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Perpetual pavement- absorbing stress and functional maintenance

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ABSTRACT: Perpetual Pavement combines the well documented smoothness and safety advantages of asphalt with an advanced, multi-layer paving design process, that with routine maintenance, extends the useful life of a roadway. Perpetual provides long lasting road and smoothness for the construction purposes. This study has the design key points of perpetual pavement based on the idea of life cycle, which has a new direction for the new highway construction, reconstruction and expansion. First, the structure of long life pavement design is studied to analyze the effect of stress absorbing layer. Second, researches on stress absorbing layer from the aspects of raw materials, mix proportion are implemented. Third, the design index of stress absorbing layer is determined by the shear strength test. The results show that the design idea of composite perpetual pavement can be realized by reasonable design of the stress absorbing layer and carrying out the surface functional maintenance can ensure the pavement to avoid structural damage in the operation stage.

Keywords: multilayer paving; long lasting road; stress absorbing layer

1 INTRODUCTION

According to the idea of life cycle, the perpetual pavement has a new direction for the new highway construction,reconstruction and expansion. According to the domestic and foreign researchers, the pavement of perpetual pavement generally refers to the pavement of 35~60 years, and the years of road design for our country are mostly more than 40 years. The concept of perpetual pavement of different countries varies, but the pavement life can be defined by two aspects: the structural life and the service life. The perpetual pavement is to ensure that pavement does not produce structural damage, which means only the surface function layer is allowed to be destroyed, and it only needs to carry out the surface functional maintenance. Although the initial construction costs will increase, but the maintenance costs are low, it is more economical in the life cycle while maintaining fast and easy. There is also an advantage that will not cause mass transportation closed and traffic interference. So it is important to put forward the idea of perpetual pavement design in the new highway construction, and it can also be used to improve the quality of the original pavement, and promotes the performance and economy of the road.

Perpetual pavement mainly consist of wearing layers (surface layer), base and subgrade layers. In order to ensure least 40 years in structural maintenance, just with regular replacement of wearing layers, we must pay attention to the pavement structure design. The pavement structure formed with "asphalt concrete layer +cement concrete base + sub grade", is mostly used at this stage. The wearing layer is an asphalt mixture layer (flexible structure), the base is cement concrete base (rigid structure), usual setting, stress absorbing layer to transfer and spread loads from the upper to the lower between the flexible and rigid structure. Appropriate stress absorbing layer can reduce the tensile force of the basement and avoid fatigue cracks in the base, and increase the overall stability and durability of the pavement structure.

In this paper, according to the concept of perpetual pavement, the key design points of the stress absorbing layer are studied by the reasonable layers structure, raw materials, mix proportion, the shear strength test and so on.

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2 COMPOSITE PERPETUAL PAVEMENT STRUCTER

The perpetual pavement design method is mainly based on the mechanical design method, and it is important to control the indexes of the tensile strain at the bottom of the asphalt layer, the compression strain at the surface of the base and the shear stress index of the surface layer. It is necessary to design the pavement structure in long life. In some cases, it is necessary to take the requirements of each layer function into design consideration; on the other hand, it is also important to improve the mechanical transfer performance between different layers by setting a special functional layer.

The existing perpetual pavement is usually achieved by increasing the asphalt layer's thickness, but this would cause a great cost increase. The main research direction is to propose a composite pavement structure, such as PCC+AC (Portland cement concrete + Asphalt concrete structure), RCC+AC (Roller compacted concrete + Asphalt concrete structure), PCC+PCC (the composite structure of two cement concrete layers with different elastic modulus), continuous reinforcement composite pavement structure, etc. The more widely application in the engineering is as shown in Figure 1, a pavement structure is formed with "asphalt concrete layer + stress absorbing layer + cement concrete base + asphalt link layer + subgrade". With this kind of structure, the stress absorbing layer plays an important role. The structure combines the advantages of flexible pavement and rigid pavement; firstly, it can improve the durability of the pavement. Secondly, it is easy to maintenance. Finally, it can extend the life of the structure, delay and restrain the development of reflection cracking.

