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RESEARCH ARTICLE

EFFECT OF GROOVE WIDTH AND SHAPE ON CONCRETE PAVEMENT SKID RESISTANCE

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ABSTRACT

The importance of surface texture characteristics of concrete pavement to reduce wet-weather accidents caused by skidding is well recognized by civil engineers. Sufficient transverse and longitudinal grooving provide good friction characteristics during wet weather conditions. Although considerable information exists on asphalt pavement surface friction characteristics on safety by British Pendulum Test, very limited attempt has been made to address concrete pavement friction characteristics on the longitudinal and transvers grooved surface effects. In this study, British Pendulum Tests were conducted on longitudinal and transvers grooved concrete samples with different groove width and shape. According to the regression analyses same skid resistance values are expected for wet and dry conditions at groove width of 11 mm for longitudinal grooves with sharp corner. If the longitudinal groove corner is rounded, higher British Pendulum Number (BPN) can be obtained for wet and dry conditions with smaller groove width. Transverse grooves have higher BPN than longitudinal grooves for the same groove width. BPN increases by increasing transverse groove width and the effect of groove shape is different for different groove widths.

Key Words: Concrete Pavement, Transverse Groves, Longitudinal Grooves, Surface Texture, British Pendulum Test, Skid Resistance.

INTRODUCTION

Grooved construction on concrete pavement roads has been proven to greatly improve the drainage efficiency and skid resistance of pavement. Transverse and longitudinal grooving is a surface texturing treatment on concrete road pavements. Longitudinal grooves provide extra microtexture on the surface and hence improve skid resistance (Purushothaman *et al*., 1990). Transverse grooves provide better drainage which allows dry contact surface between the tire and the road surface. This property improves skid resistance. More resisting force against sliding of tire occurs by increasing transverse groove width and this leads to higher skid resistance (Ong *et al*., 2006). Engineers working on airport runways and pilots have observed that transverse-grooved surfaces drastically reduce skids on wet runways and provide better handling wheel steering during landing roll-out. Overall stopping distance on grooved surfaces is a dramatic improvement over ungrooved surfaces. Grooving is most commonly produced through small surface channels, grooves, or indentations that are intentionally formed (plastic concrete) or cut (hardened concrete) to allow water to escape from beneath a vehicle's tires. Longitudinal grooves provide better directional control and resistance to lateral movement and have less tire noise than transverse grooving.

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However, longitudinal grooving has disadvantages of slightly slower surface drainage compared to transverse grooving. This is critical and it should be considered especially in wetter climates during the winter. The British pendulum test as described in ASTM E303 (2000) is a laboratory testing method to find the skid resistance of pavement surface. The test method describes the procedure for determining the skid resistance value of a pavement surface using a British Portable Skid Resistance Tester. It is a low-speed (10 km/hr) test and many researches have considered that British pendulum test can be used as an assessment of the skid resistance of the highway pavement surface and it is affected by microtexture of the surface (Foerster, 1989; Huang, 1993; Kummer, 1966; Croney *et al*., 1992).

British pendulum test is effected by aggregate gap and aggregate size parameters where BPN decreases by increasing the aggregate gap width (Liu *et al*., 2004). It is also determined that BPN decreases by increasing transverse groove width (Lee *et al*., 2005). In that study, groove spacing (center to center) was not kept constant. In another study, it is determined that BPN decreases by increasing transverse groove spacing (Purushothaman *et al*., 1990). It is imperative to know the grooving dimension characteristic features that have an effect on their performance with respect to skid resistance. This paper attempts to determine the effect of longitudinal and transverse groove width and groove shape. Understanding the influence of the geometrical features of the transverse and longitudinal grooves on its friction characteristics is important.

Experimental Program

The experimental program of this study consists of two parts. Part I involves testing longitudinal and transverse grooved surfaces with varying groove width at constant groove spacing and groove depth to determine the effect of groove width on skid resistance. Part II of the experimental program involves testing rectangular and rounded shape of longitudinal and transverse groove corners to determine the effect of groove shape on skid resistance for longitudinal and transverse grooves (Figure 1).

