RESEARCH ON LABORATORY SIMULATION TEST METHOD FOR SKID RESISTANCE PERFORMANCE OF CHIP SEALS

Yuhua Li, Dalian University of Technology, China

Yuxing Liu, Dalian University of Technology, China

ABSTRACT

Chip seals are most frequently used as preventive maintenance treatments on asphalt pavements. The surface performance should be considered as major factor in project. A laboratory simulation test method for surface skid resistance of chip seals is established in this paper. A plate specimen of asphalt mixture by long-term aging treatment is used as under layer, which simulates the original asphalt pavement structure. Followed by spraying emulsion asphalt, fiber glass (alternative reinforced material) and crushed stone aggregate, and initial rolling, the simulation process of construction for layered pavement is completed. The specimen is rolled intermittently by rubber roller and stored in curing room alternately, to simulate the long-term compaction process by actual traffic loading. Then, the molding method of composite plate specimens is established, which considers the state of original asphalt pavement diseases and the construction process. Based on the above method, the different test parameters, such as rolling and maintenance temperature, frequency and interval time of rolling, rolling load, material type and material application rate and so on, are considered in the surface texture depth test and friction test. According to the dependency relation with the field tracking test results, the rolling and maintenance parameters are defined. It's concluded that the molding method of composite plate specimens and the test method can simulate, test, evaluate and predict the performance of chip seals pavement, especially the surface skid resistance.

INTRODUCTION

Chip seals are most frequently used as preventive conservation (PM) treatments on flexible pavements. When applied on an existing flexible pavement, a chip seal will provide a surface wearing course, seal the underlying pavement against water intrusion, enhance or restore skid resistance, and enrich the pavement surface to prevent the distresses caused by oxidation.

This paper researches on the forming method of laboratory test specimens and the evaluation index of the moulding quality. Basing on the construction technology of the equipment of chip seal, this paper divides the main part of the forming method of chip seal specimens in laboratory into three steps: sparying, initial rolling and conservation, and the repressing and post-stage conservation, then conduct research on it, and determine the test parameters of rolling compaction and conservation which are corresponded with the construction condition, actual traffic volume and types.

The skid resistance or friction, an important safety characteristic for all roads, which reflects the ability that the road prevents the vehicle from sliding. Basing on research which is on the forming method of chip seal in laboratory, by means of the laboratory tests ,such as the texture depth, surface friction coefficient and so on, to research on the correlativity between different parameters of rolling compaction and conservation and the texture depth and friction coefficient ,furthermore, to compare it with the field test results and conduct analysis, then the testing and forecasting method of chip seal on the surface skid resistance can be obtained.

SPECIMENS MOULDING FOR INDOOR TEST

Consideration of Specimens Moulding

The structure and technology condition of the original pavement

There are intimate connections between the design and construction of chip seal and the structure and technology condition of original pavement. This influence should be taken into consideration when moulding the indoor specimens. Such as the embedded depth of the gravel and the dosage of the asphalt are connected with the hardness of the original pavement.

Structure of the original pavement

The chip seal is generally used for the conservation of asphalt pavement, and the structure of original pavement can be simulated by making an aging asphalt mixture layer.

Technology of the original pavement

Surface hardness refers to the most important surface properties of the pavement surface. It is a measurement that influences the nominal size of aggregate used for the chip seal and thus ultimately determines material application rates.

In addition, gravel would embed into original pavement because of rolling compaction and vehicle (as shown in figure 1), and the embedded depth is related to the hardness of original asphalt pavement.