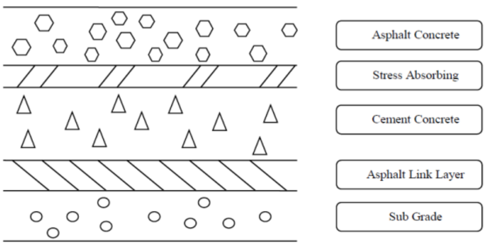

Figure 1. Structure of perpetual pavement

The wearing layer always used skeleton-density frame with better pavement performance. The reasonable material selection includes the modified asphalt, the aggregate and the control of asphalt content, which can ensure the surface adhesion strengnth of the asphalt and the aggregate and the stability. SMA is the most commonly used mixture structure. This material has higher resistance to the routing of high temperature and the cracking of low temperature, and its durability can bear the impact of road traffic load and the environment.

The base of perpetual pacvement has rigid structure of cement concrete, with higher stiffness, carrying capacity and durability. The material selection, mix proportion design and pavement performance tests play an important role in the design to ensure the structure has good durability and the ability of anti-fatigue cracking.

Subgrade is the pavement foundation, usually with the stabilized material. Its strength must meet the using requirements, and in its construction process, it needs to ensure full compaction and levelling, beyond that the surface equivalent modulus, the degree of compaction and the roughness can meet the requirements.

2.1 *Definition of rubber asphalt stress absorbing layer*

Stress absorbing layer is a kind of asphalt mixture designed to be paved between the cement concrete base and the wearing layer asphalt mixture with the composition of fine aggregate, mineral filler and high elastic polymer modified asphalt. The most frequently used is rubber asphalt stress absorbing layer, which has good capacity of flexibility, viscosity, waterproof, non-deformability and can prevent and delay the crack of cement concrete and prolong the service life of the pavement.

Compared with other stress absorbing layers, the rubber asphalt stress absorbing layer has better performance. It is paved between the semi rigid base and asphalt pavement, cement concrete base course and asphalt surface layer, or the new and old asphalt layer . With high deformation capacity of the layer structure, lower reflection cracking of the asphalt pavement, semi-rigid base and rigid base, and good waterproof capacity, it can prevent road surface from water penetration, thereby eliminating water damage of the pavement. Meanwhile, it can increase degree of viscosity between the asphalt pavement and cement concrete base, so as to eliminate the inter layer slip, reduce the temperature change caused by the tensile stress and tensile strain of the asphalt surface layer.

Single particle with uniform diameter of stone paved on the rubber asphalt layer use compacted and interlocked rubber tyred roller. The asphalt rubber is extruded to about 3/4 of the stone height, thus forming a stone interlocking instructuer and constituting a structural support, and then a chip seal mode of pavement is formed, that is the rubber asphalt stress absorbing layer.

2.2 *The functional characteristics of rubber asphalt stress absorbing layer*

2.2.1 *Anti-reflection cracking*

In the stress absorbing layer, the rubber asphalt with high dosage and single particle size of gravel has a

Table 1. Main technical indicators of rubber asphalt

Technical properties	Penetration degree 25℃,100g,5s(0.1mm)	Softening point(℃)	135℃Kinematic viscosity(Pa.s)	5℃Ductility (cm)	TFOT Residue		
					Quality change (%)	Penetration ratio(%)	Residual ductility(cm)
Rubber asphalt	58	67.2	4	26	0.1	78.5	13

Table 2. Main technical indicators of granite coarse aggregate

Technical Nature	Crushing value (%)	Needle sheet content (%)	Apparent density (g/cm^3)	Adhesion	Water absorption rate (%)
Test value	11.7	7.5	2.786	5	0.77