6 mm and a 3.8 mm thick aluminum cap of corresponding length and width. The angle between the first contact point of test surface and the lower face of the rubber slider was 18º. Sliding length of the BPT slider is 127 mm on the surface (Liu *et al*., 2003). Standard 15 cm x15 cm x 15 cm cube C40 (compressive strength of 40N/mm2) type of concrete specimens were prepared for the testing program. Plastic grooved plates were used to give the surface shape of the concrete specimens. Five different specimens with varying groove widths of 2 mm, 3 mm, 4 mm, 5 mm, and 6 mm with a constant groove spacing (center to center) of 13 mm and a depth of 6 mm were obtained.

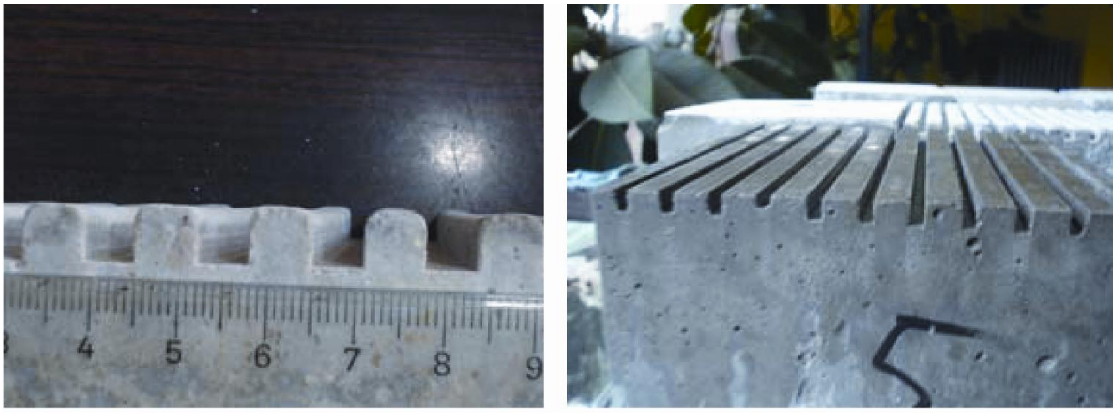


Figure 1. Grooves with rounded and sharp corner

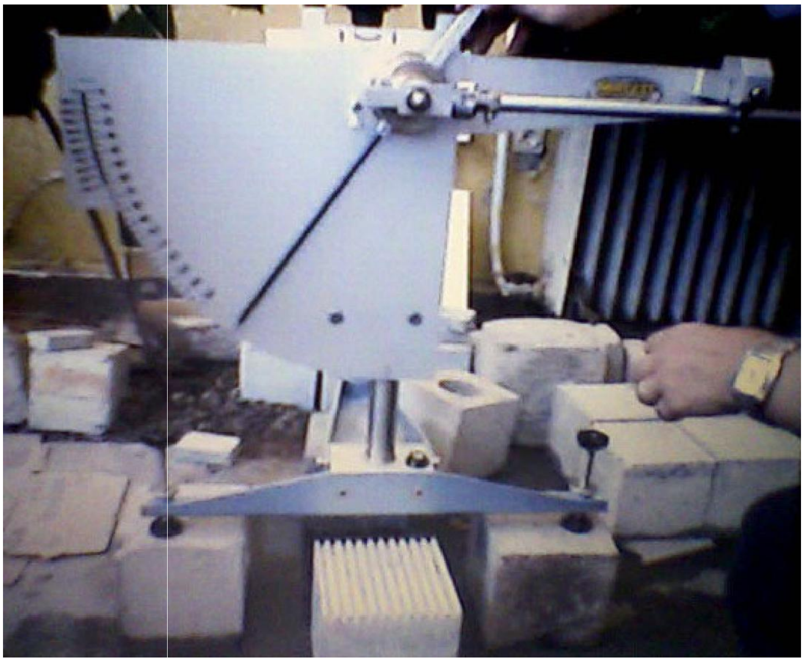
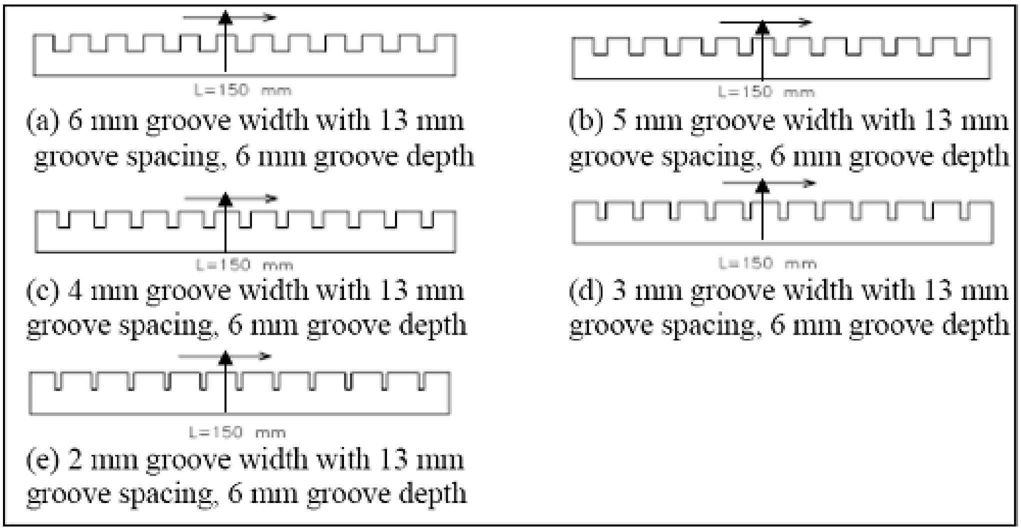


Figure 2. British Pendulum Testing on transverse grooved surface

The British pendulum test apparatus was set on prepared concrete sample surface. Samples were tested in two direction as transverse and longitudinal grooved surface not to have different micro texture on the surface (Figure 2). The British Pendulum Tester (BPT) is a dynamic pendulum impact-type tester used to measure the energy loss when a rubber slider edge is propelled over a test surface. The mean five readings gave a representative value of skid resistance of the concrete samples. The slider consisted of a rubber piece of 76 by 24 by

Plastic plates were put on the side of the sample cubes while pouring concrete into cubes to obtain smoother surface than putting plastic plates on top of the cube after pouring concrete (Figure 3). Curing was obtained when the specimens were submerged in water bath for 28 days before they were tested to find their skid resistance value. Before testing the specimens, microtexure of each surface was measured by laser profilometer. Pavement surfaces were almost smooth with an average value of 0.02 mm microtexture.

Figure 3. Plastic plates are on the side of the sample cubes



Note: Arrows denote sliding direction

Figure 3. Transverse and longitudinal grooved surfaces from front view with variable groove widths

