Evaluation for Properties of Porous Asphalt in China

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Abstract

Different from traditional road surface, the surface layer of porous pavement is constructed by open-graded asphalt mixtures, and its large void structure greatly enhances the drainage capacity. So it reduces the amount of water, water spray and mist on the surface layer, improves the safety of driving on rainy days. It also reduces traffic noise significantly. The advantages of porous asphalt make it stand out in many other road structures, but the disadvantages of easy clogging and the difficulty of cleaning make the promotion of porous asphalt challenging. Therefore, it is necessary to investigate the performace of porous asphalt during a long period. In this paper, pourous asphalt section of Ning-Jing-Yan highway is investigated. The investigation ranges include permeability, skid resistance and noise deduction. The results show that porous asphalt can keep satisfactory performances over the investigation period. Therefore, it is a high-performance road which should be popularized in China.

Keywords

Porous asphalt; Permeability; skid resistance; Noise.

1. Introduction

Compared with other situation, the rate of traffic accident is much higher in rainy days and after a few hours of rainy days. Ponding on the pavement causes a serious of grave consequences to the vehicle traveling on the road. Firstly, the water film prevents tires to contact with the pavement. To the contrary, the water film interacts with the vehicle especially when the vehicle is traveling at high speed, causing hydrodynamic pressure which decreases the friction between the vehicle and the pavement [1]. In that case, the vehicle slips, sometimes even loses control. Besides, water spray caused by tires interacting with ponding limits the field of view of the following vehicles, which confuses the drivers and decreases the response speed of drivers to emergencies.

Noise shows a negative impact on activities like speech and sleep of daily life, it also causes annoyance and fear. According to the research, the traffic noise produced by road, rail way and aviation takes 70% to 80% of the environmental noise, and road noise takes more than 60% [2]. Therefore, road noise is the main factor that destroys the environment. From 1960s, western countries began to attach importance to road noise [3]. In 1970, some European countries began to control noise produced by road through legislation. European commission has presented a goal which aiming at eliminating all the source of road noise by 2020.

Compared with traditional dense grade pavement, porous asphalt by open-graded asphalt mixtures provides the better draining capacity due to the high air voids content. More specifically, when vehicles travel on porous asphalt pavement in rainy days, the pavement can increase driving safety by remarkably preventing water spray and reflections. At the same time, porous asphalt can decrease traffic noise by a large margin as well.

Considering the defects of single layer porous asphalt such as clogging and the attenuation of sound absorption capacity, Van Bochove of Heijmans infrastructure company proposed the concept of double layer porous asphalt in the first Eurobitume and Euroasphalt Congress, 1996 [4]. Netherland applied double layer porous asphalt for highway first, in 1990s. The double layer porous asphalt consists of two layers, the finer thin porous asphalt mixture as the top layer and the much coarser and thicker porous asphalt mixture as the bottom layer. Compared with single layer porous asphalt, it has three advantages including mitigating clogging, a longer service life expectancy and absorbing more noise [5]. It is easy to clean up the pollutants hiding in the top layer by hydro vacuuming. Furthermore, double layer porous asphalt could make self-cleaning for the clogging part in heavy raindrops.

These advantages, skip resistance, water permeability and noise absorption make porous asphalt popular. It meets the concept of future pavement construction proposed by most specialists, which is defined by safety, comfort, high quality, environment-friendly and low pollution [6]. However, it has been proved that after years in service the permeability of porous asphalt obviously reduced because the surface is clogged with debris [7-10]. Clogging noticeably limits the performance of porous asphalt, and it is hard to totally unclog the debris, which become the obstruction to popularize the porous asphalt. Therefore, this paper focused on the property attenuation of porous asphalt in the process of clogging. It studied the property of double layer porous asphalt to compare with single layer porous asphalt as well. Three properties skip resistance, water permeability and noise absorption were studied. The result reveals the variation tendency of porous asphalt and the effect of aggregate. It will help the further study on the property promotion of porous asphalt.

2. Research Content

2.1 Water Permeability

To porous asphalt pavement, permeability is the primary requirement. It is the most important capacity that makes porous asphalt competitive, it affects other capacities, too. For example, the noise absorption, durability and skip resistance are all closely related to permeability. Therefore, it is a vital branch of research on porous asphalt. Researchers have made progress in these fields: the mechanism of permeability laboratory test and the test device, factors of permeability coefficient, permeability coefficient model of rainfall, the monitor of the internal interconnected voids and prediction of decay of voids [11].

