded gravel thickness along the pavement depth

S when establishing the finite element model, the combined base asphalt pavement structure adopts the

main line structural layer of Shao Gan expressway [9]. The length, width and height of the pavement structure are 10m, 6m and 0.78m respectively. The pavement is divided into five layers: cushion, subbase, lower base, upper base and surface layer. The thickness is 0.15m, 0.19M, 0.19M, 0.15m and 0.1M respectively, and the thickness of soil foundation is 2m. The semi-rigid base asphalt pavement structure is divided into four layers, namely cushion, subbase, base and surface, with the thickness of 0.15m, 0.19M, 0.34M and 0.1M respectively, and the thickness of soil foundation is 2m. The length, width and height of pavement structure are the same as those of combined base asphalt pavement structure. The calculated displacement to the corresponding asphalt pavement. Figure 8 and Figure 9 show the vertical displacement distribution of combined base asphalt pavement and semi-rigid base asphalt pavement respectively.



**Figure 8** Vertical displacement distribution of combined base asphalt pavement



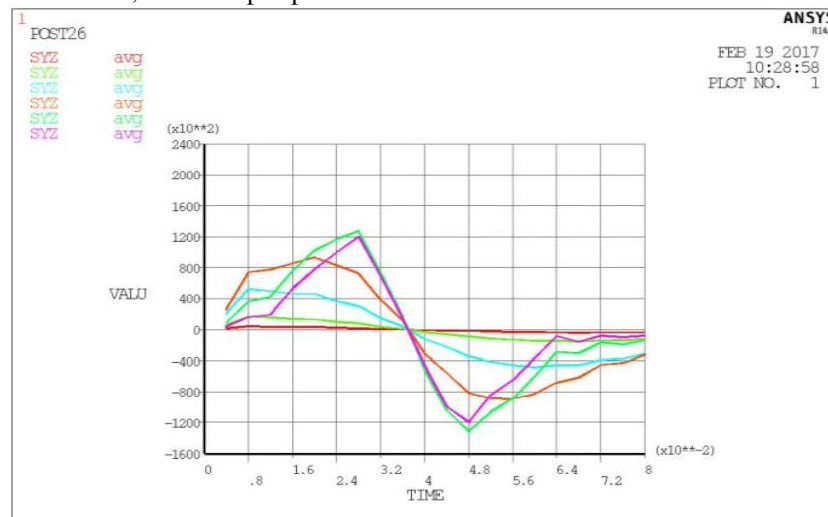
**Figure 9** Vertical displacement distribution of semi-rigid base asphalt pavement



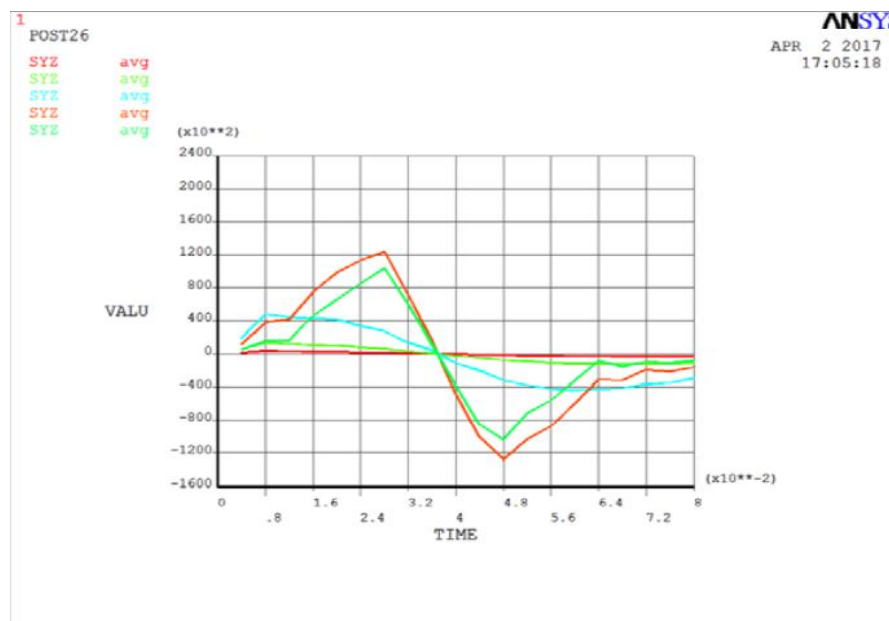
According to the displacement distribution diagram, the maximum displacement of combined base asphalt pavement is 0.451mm and that of semi-rigid base asphalt pavement is 0.357mm. It can be found that under the same load, the displacement of semi-rigid base asphalt pavement is smaller. Therefore, from the perspective of