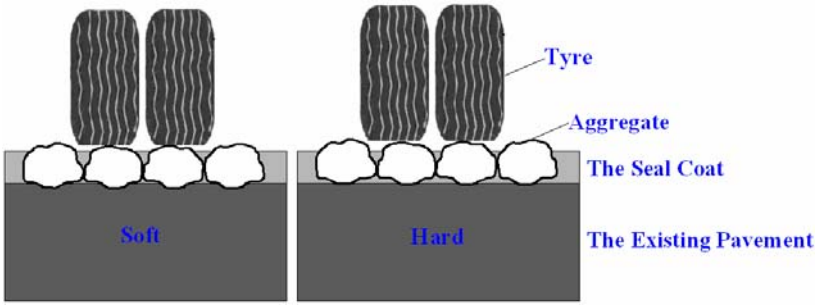


Figure 1: The influence of the hardness of original asphalt pavement.

The main function of chip seal is to seal the cracks that occurred on the original pavement, and enhance surface skid resistance, so it should take cracks and surface voids that occurred on the original pavement into consideration.

Construction conservation and operation process

The application of the chip seal involves essentially four pieces of equipment: the binder distributor, aggregate spreader, rollers, and brooms.

The binder distributor provides application of the binder to the pavement surface. A chip spreader immediately applies a uniform, predetermined rate of aggregate onto the binder. These two operations are at the heart of constructing a surface that is one stone thick and has enough binder to retain the aggregate, but not an excess amount of binder that causes the surface to bleed. Depending on the binder, aggregate, and actual type of chip seal being constructed, various rollers will be used to orient the aggregate to achieve appropriate embedment. Pneumatic rollers are typically found on all chip seal projects. The rollers are followed by the brooms that remove excess aggregate from the finished surface [1].

The method of inside moulding should cover the aforementioned process which can be summed up as spraying, rolling compaction and conservation.

Spreading in layers

When making the chip seal specimens in laboratory, we should separately spray a layer of asphalt and bestrew a layer of gravel, in order to simulate the process of spreading in layers which is used in actual construction. To get good moulding quality of specimens, selected asphalt binder should ensure enough adhesive property and flow property, so as to ensure the bonding between aggregate and original pavement, aggregate and aggregate. In addition, the bestrewing method of asphalt binder and gravel is another important factor should be taken seriously.

The initial rolling and conservation

The covering aggregate is initially rolled and conserved for the following reasons:

- To redistribute the aggregate,
- To seat the aggregate into the binder, and
- To embed the aggregate into the binder.

To realize proper embedment and orientation when moulding in the laboratory, particular attention must be paid to the time between the aggregate spread and initial rolling, selection of the most appropriate roller type, and determination of rolling requirements such as rolling patterns.

Repressing and post-stage conservation

After the initial rolling and conservation, the bonding strength between asphalt binder and gravel couldn't reach a certain request, so it is need to conduct repressing and post-stage conservation. The emulsified asphalt can regain a certain degree of flow ability after conservation in high temperature, conducting repressing at this moment is beneficial to improve the embedded depth and embedded degree of the gravel, further contribute to the emulsified asphalt which could gradually reach at two-thirds height of the gravel, then produce ideal bonding strength.

To achieve mechanical interlock between the individual pieces of aggregate, particular attention must be paid to the time of repressing and the way of post-stage conservation etc.

Forming Method of The Specimens

Making under layer plate

Making indoor asphalt concrete (AC) under layer plate is to simulate the structure of original pavement. Using the mould trial of standard rutting, and taking the dimension as 300mm×300mm×35□45mm. The material of the under layer is AC-16 asphalt mixture, and conducted short and long-term ageing treatment referred to criterion which contains the method of accelerating ageing of hot mixture asphalt (HMA). The AC-16 under layer made in laboratory, whose size is 300mm×300mm×40mm, is shown in figure 2.

Figure 2: AC-I3 filing block with 40mm thickness.

Analogy method of crack

The main types of crack existing on the AC pavement include shaped crack (such as block fracture and slight chap) and fragmentation (such as serious chap and zigzag cracks), we can use handle cutterbar to make cracks with relevant width and shape on the surface of the under layer in laboratory test, the depth of the cracks is about 5mm, then conduct rough chiseling on the rim of the cracks, and sweep away the chippings and dust in the simulated cracks.