Among these studies, American has taken advantages due to an early beginning [12-13], National Center for Asphalt Technology (NCAT) developed a test device for permeability coefficient of pavement based on Darcy law, in 1999. It is widely used to evaluate the permeability of porous asphalt because the pavement surface does not get impaired during the test. In 2009, American Society for Testing Material (ASTM) formally proposed ASTMC1701, another test of permeability coefficient for porous asphalt pavement. These two test devices are show in figure 1 and 2. In China, Research Institute of Highway Ministry of Transport (RIOH) developed two methods for laboratory test and in situ test, and designed the special test devices. By these two methods, researchers could evaluate the permeability coefficient of both porous asphalt mixture and the pavement.

Fig.1 NCAT test device

Fig.2 ASTM test device

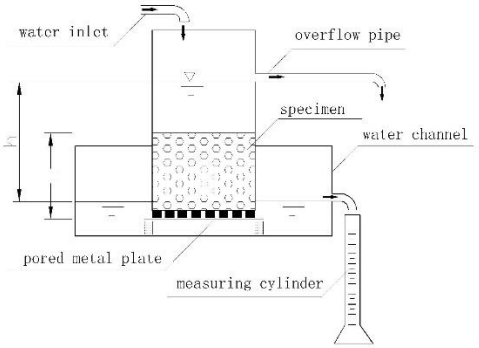

Fig.3 RIOH test device (for specimen)

Fig,4 RIOH test device (in situ)

2.2 Skip Resistance

There are three main factors that affect the friction between tires and pavement when the vehicles are traveling, the tire, the surface of pavement and the interaction between them. For tires, the type, the texture, the wear condition and inflation pressure contribute to the friction between tires and the pavement. The surface of pavement depends on its texture depth to affect the friction. More specifically, the skip resistance of the surface of pavement relies on its microstructure and macrotexture at the same time. On the micro level, the friction can be defined as the interaction between micro-bulge existing in the surface of objects. On the macro level, the friction coefficient is related to the roughness of the pavement, the rougher surface of pavement could originate higher friction coefficient. Researchers has also invested the relationship between aggregate gradation and skip resistance of asphalt mixture. The result indicated that nominal maximum size of aggregate and the content of coarse aggregate which is over 4.75mm have enormous effect on skip resistance. The contact between tires and the pavement is another vital factor that effect skip resistance especially when runoff occurs on the pavement. When the vehicle is travelling at high speed, water film prevents the contact between tires and pavement, therefore the friction significantly decreases.

2.3 Noise Absorption

In 1990, some specialists from Europe made research reports about the noise absorption capacity of porous asphalt in Transportation Research Board (TRB) meeting [14]. The reports indicated that porous asphalt could decrease the noise from 3 to 6dB, compared with traditional dense grade asphalt pavement.

Like other porous material, porous asphalt could absorb noise by numerous gaps inside it, these gaps could transmit the acoustic wave into forward. Porous asphalt converts sound energy into heat energy by viscosity and thermal conductivity effects.

Air voids and the thickness of porous asphalt are the two factors that affect noise absorption capacity. Normally, air voids should be over 15%. And some European countries, like French, Germany and Italy regulate the air voids should be more than 20% [15]. Thickness of porous asphalt also affects sound absorption performance, the thickness of 3.8 to 5.1cm is recommended [16].

Generally, double layer porous asphalt could achieve a better noise absorption performance than single porous asphalt in the range of 500 to 1000HZ. It can decrease noise from 4 to 6dB when the vehicle is travelling at a speed of 50km/h, which is the highest level for low noise pavements. The top layer contains fine aggregates, and the finer the aggregates are, the better noise absorption performance could be expected. The thicker layers can also provide better performance. Unlike single layer, double layer porous asphalt is more convenient for maintenance, it only need hydro vacuuming cleaning for twice a year.

However, the durability of noise absorption capacity is still a serious problem for porous asphalt. It is observed that when the service life is over 6 years, the noise absorption capacity attenuates [17]. Raveling is the main disease that causes its attenuation.

In China, researchers have investigated the durability of Yan-Tong highway [18]. There are three kinds of top layer: PAC-13, SMA-13 and AK-13. The paper reveals that at first PAC-13 experienced the best noise absorption performance. While 3 years later, the noise absorption capacity attenuated to the same level as SMA when the speed of vehicle was 80km/h or 100km/h.

