MATEC Web of Conferences **31**, 12006 (2015)
DOI: 10.1051/matecconf/20153112006

Pavement structure mechanics response of flexible on semi-flexible overlay that based on the old cement concrete pavement damage

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Abstract: The old cement pavement damage status directly affect the design of the paving renovation. Based on the state of the old road investigation, combined with the research data at home and abroad, use the control index that average deflection, deflection value and CBR value to determine the reasonable time to overlay. Draw up the typical pavement structure according to the principle of combination of old cement pavement overlay structure design, and calculated that the tensile stress and shear stress in asphalt layer ,semi-flexible layer and the tensile in the old cement pavement adopting BISA3.0 statics finite element analysis model when modulus in the old road was diminishing. Use the computed result to analyses the influence of old road damage condition the influence of pavement structure.

1 introduction

The highway and city road of cement pavement-based in domestic, it appeared a variety of damage phenomenon in the early construction of the pavement. This phenomenon lead the bearing capacity is insufficient of old pavement structure, and poor driving comfort. If we reconstructed directly, it will serious impact on the performance of road traffic that waste of time and extension of time limit for a project.

If take the way that overlay the asphalt layer and don't take invisible old cement concrete pavement. It will effective utilization of old cement concrete pavement and reflect the advantage of rapid and economic. But the old cement pavement usually exist all kinds of diseases, such as pit slot, cracks, etc. The massive character of old cement pavement was impact by the threat situation of old cement pavement. Therefore, through the analysis of the mechanical response, to research the impact of semi-flexible overlay structures design by the threat situation of old cement pavement.

2 The premise of overlay

A large number of domestic and foreign researches show that before the old pavement overlay the asphalt, should accurate judge the strength of the old cement pavement. And accurately determine what the paving layer to be done, as a base or as a sub base. It would be as far as possible to effective using the strength of original road. At present, the strength evaluation of old cement pavement mainly include: deflection differential and average deflection value and the CBR value.

（1）The deflection differential

Joint of old concrete pavement is the weak part; therefore most of the cement concrete pavement damage occurred near it. The major reason of reflection cracks on asphalt paving layer is the deflection differential of old pavement plate joint (or cracks) edge. the American Association Institute (AI) in order to the deflection differential of old pavement plate joint (or cracks) as the one of indicator of the design control index on old cement concrete

pavement asphalt overlay. And proposes the 0.05 as deflection difference threshold, it also not make overlay on fatigue life of asphalt layer attenuation threshold, the research results as shown in figure 2.1.

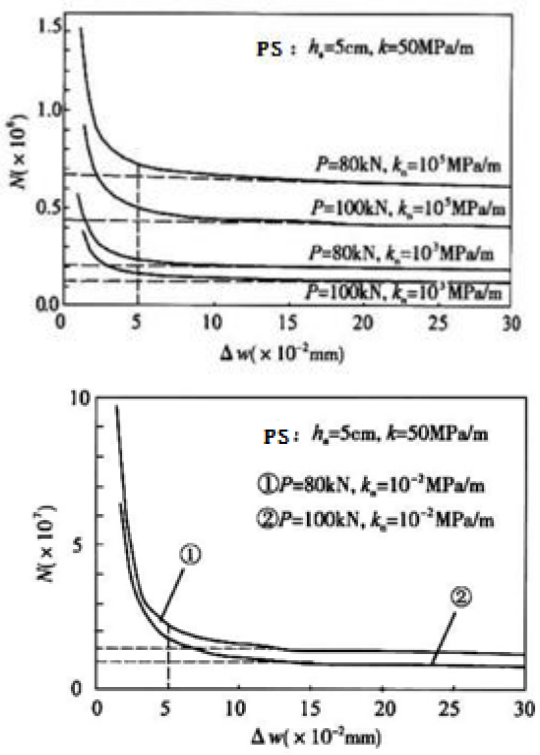

Fig. 2.1 Joint (or crack) deflection difference compared with overlay fatigue life relationship

Specification for design of highway asphalt pavement clearly stipulated in the JTGD50-2006, according to analysis the fatigue fracture mechanics of the reflective crack of asphalt layer under the traffic load, our country should adopt the control values of 0.06 mm for the deflection differential; the corresponding load transfer coefficient is 75%. Before overlay, to avoid fatigue life sharp attenuation of overlay, it asked the old cement concrete pavement plate (whether or not treatment) should satisfy the minimum requirements at the joint or crack deflection difference or load transfer coefficient.