Analogy method of the pitted surface

Pitted surface is also a common disease on the AC pavement, we can use chisel to get rid of the fine aggregate and asphalt binder on the surface of under layer, then sweep away the chippings and dust.

Spraying specimens

Material of the chip seal

On condition that to ensure suitable spilling temperature and spilling content, substrate bitumen (110#) or modified emulsified asphalt acted as asphalt binder can get very good result. The gravel are usually use basalt with diameter of 3mm ~ 5mm and limestone with diameter of 5mm ~ l0mm.

Spraying the asphalt

Adopting manual brushing, as shown in figure 3.

Figure 3: Manual brushing.

Spreading gravel

Adopting manual spreading, as shown in figure 4.

Figure 4: manual spreading.

Initial rolling and conservation

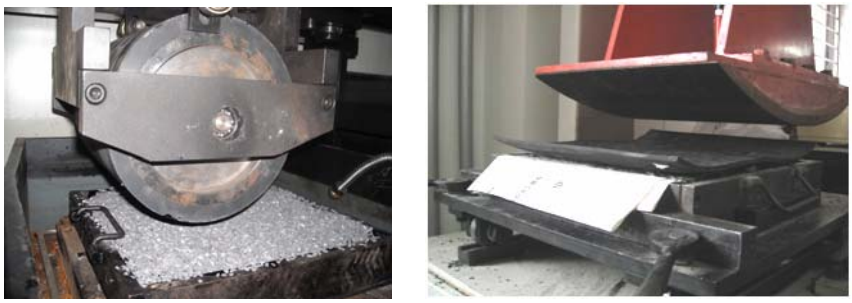
Types of rolling

There are two primary types of rolling for chip seal:

- Pneumatic (rubber-tired) rolling: For all practical purposes, pneumatic (rubber-tired) rolling is being universally used. The type of rolling exploits the machine's weight per unit area of surface contact to provide the forces needed to embed the aggregate firmly in the binder.
- Steel-wheeled rolling: Use of steel-wheeled rolling should be carefully observed, because the type of rolling can crush and degrade the aggregate.

When mould the chip seal specimens in laboratory, there are two ways of rolling compaction we could adopt:

- Using rubber-tired of the rutting tester for rolling compaction, shown in figure 5(a).
- Using the rigid wheel of the molding instrument of rutting specimens for rolling compaction is shown in figure 5(b). When adopting this method, it is need to cover the specimens' surface with rubber blanket in a certain thickness, through testing, when the thickness of the rubber blanket is 15mm, the quality of the molding specimens is the best.



(a) (b)

Figure 5: Types of rolling.

Number of initial rolling

To avoid too much crushing, the number of initial rolling can't be excess; To ensure gravel can take their place and get desired embedded depth and have a good connection with emulsified asphalt, the number of initial rolling should be 3 times at least. After initial rolling, it's need to detect the direction of emplacement and the embedded depth of the gravel, so as to insure the result of the initial rolling. In document [2], the embedded depth of initial rolling should achieve about 50% of gravel diameter; when gravel mainly emplaced in the flattest and thinnest direction, that is to say the number of initial rolling is enough. From testing, the quality of the specimens is good when the number of initial rolling is 3~5 times.

Time of initial conservation

After spraying and initial rolling, the specimens should be conduct initial conservation in constant temperature oven. When in actual construction, generally it can open to traffic after initial rolling in 2~4 hours. So in laboratory, the initial conservation should be controlled into 4 hours.

Temperature of initial conservation

The temperature of initial conservation should agree with that in actual construction. The Asphalt Institute recommends that the temperature of the surface be a minimum of 70°F (21°C) when constructing a chip seal. If the surface temperature were low as, for example, during the morning, asphalt would be more viscous than desired to attain appropriate adhesion between aggregate and binder. On the other hand, excessive pavement temperatures can also be a problem, particularly with the emulsions. In such a case, viscosity would be so low that binder could not secure the aggregate in place. The survey results indicate that Michigan limits construction to a pavement surface temperature of less than 130°F (54°C), whereas Ohio specifies a maximum surface temperature of 140°F (60°C) [1]. So the temperature determined in this paper is 60°C.