Analysis

3. Research Content

3.1 Water Permeability

Table 1. 2014 Section(ml/min)

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K85+000	4914.72	5074.42	4306.35	4353.90
K85+100	4951.67	5092.79	3913.52	5396.28
K85+200	5790.12	5168.49	5268.78	5098.12
K85+300	5106.59	4785.71	4200.81	4408.15
K102+800	4966.08	4503.75	5279.72	4628.84
K102+700	4619.87	4734.11	5102.62	5117.85
K102+600	5457.96	5367.19	4984.86	4611.99

Table 2. 2015 Section (ml/min)

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K85+600	5247.40	3711.20	4703.26	5019.19
K85+700	4760.86	3837.69	4712.14	4687.50
K85+800	4166.47	5487.79	4494.52	4772.90
K102+300	3650.18	3437.22	2203.66	3694.91
K102+200	4088.44	4655.68	4895.73	4633.27
K102+100	3898.81	3727.44	2885.62	3334.78

Table 3. 2016 Section (ml/min)

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K92+100	5536.69	5742.45	5285.91	5145.17
K92+200	5261.34	5423.90	4699.63	4616.77
K92+300	5376.90	5272.30	4998.25	5183.61

Table 1-3 show the result of water permeability test of three sections which were constructed in 2014, 2015 and 2016 seperately. In general, the traffic lane section is worse than the emergency lane section, the main reason is that the traffic lane is under wheel load for a long time.It is noticeable that the

permeability capacity decrease with the increase of service period. However, most of them are higher than starandard, which is 4500ml/min.

Table 4. 2016 Basalt Section (ml/min)

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K92+100	5536.69	5742.45	5285.91	5145.17
K92+200	5261.34	5423.90	4699.63	4616.77
K92+300	5376.90	5272.30	4998.25	5183.61

Table 5. 2016 Diabase Section (ml/min)

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K91+600	5468.22	5521.98	5690.40	5735.43
K91+700	5277.64	5411.30	5376.28	5343.40
K91+800	5275.44	4955.99	4801.56	5186.51

Compare the results of table 4 and 5. The results are very close and both are at a high level, proving that both materials are suitable for laying porous asphalt pavement, which also proves that the drainage performance of porous pavement is not affected by the aggregate type.

3.2 Skip Resistance

During the investigation, the pendulum value was used to evaluate the skip resistance performance of the road surface. The pendulum value is measured by the bm-iii pendulous friction coefficient meter. The results are shown in table 6-9.

Table 6. 2014 Section Pendulum Value

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K85+000	69	67	80	79
K85+100	75	75	77	81
K85+200	65	69	74	82
K85+300	68	81	81	87
K102+800	68	77	82	87
K102+700	70	73	82	83
K102+600	76	72	81	82

Table 7. 2015 Section Pendulum Value

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K85+600	75	74	75	86
K85+700	78	76	77	83
K85+800	68	70	89	83
K102+300	77	73	77	86
K102+200	67	77	80	87
K102+100	75	68	77	84

Table 8. Basalt Section Pendulum Value

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K92+100	60	59	58	57
K92+200	64	61	61	63
K92+300	64	61	61	63

Table 9. Diabase Section Pendulum Value

Stake	Traffic Lane (right)	Traffic Lane (middle)	Traffic Lane (left)	Emergency Lane
K91+600	61	60	66	70
K91+700	63	59	60	65
K91+800	62	59	73	68

It can be seen that the skip resistance performance of each section is close, the reason is that the asphalt pavement has a large amount of coarse aggregates, the nesting of aggregates is stronger, the structure is more stable, although the aggregate surface is subjected to a certain degree of polishing, the skip resistance performance is less affected. It is important to note that the section served for one year has smaller pendulum value tha two years or three years, the main reason is to pave the way for the new period of aggregate surface covered with a layer of asphalt membrane, and that of bitumen membrane can be wear as vehicle load, makes the aggregate angularity exposed to direct contact with the outside load from the film, makes the new layer of asphalt pavement in the process of service will be a process of skip resistance performance increase gradually.

Compare the results of basalt with diabase, it shows that basalt leads a better result.

3.3 Noise Level and Absorption Capacity

3.3.1 Noise Level

Used HT-8352 sound level meter to test the traffic noise level around porous asphalt pavement. The equipment and software system are shown in figure 5. The results are shown in table 10 -12.