（2）The average values of deflection

The other control index of the old cement concrete pavement asphalt layer design is the average deflection in the Old pavement plate joint or crack. According to analysis the fatigue mechanics, average deflection directly affects the destruction of the old cement concrete pavement plate and reflects the weak foundation. It was conceder the difference the United States and China standard axle load, and combining the practical application of domestic situation, for average deflection value should be not less than 0.45 mm. it is very important that confirm the reasonable average deflection value of control index. If the control index is too strict will directly lead to increase to the quantity and too loose ill affect the quality of the paving renovation, in engineering practice, the general processing according to the following principles:

1）The average deflection value $L_r \le 20$,the board does not make the treatment;

2）Average deflection value $20 \le L_r \le 45$ to , local processing, replace the broken plate, repair the crack plate, escapes plate grouting, it can be overlaid when the value is less than twenty after the treatment;

3）Deflection $\Delta D \ge 6$,it means that the joint load transfer capacity is insufficient. It can be overlaid when the grouting filling sealing or adopt cracked process to eliminate the vertical and horizontal deformation.

（3）CBR value

It was put forward the old road sugared CBR range and at the grass-roots level and total thickness on the surface that the old cement pavement need to overlay by abroad of construction experience. The total thickness of base and surface course, $h \le 15.3\text{cm}$ 和 $CBR < 2\%$, the old cement concrete pavement is absolutely not suitable for crushing and surface area; When $15.3cm \le h \le 50.9cm$, the CBR value to determine whether to break,As shown in figure 2.2.

$$\begin{cases} \text{May not be suitable for crushing} & \begin{cases} 15.3cm \le h < 30.5cm \\ 1.5\% < CBR < 7\% \end{cases} \\ \text{Suitable for crushing area} & \begin{cases} 30.5cm < h \le 50.9cm \\ 7\% < CBR < 10\% \end{cases} \end{cases}$$

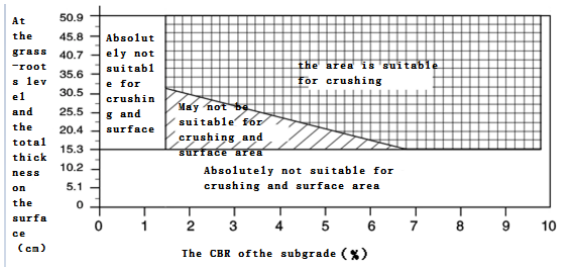

Fig2.2 Suitable for overlay scope

Combining with domestic and abroad control index, this article selects the average deflection value and CBR two indicators to control the timing of the overlay. Among them, using CBR value judgment whether need treatment was carried out on the old cement concrete pavement, and uses the average deflection values determine what kind of treatment.

3 Add layer pavement structure combination design

In order to optimize the old cement concrete pavement overlay structure, first of all should analyze the actual road use performance of the old pavement, combining local traffic, climate and material supply condition, as far as possible, considering the local construction technology level, in view of the main damage type and severity of old pavement, adjust measures to local conditions, according to certain principle, structure composition made after placing the pavement structure can meet the requirements of traffic and environment.

（1）Regular old cement pavement overlay structure combination design

There is damage of cement concrete pavement, the best effective way is paving asphalt surface. There are two common types of asphalt layer, first is paving asphalt concrete layer directly on the old cement road surfaces; The second is to add a layer of semi-rigid material, and paving asphalt concrete pavement. This kind of transformation way is using the reflection crack (figure 3.1).