Repressing and post-stage conservation

In order to simulate the long-term compaction process of natural vehicle after opening to traffic, it adopted pneumatic rollers to compact in interval and standing conservation after the specimens was through initial rolling and conservation. The result of this test shows that the adhesion between layers is increase, with the time of repressure increase, but the texture depth is to go steady although it is decrease in the mass, that is to say, after repressure, the performance index of chip seal specimens (such as texture depth) is to go steady. But it is not to say that the number is bigger, the result is better, when it outnumbers its limited number of repressure, it may cause serious spalling of the gravel and so on. Through lots of testing, the result is:

- Using rubber-tired of the rutting tester for rolling compaction, the quality of specimens is very good when the number of repressure is 1260 times.
- Using the rigid wheel of the moulding instrument of rutting specimens for rolling compaction, the quality of specimens is very good when the number of repressure is 60 times.

EVALUATION INDEX OF THE QUALITY OF MOULDING SPECIMENS

The objective of this chapter is to identify performance indicators of chip seal specimens. Evaluation index of the quality of moulding specimens can be divided into: qualitative index and quantitative index. The quantitative index is in connection with road performance, such as texture depth and the value of surface abrasion and so on; the qualitative index is in connection with the result of design requirements, its main function is to distinguish defects, such as inferior quality of moulding specimens which exist visible defects (bleeding or raveling).

Engineering-Based Performance Indicators

Texture depth

In the Pennsylvania study, the mean texture depth (MTD) was found to give the best indication of chip seal performance, in addition to being an objective manner of comparing chip seals on a relative basis. Aggregate retention and resistance to bleeding are both evident by evaluating MTD. The study in Pennsylvania proposed that the rationale for using MTD as the best indication of performance is that greater macrotexture generally implies greater skid resistance. This same study found that the MTD, as indicated by macrotexture, decreased with time as a result of both aggregate wear and embedment. The study in Pennsylvania, which proposes that

MTD is the best indication of chip seal performance, is in agreement with New Zealand and United Kingdom philosophies in the development of performance specifications. Texture depth appears to be the performance measure of choice [1].

Of course, the texture depth can act as the evaluation index of indoor chip seal moulding specimens. The only measurement with widespread acceptance by the international respondents is the sand patch method.

Wet Track Abrasion Loss

The wet track abrasion loss is a evaluation index of quality of moulding chip seal specimens. The value of it is in connection with the cohesive strength between aggregate and the emulsified asphalt. The bigger cohesive strength is ,the more area that the emulsified asphalt enveloped the aggregate, and the smaller wet track abrasion loss is; The smaller cohesive strength is ,the less area that the emulsified asphalt enveloped the aggregate, and the bigger wet track abrasion loss is.

Wet track abrasion loss, which is from wet track abrasion instrument, is got by wet track abrasion test on indoor moulding chip seal specimens that is water immersion for 1 hour, and the computational formula 1. The chip seal specimens with low wet track abrasion loss have serious problem of gravel spalling.

$$WTAT = \frac{m_a - m_b}{A} \quad (1)$$

Where

WTAT= wet track abrasion loss,
ma= the quality of the chip seal specimens before test,
mb= the quality of the chip seal specimens after test,and
A= the abrasion area of the rubber hose on the abrasion head.

Qualitative Performance Indicators

The idea that the chip seal specimens should look good after they are completed is an important driver of chip seal specimens performance perception. Visual performance assessment is irreplaceable, even though it is inherently subjective. Therefore, Make sure that experienced personnel make these assessments.

As evident from the experiments, bleeding and raveling are the most common distresses found with a chip seal specimen surface.