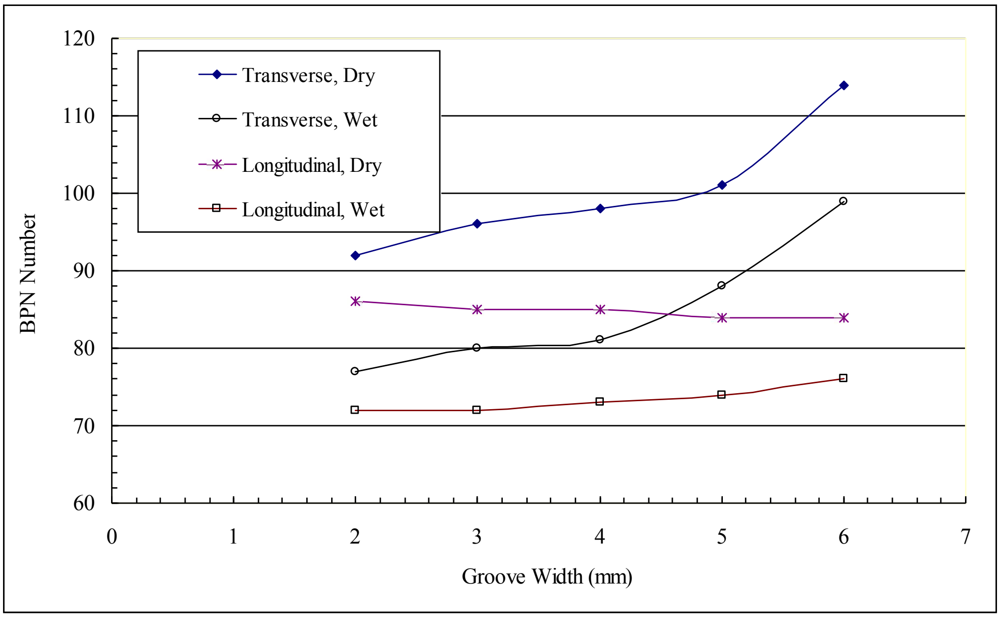


Figure 4. British pendulum measurements for longitudinal and transverse grooved surfaces with variable groove width, constant groove spacing and constant groove depth.

Effects of Groove Width and Direction

Five different types of grooved surfaces with sharp groove corner were prepared as shown in Figure 3. Samples were used in longitudinal and transverse way during British Pendulum Test. The measured British Pendulum Test results for longitudinal and transverse grooved surfaces are presented in Figure 4. Figure 4 provides a comparison of longitudinal and transverse groove width and BPN values for dry and wet conditions. It was determined that the effect of groove width on BPN value is different for dry and wet testings for longitudinal grooves. BPN values increases under wet conditions and decreases under dry conditions when longitudinal groove width increases. BPN difference between wet and dry conditions decreases as the groove width increases for longitudinal grooves. BPN of transverse grooves is bigger than longitudinal ones at the same groove width.

Equation 1 and Equation 2 are obtained from Figure 4.

Y (dry longitudinal groove with sharp corner) =-0.8x + 87.4 (R^2=0.9412) (Eq. 1)
Y (wet longitudinal groove with sharp corner)=0.8x + 70 (R^2=0.9412) (Eq. 2)
Y= BPN; x=longitudinal groove width

BPN is 78.7 when longitudinal sharp corner groove width is 10.9 mm under wet and dry conditions.

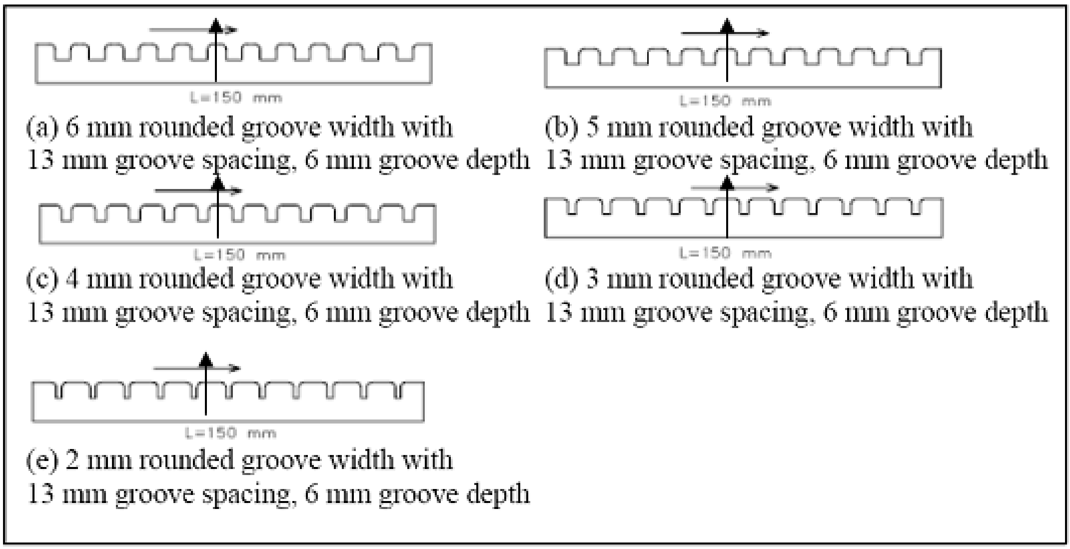
BPN values of longitudinal grooves decreases for dry surfaces and increases for wet surfaces as the rounded groove width increases.