Table 3.Main technical indicators of mechanism sand

Technical nature	Apparent density (g/cm^3)	Robustness (%)	Sediment percentage (%)	Sand equivalent (%)	Methylene blue number (g/kg)
Test value	2.719	34	0.5	87	16

Table 4. Main technical indicators of mineral powder

Test items	Apparent density(g/cm^3)	Water absorption rate(%)	Appearance	Hydrophilic coefficient	Plasticity index(%)	Heating stability	Size range		
							<0.6mm	<0.15 mm	<0.075 mm
Test results	2.12	0.85	No agglomeration	0.7	2.1	No apparent discoloration	100	98	94.6

strong viscosity. With a thickness of about 1cm of reflection cracking structure layer, hardpan steady used water or old cement concrete pavement, it will be difficult to penetrate the reflection layer, thus effectively curbing the cracks.

2.2.2 *Resistance to water damage*

A large amount of rubber asphalt (2.3kg/m^2) form the asphalt film with about 3mm thickness. It can prevent rainwater penetration and damage to the roadbec. Moreover, in the above process of asphalt pavement, the rubber asphalt stress absorbing layer is spreaded twice and will be fully compacted when the asphalt melting into the bottom of the mixture, and this can eliminiate the possiblity of interlayer water which can cause water damage.

2.2.3 *Strong viscosity*

The rubber asphalt has strong viscosity; it can bond the hardpan or the old cement pavement with strong stablitity and thus the whole pavement structure will me formed.

3 THE DESIGH OF STRESS ABSORBING LAYER

In general, in order to improve the conditions of stresses between the layers, the main method of the transition between the layers is the application of stress absorbing layer, the geogrid and geotextile and so on. The biggest weakness of the geogrid and geotextile is that they have no waterproof capacity and easy to be destroyed. In comparison, the stress absorbing layer has good elasticity and it can play a good role in dispering the strss. In the practical engineering, it is usually used to combine the rubber asphalt stress absorbing layer and the fiberglass-polyester, thus reducing the reflection cracking and prolong the life of the pavement.

3.1 *Raw Materials*

3.1.1 *Asphalt*

The ratio of asphalt in the stress absorbing layer is much higher than that in the ordinary asphalt mixture. The performance of the asphalt directly influences the bonding performance of the asphalt mixture, especially the resistance to low temperature cracking and the elastic properties of the asphalt. This experiment used rubber modified asphalt. The main technical indicators are shown in Table 1, and the indicators can meet the technical requirements.

3.1.2 *Aggregate*

The selection of aggregate for the rubber asphalt stress absorbing layer is mainly determined by the aggregate angular property, elongated particle contents and sediment percentage. Coarse aggregate in the stress absorbing layer plays a role as skeleton frame, in which the viscosity is also considered. In order to improve the viscosity, acid granite coarse aggregate is used in this experiment as it adds 4% of the lime as binders. The main technical indicators of granite coarse aggregate are shown in Table 2 and the indexes can meet the standard requirements.

Fine aggregate which is clean, dry, and has no impurities of the mechanism of sand is selected to ensure that the asphalt has good bonding property, the main technical indicators are shown in Table 3 and the indicators can meet the standard requirements.

3.1.3 *Mineral powder*

Mineral powder plays an important role in stress absorbing layer. The combination of the mineral powder and the asphalt forms the asphalt mortar which is used to fill the void in the aggregage, thus making the asphalt mixture form an entirety. The stress absorbing layer has a higher demand of the viscosity and it can be enhanced by increasing the content of mineral powder.

This paper used limestone mineral powder in the experiment. Specific technical indicators are shown in Table 4 and the indicators can meet the standard requirements.

3.2 *Mix proportion design*

The general gradation of stress absorbing layer is suspended dense gradation, which has a maximum size of 4.75mm. The gradation of the test is shown in Table 5.