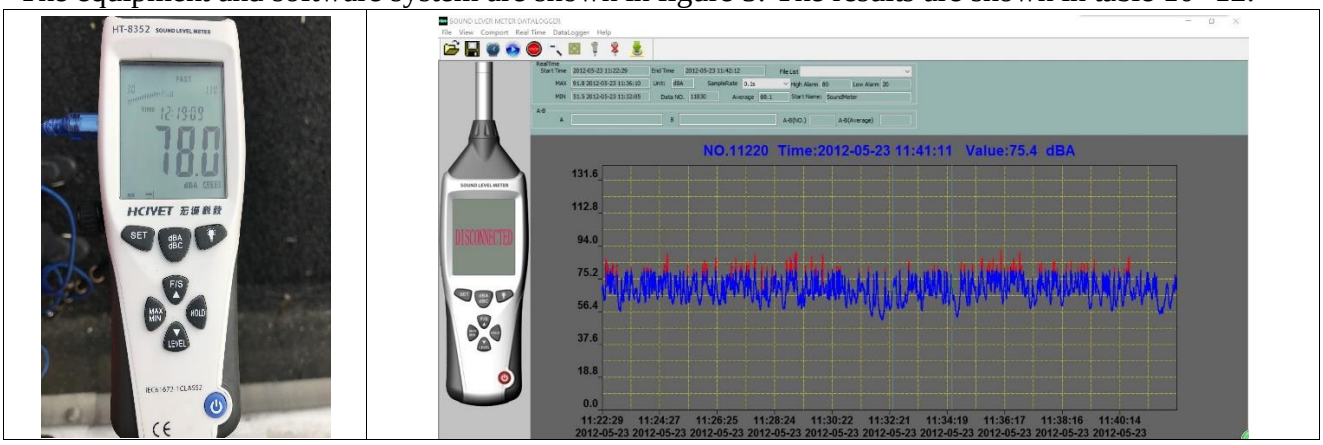

Fig. 5 Sound Level Meter

Table 10. Noise level by year

Year	Noise level		
	Max	Min	Avg
2014	91.4	53.3	69.6
2015	93.5	51.6	68.8
2016	93.0	56.6	69.0
Common pavement	94.7	56.6	73.0

Table 11. Noise level by structure

Structure	Noise level		
	Max	Min	Avg
Single layer	93.0	56.6	69.0
Two-layer	90.5	42.0	68.3
Common pavement	94.7	56.6	73

Table 12. Noise level by aggregate type

Aggregate type	Noise level		
	Max	Avg	Min
2015 single basalt	93.7	69.3	52.3
2016 single basalt	93.8	69.6	57.6
2015 single diabase	92.7	67.4	49.7

2016single diabase	91.5	68.0	54.5
Common pavement	94.7	73	56.6

The results of these three years are very close. And compare them with common pavement, it is noticeable that pourous asphalt can reduce noise significantly. And two layer porous asphalt has lower noise level than single layer. To some extent, diabase can can improve the noise reduction performance of porous asphalt.

3.3.2 Noise Absorption

Used IMP-PI-SCT sound absorption coefficient tester to test the capacity of noise absorption. The equipment is shown in figure 6. The results are shown in table 13 and 14.

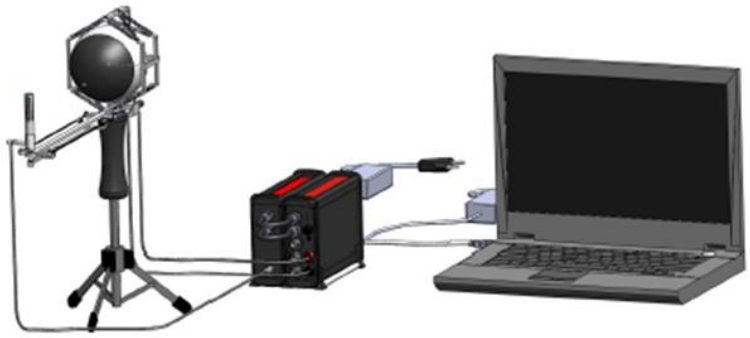

Figure. 6 Sound Absorption Coefficient Tester

Table 13. Noise absorption by structure

Structure	Sound absorption coefficient			
	Emergency lane (right)	Emergency lane (middle)	Traffic Lane (left)	Traffic Lane (middle)
Single layer	0.57	0.63	0.68	0.68
Two-layer	0.84	0.81	0.84	0.83

The structure two-layer porous asphalt determines it has larger allied air voids, and on a level with a finer, aperture is smaller than single porous pavement, not easily get congestion, so the sound absorption coefficient of the double porous pavement will be higher than that of single porous pavement.

Table 14. Noise absorption by aggregate

Aggregate	Sound absorption coefficient			
	Emergency lane (right)	Emergency lane (middle)	Traffic Lane (left)	Traffic Lane (middle)
Basalt	0.48	0.55	0.60	0.64
Diabase	0.66	0.71	0.77	0.73

Choose diabase as aggregate, can improve the sound absorption capacity of porous asphalt asphalt.