BPN values for longitudinal grooves with sharp corner are almost same with rounded ones for dry surfaces and less for wet surfaces. The difference in BPN for dry and wet conditions decreases as the groove width increases for rounded longitudinal grooves. BPN values for transverse grooves with sharp corner are higher than rounded ones for 2 mm and 3 mm groove width under wet and dry conditions. BPN remains almost same for 4 mm, 5 mm and 6 mm sharp and rounded transverse groove width under dry conditions. But, transverse grooves with rounded corner have bigger BPN than sharp ones for 4 mm, 5 mm and 6 mm transverse groove width under wet conditions.

Equation 3 and Equation 4 are obtained from Figure 6.

Y (dry longitudinal groove with rounded corner)= -0.8x + 87.4 (R^2=0.9412) (Eq. 3)
Y (wet longitudinal groove with rounded corner)= 1.8x + 68.6 (R^2=0.8804) (Eq. 4)
Y= BPN; x=longitudinal groove width

BPN is 81.6 when longitudinal rounded corner groove width is 7.2 mm under wet and dry conditions.



Note: Arrows denote sliding distance

Figure 5. Transverse and longitudinal rounded grooved surfaces from front view with variable groove width.

Effects of Rounded Groove Corner

The concrete specimens were prepared as described previously with plastic grooved plates. In this part, the groove corners of plates were rounded with radius of 1.5 mm so that the surface of the new concrete specimens had rounded grooves (Figure 5). Five different specimens were tested by British pendulum test device. Figure 6 provides a comparison of longitudinal and transverse groove width and BPN values for dry and wet conditions.

DISCUSSION

This study demonstrated that groove width and groove corner shape are important factors for skid resistance on pavement. BPN increases when transverse groove width increases under wet and dry conditions. But it decreases when longitudinal groove width increases under dry conditions. The general trend is that grooves with sharp corner (diamond saw cut grooves) are more effective than rounded groove corners.

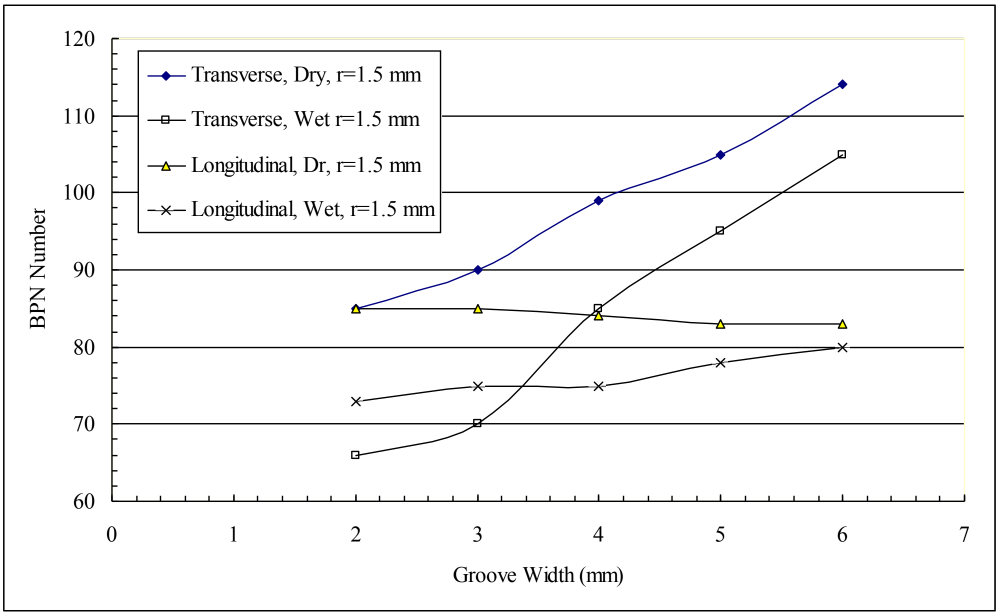


Figure 6. British pendulum measurements for longitudinal and transverse rounded grooved surfaces with variable groove width, constant groove spacing and constant groove depth