Table 5. Gradation design of stress absorbing layer

Composition	Granite coarse aggregate(4.75mm)	Mechanism sand	Powder
The ratio of composition (%)	13	80	7

Five asphalt aggregate ratios of asphalt mixture at 8%, 8.5%, 9%, 9.5% and 10% were selected based on the experience. Marshall test was applied in the experiment and the results are shown in Table 6.

According to the standard design method, the void ratio of stress absorbing layer ranges between 0% ~ 3% and the optimum asphalt-aggregate ratio is 8.5%~ 9.8%. Combined with engineering experience and theoretical analyses, it’s finalized with 9.2%.

3.3 *Evaluating the pavement performance*

The asphalt-aggregate ratio of 9.2% is taken to test the pavement performance and the road performance of asphalt mixture. The tests include dynamic stability test (40℃), water immersion test, situ permeability test and freezing and thawing split test. And the test results are shown in Table 7.

It can be seen from Table 7 that the dynamic stability of the stress absorbing layer is very low, but the anti-permeability is good, and has good waterproof property.

3.4 *The shear strength test between layers*

The shear test and pullout test were carried out in the laboratory to determine the bonding properties according to the stress absorbing layer, asphalt mixture and cement concrete. The pavement of the stress absorbing layer and the asphalt mixture on the prepared cement concrete slab are used to simulate the actual engineering situation. Then the shear test and pullout test need to be applied to the samples from the drilling core. The results are shown in Table 8. It can be seen that the stress absorbing layer has good bonding property.

Table 8. Results of shear test and pullout test

Trial Part Number	1	2	3	4
Maximum shear force(N)	4723	4775	4709	4684
Shear strength (MPa)	0.5958	0.6255	0.5938	0.5773
The average value of shear strength(MPa)	0.5981			
Maximum pulling force(N)	4493	4098	5170	3994
Tensile strength (MPa)	0.5633	0.5278	0.6539	0.4202
The average value of tensile strength (MPa)	0.5413			

4 CONSTRUCTION

Construction machineries of the rubber asphalt distributor, gravel spreader and rubber roller are used during the construction.

4.1 *Construction preparation*

First, it needs to do a comprehensive clearing for the road work base by artificial broom sweeping, and then three air-blast gins should be longitudinally arranged

Table 6. Result of Marshall test of different asphalt aggregate ratio of asphalt mixture

The asphalt aggregateratio（%）	Bulk density(g/cm^3)	VV(%)	VMA(%)	VFA(%)	Stability (KN)	Flow value (0.1mm)
8.0	2.395	2.9	20.4	85.7	10.4	39.5
8.5	2.396	2.6	20.9	88.0	10.6	35.8
9.0	2.398	2.3	21.4	90.4	10.7	32.6
9.5	2.394	1.5	22.5	91.6	10.4	32.8
10.0	2.391	0.7	22.6	98.4	9.8	31.3

Table 7. Results of the pavement performance

Test items	40℃ dynamic stability	Residual stability (%)	Water permeability coefficient(ml/min)	Residual strength(%)
Test results	261	91.2	0	83.7

in a diagonal float ash blowing to net. If still not meeting “the requirements of net”, it will need to rinse with water, remove surface dust and mud and try to make the surface aggregate particles partially exposed.

Second, before the construction, it needs to determine the spraying amount of the asphalt, the inclination angle of the spreading car of crushed stone, speed and standard through the experiment.

In order to ensure the construction quality of the ruber asphalt strss absorbing layer, it needs to meet the following construction conditions:

(1) Air temperature and ground temperature should not be lower than 15 ℃;

(2) After the road cleaning and dust blowing, strictly ensure that the bearing layer is under thoroughly dry state and good protection;

(3) Make sure that the required equipment including synchronous chip sealer and the rubber tire roller are in the standby state.

4.2 *Spread of rubber asphalt*

(1) Under the surface layer of rubber asphalt stress absorbing layer, the spraying amount of rubber asphalt is 2.3~2.6kg/m^2; the spraying amount of the rubber asphalt at the top of the base surface is generally 2.5~2.8kg/m^2; the spraying amount of the asphalt can be appropriately reduced if pre-wrapped asphalt attached aggregate.