4. Conclusion

Through the research of porous asphalt pavement in Jiangsu province including skid resistance, drainage and noise reduction performance, get the following conclusion:

(1) The skip resistance performance of porous asphalt pavement is at a high level, which will attenuate with time. The skip resistance performance of the section with diabase is slightly better than that of basalt.

(2) The drainage performance of the road decreases with time, and the type of material has little effect on the pavement drainage performance. The comparison shows that the drainage performance of double-layer porous asphalt pavement is higher than that of single layer.

(3) The survey found that the average noise level of porous asphalt pavement was around 68dB (A), less than the normal surface of the road (A). The performance of the noise reduction was basically unchanged. The performance of two-layer porous asphalt pavement is better than that of single layer and noise can be reduced by 1dB (A). Diabase can have a better performance than basalt.

(4) The sound absorption coefficient of traffic lane is higher than the emergency lane. It is most influenced by pavement structure, and the sound absorption coefficient of two-layer porous asphalt pavement is 30~50% higher than that of single layer.

Acknowledgements

The investigation program is funded by Ministry of Transport, China. Title: Study on the Feasibility and Application of Porous Asphalt Pavement Technology in Jiangsu Province.

References

[1] Pagotto C, Legret M, Cloirec P L. Comparison of the hydraulic behaviour and the quality of highway runoff water according to the type of pavement [J]. Water Research, 2000, 34(18):4446-4454.

[2] Wayne Jones P E. Quite Pavement-Coming to a Highway Near You [R]. Asphalt Institute Field Engineer, 2005.

[3] Noise Standards and Procedures. Transmittal 279 Policy and Procedure Memorandum 90-2 [R]. Washington D.C: Federal Highway Administration, 1973.

[4] Van Behoove, G.G. (1996) Twinlay, a new concept of drainage asphalt concrete. Proceedings of 1st Eurobitume and Euroasphalt Congress, Strasbourg.

[5] Hardiman M Y. The Comparison of Engineering Properties between Single and Double Layer Porous Asphalt made of Packing Gradation [J]. Civil Engineering Dimension, 2008, 10(2).

[6] FEHRL. ISSN 1362-6019 New Road Construction Concepts: Vision 2040 [R]. Brussels: FEHRL, 2006.

[7] Scholz, M., & Grabowiecki, P. 2007. Review of Permeable Pavement Systems. Building and Environment. 42(11): 3830-3836.

[8] Fwa, T. F., Tan, S. A., & Guwe, Y. K. 1999. Laboratory Evaluation of Clogging Potential of Porous Asphalt Mixtures. Transportation Research Record: Journal of the Transportation Research Board. 1681(1): 43-49.

[9] Yu, B., Jiao, L., Ni, F., & Yang, J. 2014. Long-term Field Performance of Porous Asphalt Pavement in China. Road Materials and Pavement Design. 1-13.

[10] Moriyoshi, A., Jin, T., Nakai, T., & Ishikawa, H. 2013. Evaluation Methods for Porous Asphalt Pavement in Service for Fourteen Years. Construction and Building Materials. 42: 190-195

[11] Fwa, T.F., Tan, S.A. and Guwe, Y.K. (1999) Laboratory evaluation of clogging potential of porous asphalt mixtures, Journal of the Transportation Research Board (TRB), No. 1681, 43-49.

[12] ASTM（2003a）. "Standard test method for infiltration rate of soils in field using double-ring infiltrometer." ASTM D3385, West Conshohocken, Pa.

[13] Harvey, J. T. Comparative field permeability measurement of permeable pavements using ASTM C1701 and NCAT permeameter methods [J]. Environ. Manag. 2013, 118, 144-152.

[14] Transportation Research Board. Transportation Research Record 1265 Porous Asphalt Pavements: An International Perspective[R]. Washington D.C: TRB, 1990.

[15] Bendtsen H, Larsen L E. Two-Layer Porous Pavements and Noise Reductions in Denmark, Internoise 2001[C]//Ninth International Conference on Asphalt pavements, Copenhagen, Denmark, 2002.

[16] Crocker M J, Hanson D, Li Z, et al. 84#TRB-2004 Measurements of the Acoustical and Mechanical Properties of Porous Road Surfaces and Tire/Road Noise[R]. Washington D.C: TRB, 2004.
[17] Raaberg J, Schmidt B, Bendtsen H. Technical Performance and Long-Term Noise Reduction of Porous Asphalt Pavements[R]. Copenhagen: Road Directorate, Danish Road Institute, 2001.
[18] Xu G, Jun Y. Early Age Field Performance Assessment of Porous Asphalt Pavement on Yan-Tong Expressway in China[C] Transportation Research Board 89th Annual Meeting. 2010.