Reflection cracks can result the crack of the paving layer, make water along the crack fracture infiltration. The road will be destroy by the damage when it was under the car load and the environment temperature, it will serious influence the normal use of the road, and make modified composite pavement decline and shorten life. Therefore the most important combination principle is preventing the cracks of reflection and extension when placing the structure design

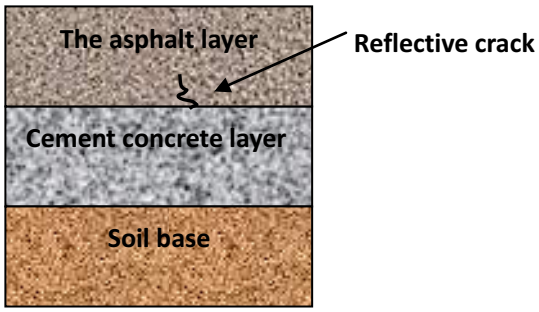

Fig 3.1 Asphalt layer reflection crack

（2）Semi-flexible pavement overlay structure combination design

It is different of the conventional structure of old cement pavement overlay, the semi-flexible pavement overlay structure is that overlaid the emulsified asphalt overlay on old cement road surfaces semi-flexible cement, and put one to two layer on the asphalt road surface. The grass-roots level is the old cement concrete pavement, as shown in figure 3.2.

The main ingredients of semi-flexible are the cement emulsified asphalt. Cement emulsified asphalt mixture is adding a certain amount of cement to the emulsified asphalt mixture. Cement can increase moisture adsorption mixture and mixture of filling material, the use of cement hydration temperature high characteristic, accelerate the emulsified asphalt emulsion breaking, so that the

early strength of emulsified asphalt mixture is improved. The cement make it stiffness and strength, coupled with the increase of the structure of asphalt mixture, the strength of the cement emulsified asphalt and high temperature stability are greatly improved. The flexible cement emulsified asphalt mixture as has a good fatigue performance, good bearing capacity and strong shear strength for the overlay.

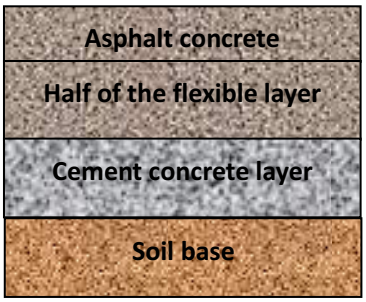

Fig 3.2 semi-flexible pavement structure diagrams

4 Based on the old road damage condition of pavement structure mechanics response analysis

Proposed two kinds of pavement structure form, one is overlay one asphalt layer on the semi-flexible layer, and the other one is laid two asphalts. Use the BISAR program to calculation the two forms. The load for double circular uniformly distributed load, the standard axle load of 100 kn, circle radius of 10.65 cm, calculate icon as shown in figure 4.1.

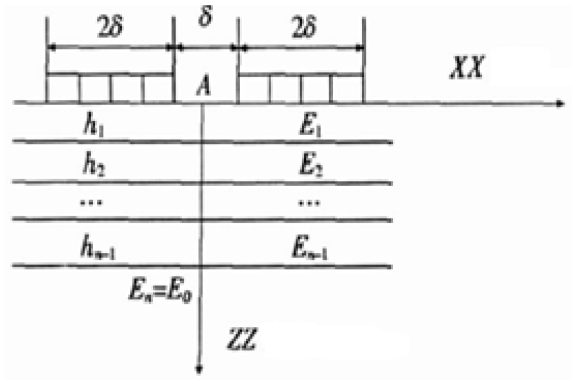

Fig 4.1 Pavement calculated here

According to the code for design of highway asphalt pavement (JTG D50-2006), the old cement concrete pavement is a whole. In order to facilitate comparative analysis, the single layer asphalt layer thickness is 3 cm, double the thickness of asphalt concrete pavement is 4 cm, 6 cm respectively, the thickness of semi-flexible paving layer off for 9 cm, and parameters are shown in table 4.1.

Table 4.1 Pavement structure combinations each parameter selection

Asphalt layer	The structure layer	thickness/cm	modulus/MPa
A single layer asphalt layer	asphalt surface course	3	1500
	Semi-flexible layer	9	900
	cement concrete	22	20000
	soil base	—	300
Double layer asphalt layer	asphalt surface course a	4	1500
	asphalt surface course b	6	1200
	Semi-flexible layer	9	900
	cement concrete	22	20000
	soil base	—	300

The strength and stability of the old cement concrete pavement can be reflecting by the old cement road surface modulus decay. When the old cement concrete pavement modulus from 20000MPa attenuation to 700MPa, single mechanics response of asphalt road surface pavement structure is shown in table 4.2.