Bleeding

Bleeding is normally distinguished by black patches of excess binder appearing on the surface of the chip seal specimens. In other words, a bleeding surface has a smooth and slick appearance where the aggregates are less visible. Bleeding is caused by either an excess of binder in proportion to the aggregate or where the aggregate is forced to achieve levels of embedment beyond the design embedment depth. Bleeding problems are generally associated with high binder rates and non-uniform aggregate gradations.

Raveling

Raveling is the loss of aggregate from the chip seal specimen’s surface. Such chip seal specimens’ surfaces have a very irregular appearance, because the surface is not completely covered by the aggregate.

SKID RESISTANCE TEST

Skid resistance or friction, an important safety characteristic for all roads, which develops between a vehicle's tires and the surface of the road, is a function of two components, macrotexture and microtexture. Basically, the microtexture is determined by the frictional properties of the aggregate, whereas the macrotexture is determined by the size, shape, and spacing of the aggregate particles [1]. The texture depth and friction coefficient of pavement are usually used to measure the skid resistance of the pavement.

Field Texture Depth Test

Through field test on construction, the variation characteristic that is relation between surface texture depth and the natural vehicle were mastered, and it acted as the reference bases to determine rolling parameters when doing the indoor chip seal specimens.

Using the sand patch method mentioned in Normative reference [3] to determine surface texture depth, this paper selected a road that the chip seal was under medium mend and conservation, wheel traces sites and no wheel traces were selected, and conducted texture depth test according different time that the road open to traffic after construction, as shown in figure 6. in order to analyse the total variation characteristic of texture depth on all the testing sites, we got the average value of the test results which had the same time(open to traffic) as the texture depth on that time. The testing data is shown in figure 7 and 8.

Figure 6: Texture depth tracking test.

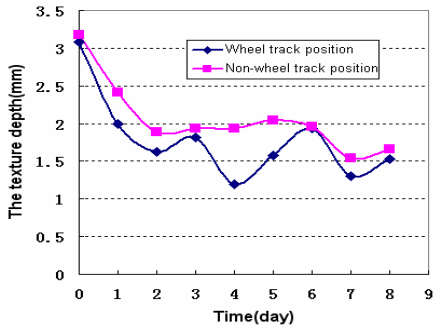


Figure 7: The texture depth curves (8d).

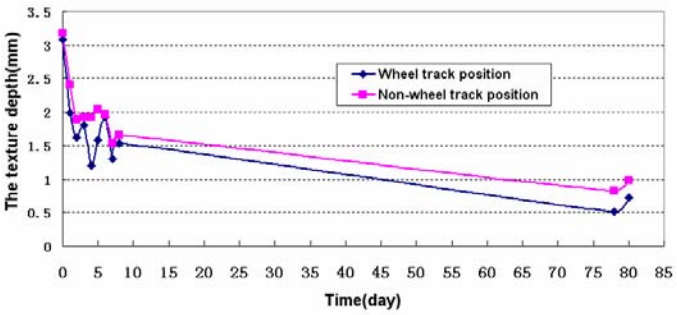


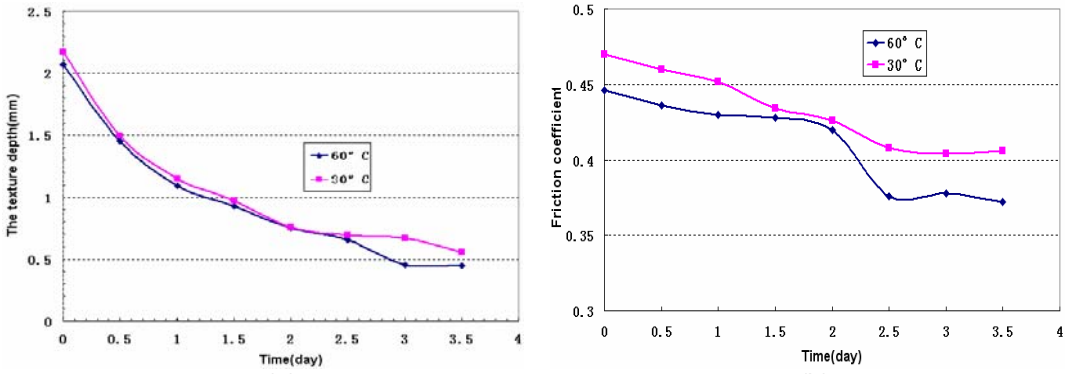
Figure 8: The texture depth curves (80d).