(2) The spraying temperature of rubber asphalt is generally controlled at 180 ~ 190℃. If it’s higher than this temperature, the rubber asphalt will be aged with poor adhesion to aggregate.

(3) The starting and ending positions should be determined accurately, and the vertical convergence should be and has been spread and overlaped about 10cm.

(4) No cars or pedestrians passing through the rubber asphalt layer should be prior to the spread of the aggregate.

4.3 *Stress absorbing layer of crushed stone spreading*

(1) Before spreading, mix the single diameter particle gravel in the mixing building. The preheat temperature is not lower than 120 and the stacking time of preheating the attached aggregate is not longer than two weeks. Also, the corresponding damp proof measures should be taken.

(2) After the rubber asphalt being sprayed, it needs to spread the crushed stone immediately for effective bonding.

(3) When the mechanical construction cannot be executed, it can use artificial construction instead; for the overlapped gravel, it must use cleaning vehicle to do the cleaning and recycling.

4.4 *Rolling-forming of rubber asphalt stress absorbing layer*

(1) While the crushed stome being spread, a heavy tire roller follows the spreading car to roll the crushed stone and thus form the rubber asphalt stress absorbing layer. The crushed stone should be embedded in and reach 50%-70% of the rubber asphalt. The requirement of the construction time should meet the specific requirements.

(2) Before paving the top layer of asphalt mixture, it must be cleaned. The rubber asphalt stress absorbing layer is used to remove loose crushed stone without sticking, avoiding the influence on the bonding properties of rubber asphalt stress absorbing layer and the upper layer.

(3) In the compact construction of the asphalt mixture in the upper layer and the asphalt rubber stress absorbing layer, it usually takes less than 24 hours. And it will not be open to the traffic, avoiding secondary pollution or destruction. If there is a must to be open to the traffic during this period, it at least needs 3 hours after stress absorbing layer construction being completed and the driving speed should not be faster than 25km/h.

After the stress absorbing layer construction, uniform gravel is firmly bonded with the asphalt for the protection of stress absorbing layer from fatigue damage.

4.5 *Quality inspection of rubber asphalt stress absorbing layer*

The test items of construction phase always include the rubber asphalt properties, spraying amount of asphalt, spreading amount of the gravel, the test of simulating brake and appearance inspection and so on. Test methods and standards should follow the belowing specifications:

The main test of rubber asphalt properties is the viscosity under the tepmrature of 180℃ by rotational viscometer in each phase of production.

The spraying amount of asphalt is tested by checking the amount of rubber asphalt aggregate in the fixed area.

The test of simulating brake is taken in the test section.

The appearance inspection includes the test of uniformity of overall outward appearance with a scratch observation by a hard object and also the test that if the basal surface (surface layer) is bonded firmly without oil package and grassroots exposed etc. The effect of stress absorbing layer after construction is shown in Figure 2.

Figure 2. Rubber stress absorbing layer

5 CONCLUSION

The perpetual asphalt pavement,which is designed to be longer than 40 years,is characterized in that the surface of the pavement is damaged only in the surface layer, and no structural damage occurs during the service period. It means that pavement maintenance does not need structural treatment and only the surface layer of asphalt mixture needs maintenance, which can be relegalized by re-spraying the new asphalt mixture. In this way, the performance of perpetual asphalt pavement can be guaranteed by the periodic maintenance and repair, which is very convenient.

By setting reasonable stress absorbing layer which plays a good transition role, the stress state of asphalt pavement and concrete pavement can be effectively improved, and the reflection cracking can be avoided or reduced. The composite perpetual pavement combined with the advantages of flexible pavement and rigid pavement can extend its service life,thus achieving the most economical total cost in the whole life cycle of a road.

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