Table 4.2 the old cement concrete pavement modulus changes, single layer asphalt layer structure inner stress condition

Equivalent modulus of old road /MPa	asphalt surface course/MPa		Semi-flexible layer/MPa		cement concrete/MPa
	maximum tension stress	maximum shearing stress	maximum tension stress	maximum shearing stress	maximum tension stress
700	0.321	0.175	0.162	0.124	0.635
800	0.318	0.177	0.162	0.128	0.593
900	0.316	0.178	0.162	0.136	0.405
1000	0.315	0.179	0.154	0.137	0.285
2000	0.302	0.188	0.147	0.129	0.251
3000	0.292	0.194	0.136	0.136	0.210
4000	0.284	0.198	0.111	0.137	0.160
5000	0.276	0.201	0.047	0.146	0.091
10000	0.253	0.212	0.035	0.150	0.083
15000	0.240	0.228	0.020	0.156	0.074
20000	0.232	0.231	0.019	0.163	0.064

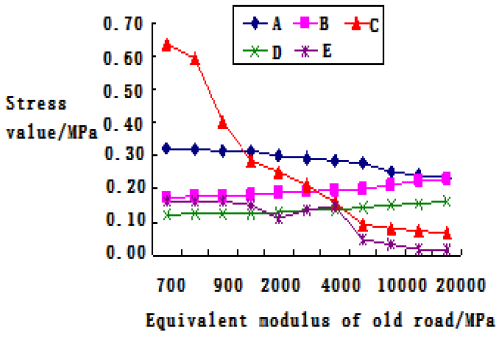

Figure 4.2 Stress and the modulus of old road history

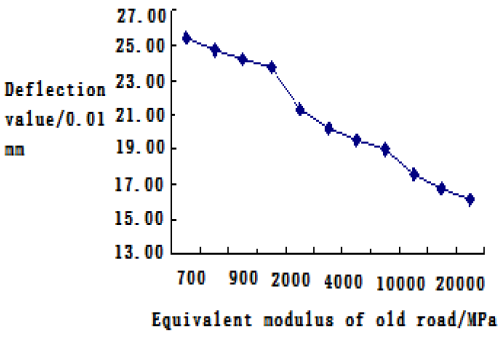

Figure 4.3 Deflection value modulus relation curve and the old road

Double-layer structure mechanics response of asphalt road surface conditions is shown in table 4.3.

Table 4.3 the old cement concrete pavement modulus changes, double layer asphalt layer structure inner stress condition

Equivalent modulus of old road /MPa	asphalt surface course/MPa		Semi-flexible layer/MPa		cement concrete/MPa
	maximum tension stress	maximum shearing stress	maximum tension stress	maximum shearing stress	maximum tension stress
700	0.085	0.198	0.113	0.087	0.475
800	0.085	0.199	0.111	0.088	0.421
900	0.083	0.199	0.111	0.088	0.349

1000	0.082	0.199	0.102	0.089	0.242
2000	0.079	0.200	0.096	0.091	0.212
3000	0.079	0.201	0.086	0.092	0.177
4000	0.076	0.201	0.069	0.093	0.134
5000	0.065	0.202	0.033	0.108	0.077
10000	0.062	0.207	0.023	0.111	0.071
15000	0.059	0.211	0.017	0.116	0.062
20000	0.055	0.213	0.014	0.121	0.054