From figure 7 it is readily apparent that the texture depth on the wheel traces is lower than that on non-wheel traces. So it ought to adopt suitable traffic control measures after the chip seal opens to traffic, then it can reasonably adjust the traffic flow on the across section and improve the total applying performances and results of the chip seal; on the other hand, the distribution of the traffic volume on the across section should be taken into consideration, then the dosage of the emulsified asphalt and gravel aggregate should be adjusted in order to avoid distresses such as bleeding, ravelling and so on.

Figure 7 and 8 shows that the surface texture depth would decrease greatly in the first two days to seven days after opening to traffic, no matter where the testing sites are, after 7 days the speed reduces, when the time is 2-3 months, the speed is going steady; at the moment of opening traffic, the surface texture depth is very big (more than 1.8mm), so the noise is bigger and the comfort is influenced; after about 3 months, the surface texture depth reduces a lot.

Indoor Skid Resistance Test

Basing on the method of moulding and test aforementioned, this chapter study the correlativity between different parameters of rolling compaction and conservation (rolling time、conservation temperature) and the texture depth and friction coefficient. The experimental results are shown in figure 9.



(a) (b)

Figure 9: Indoor skid resistance test results.

Figure 9(a) shows that, indoor texture depth test results agree with field texture depth test results, and the texture depth decreases with increasing rolling time, and be more stable. In addition, smaller values of texture depth are obtained in high curing temperature conditions.

From figure 9(b) it is readily apparent that，indoor friction coefficient test results indicate that friction coefficient also decreases with increasing rolling time, and be more stable. In like manner, smaller values of friction coefficient are obtained in high curing temperature conditions.

CONCLUSION

Taking the structure and technology condition of the original pavement into consideration, the moulding method of specimens that simulates the construction conservation and the process of operation, is closed to the real circumstances, so it can truely complete the test.

Using the indoor moulding specimens to conduct the research on the indoor skid resistance, it can approximately gain the road performance of the chip seal.

The moulding method mentioned in this paper can also be used on the indoor test and forecast of the chip seal design results.

REFERENCES

Joseph H. Boardman, Michael D. Meyer & Robert E. Skinner, et al. Chip Seal Best Practices, Transportation Research Board, Washington, D.C., 2005.

Douglas D. Gransberg, et al. Calculation Roller Requirements for Chip Seal Projects, Journal of construction engineering and management, pp378—384, 2004.

Department of Transportation. Field Test Methods of Subgrade and Pavement for Highway Engineering(JTG E60-2008), Beijing, 2008.

Thomas J. Wood, David W. Janisch & Frank S. Gaillard. Minnesota Seal Coat Handbook 2006, Minnesota Department of Transportation Office of Minnesota Road Research, Maplewood, 2006.

Tommy L. Beatty, Dennis C. Jackson, et al. Pavement Preservation Technology in France, South Africa, and Australia, US Department of Transportation, Washington, D.C., 2002.

Shulze K H., Gerbaldi A., Chavet J. Skidding Accidents, Friction Numbers, and the Legal Aspects Involved. Skidding Accidents. Transportation Research Record 623. Transportation Research Board. Washington D.C., 1976.

AUTHOR BIOGRAPHIES

Yuhua Li, male, 39 years old, professor of Road engineering institute, School of Transportation, Dalian University of Technology, Dalian City, Liaoning Province, China. Major in techniques of preventive conservation of asphalt pavement, especially in application research on fiber seal coat technology for construction and conservation.

Yuxing Liu, female, 24 years old , postgraduate of Road engineering institute, School of Transportation, Dalian University of Technology, Dalian City, Liaoning Province, China