displacement alone, semi-rigid base asphalt pavement is the primary choice for long-life asphalt pavement 30, because it can withstand greater loads.

At the same time, the shear stress analysis of asphalt pavement is also made: see Fig. 10 and FIG. 11.



**Figure 10** Time history curve of shear stress in YZ direction of combined base asphalt pavement



**Figure 11** Time history curve of shear stress in YZ direction of semi-rigid base asphalt pavement

Figure 10 and Figure 11 respectively show the vertical dynamic strain  $\epsilon_y$  of combined base asphalt pavement and semi-rigid base asphalt pavement under load  $\epsilon$  Time history curve; The maximum compressive strain of the two types of asphalt pavement occurs in the asphalt layer, and the compressive stress of the combined base asphalt pavement changes greatly; The vertical compressive strain combined base asphalt pavement on the top surface of subgrade is  $245 \mu \epsilon$ ,  $216$  for semi-rigid base course  $\epsilon$ .

### 3. APPLICATION OF NEW ASPHALT PAVEMENT IN CHINA AND RESEARCH SHORTCOMINGS

As research into flexible subgrades and combined subgrades progresses. Managers are increasingly focusing on the durability of asphalt pavements and the concept of whole life cycle costs. China's highway structures are no longer limited to a single structure, and have started to experiment with new asphalt pavement structures on highways. For example, on two highways in Fujian Province, the construction department has adopted

a new pavement structure as the main highway structure type. Although the cost of the new pavement structures has increased compared to the original semi-rigid reinforced base asphalt pavement structures, the increase is not significant and does not exceed 1% of the total cost. In terms of the whole life cycle cost of the asphalt pavement, it is reasonable to adopt a higher initial investment to reduce the maintenance costs and extend the service life of the pavement.

There are shortcomings in the first stage of the study. The general study is only under a single load and does not take into account the effect of dynamic and temperature loads, so there are some shortcomings. Also, in the functional analysis of asphalt pavement layers the upper layer forces were not considered. We can carry out further analysis and research on the upper layer of the pavement. At the same time, most of the analysis in the literature using the ANSYS program for modelling uses moving loads with constant load magnitude. In reality, the load on the asphalt pavement not only changes in spatial location, but its load magnitude also changes. Therefore, the variability of load locations and magnitudes should be fully considered in future analyses so as to reflect more realistically the actual forces on the pavement.

#### 4. CONCLUSION

This paper synthesises the research results of different predecessors on the new combined asphalt pavement, combining the analysis of the rutting test results of the new combined asphalt pavement structure with its excellent high temperature stability performance, as well as its good resistance to compression and tensile deformation using the theoretical method. The new combined asphalt pavement structure was found to be suitable for road construction in China. The new combined asphalt pavement structure is not completely superior to the traditional semi-rigid base asphalt pavement.

From the displacement point of view, semi-rigid base asphalt pavement is the primary choice for long-life asphalt roads. However, the overall analysis shows that the new combined asphalt pavement structure has more advantages. Therefore, this paper can argue that the next step of research could be to develop the vertical displacement of the pavement, and to reduce the vertical displacement values of the new combined asphalt pavement structure to further improve the overall capability of the new combined asphalt pavement structure, while ensuring other excellent performance of the new combined asphalt pavement.

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