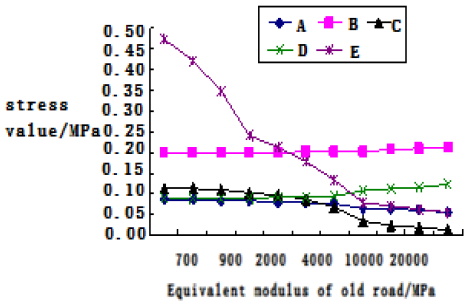

Figure 4.4 Stress and the modulus of old road history

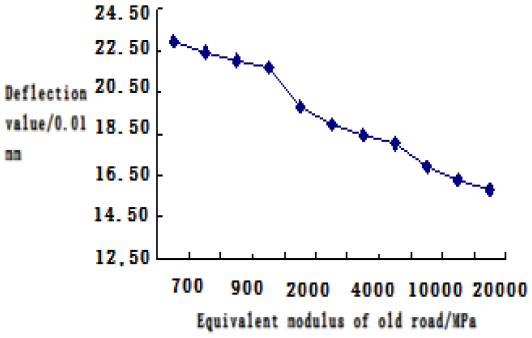

Figure 4.5 Deflection value modulus relation curve and the old road

In figure 4.2 and figure 4.4, Curve A is maximum tensile stress of asphalt; Curve B is maximum shear stress of asphalt layer; Curve C is for semi-flexible paving layer of maximum tensile stress; Curve D is for semi-flexible paving layer of maximum shear stress; Curve E is maximum tensile stress for old cement concrete.

From figure 4.2, for single layer asphalt layer, semi-flexible paving layer bottom tensile stress and tensile stress in the asphalt surface layer upon layer at the bottom of all present a nonlinear growth trend when the old cement concrete modulus decay. When the modulus attenuation to 4000MPa, paving layer upon layer bottom tensile stress appeared inflection point, old road modulus from 20000MPa to 700MPa, over layer bottom tensile stress increased 89.3%, the bottom of the asphalt surface layer upon layer of tensile stress increased 27%;When modulus of less than 1000MPa, paving layer upon layer bottom tensile stress increases suddenly accelerated speed, and continue to decline.

But the asphalt surface layer and semi-flexible layer shear stress is reduced with the decrease of the old road modulus present trend, the damping were 24.2% and 23.9% respectively;

From the figure 4.3, the deflection value is also affected. Deflection value of old road increase with the decrease of the modulus of the paving layer upon layer and the change curve and bottom tensile stress change curve approximation, increase the rate of 36%.

From the figure 4.4, the double layer of asphalt road surface, paving layer bottom tensile stress increases speed relatively flat when the old road modulus is greater than 4000MPa. The paving layer bottom tensile stress increases speed relatively flat when the old road modulus decreases to less than 3000MPa. The paving layer bottom tensile stress and tensile stress of asphalt surface layer upon layer bottom change speed increases quickly. In the process of old road modulus decay, paving layer upon layer bottom tensile stress, an increase of 87.6%, and asphalt surface of tensile stress increased 35.2%.

But modulus decay of the old road, asphalt surface layer and semi-flexible layer maximum shear stress linear decreasing trends, and its damping were 0.31% and 28.1% respectively. That old road attenuation change on modulus of asphalt layer shear stress influence can be neglected; From figure 4.5, the deflection values are increased with the decrease of the old road modulus, increase the rate of 31.1%.

5 Conclusions

At first, this paper puts forward the premise condition about placing the timing, and formulate the common semi-flexible pavement structure, and the overlay on different layers of asphalt road surface of the structure of the mechanical response analysis, found that the old road damage condition of the stress state of overlay structure has a great influence.

When considering the old road modulus decay, paving layer in the paving layer upon layer at the bottom of the maximum tensile stress is maximum tensile stress. It was occurs in the center of the load and is in the vertical direction along the road; Old road modulus serious attenuation, the maximum tensile stress to the wheel load outside edge that occurred in the wheel load of outer. But when the modulus decay to a certain range, and the maximum tensile stress in the surface of the layer was in double circular load wheel gap, and the path along the lateral; Over layer maximum shear stress of paving layer in a certain depth, is the XY plane shear stress, tensile stress in the surface of the paving layer and the location is very close, the role of depth will not change with the change of modulus.

Therefore, by combination of all kinds of stress, there is easy to appear the top-down vertical paving

layer surface fatigue cracks and from bottom to top of transverse crack.

By analyzing the deflection value shows that the two kinds of combination, it is very harmful that the modulus is less than 700MPa in the old cement pavement, the pavement deflection value will be higher than 0.25 mm. that is very harmful for overlay. Because the shear stress is very big, and the wheel load repeatedly function will produce cumulative deformation leading to rutting.

Generally speaking when modulus attenuation serious, it is not suitable for direct overlay on old cement concrete pavement, should take certain reinforcing measures.

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