However, this study demonstrated that rounding the longitudinal groove corner is more effective on getting higher skid resistance under wet conditions. The affect of groove corner shape also depends on the transverse groove width. The findings of this study demonstrated that both longitudinal and especially transverse grooving BPN is much higher when compared with asphalt pavements. Usually the BPN for asphalt pavement varies between 30 to 60. BPN obtained in this study for grooved surfaces varied from 68 to 115 under wet conditions. There is an optimum longitudinal groove width according to groove corner shape under dry and wet conditions. Because BPN increases when longitudinal groove width increases under wet conditions but it decreases under dry conditions. The optimum longitudinal groove width is smaller and it has higher BPN when the groove corner is rounded. Keeping groove spacing (center-to-center) constant while increasing groove width, make sliding rubber passes same amount of groove on the surface and that gives more realistic BPN comparison according to BPN values for changing groove spacing and groove width together.

Conclusion

In this study laboratory experimental program was conducted to examine the effect of groove width and shape on the skid resistance of concrete samples by measuring the BPN values. The following results can be concluded;

- Transverse grooves have higher BPN than longitudinal grooves and the difference increases as the groove width increases.
- Transverse grooves have higher BPN when the groove width increases for wet and dry conditions.
- Transverse grooves with rounded corner have higher BPN than the sharp corner ones after 4 mm groove width under wet conditions.
- BPN difference between wet and dry conditions decreases as the groove width increases for longitudinal grooves.
- Ideal groove width when wet and dry conditions are taking into account together is 10.9 mm for longitudinal grooves with sharp corner and it is 7.2 mm for longitudinal grooves with rounded corner (r=1.5 mm) when groove spacing is 13 mm and groove depth is 6 mm. BPN are 78.7 and 81.6 respectively.
- It is better to use rounded longitudinal grooves than the sharp ones to get higher skid resistance. Optimum longitudinal groove width for wet and dry conditions is smaller for rounded grooves while it has also higher BPN.

REFERENCES

ASTM Standard E 303, Test Method for Measuring Surface Friction Properties Using The British Pendulum Tester, Annual Book of ASTM Standards, ASTM International, 2000.

Croney, D. and Croney, P. 1992. The Design and Performance of Road Pavements, McGraw-Hill Book Company, New York.

Foerster, S.W. 1989. “Pavement Micro-texture and its Relation to Skid Resistance,” Transportation Researched Record, Vol. 1215, Transportation Researched Board, Washington, D. C., pp. 151-164.

Huang, Y.H. 1993. Pavement Analysis and Design, Prentice Hall, Englewood Cliffs, *NJ.,*

Kummer, H. W. 1966. Unified Theory of Rubber and Tire Friction, Engineering Research Bulletin B-94. Pennsylvania State University, College of Engineering, University Park, PA.

Lee, Y. P. K., Fwa, T. F. and Choo, Y. S. 2005. “Effect of Pavement Surface Texture on British Pendulum Test,” Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, 1247-1257.

Liu, Y. R., Fwa, T. F. and Choo, Y. S. 2003. "Finite Element Modeling of Skid Resistance Test," ASCE Journal of Transportation Engineering, Vol. 129, No. 3, pp. 316-321.

Liu, Y. R., Fwa, T. F. and Choo, Y. S. 2004. "Effect of Surface Macro texture on Skid Resistance Measurements by the British Pendulum Test," Journal of Testing and Evaluation, Vol. 32, No. 4, 304-309.

Ong, G. P. and Fwa, T. F. 2006. "Guidelines for Transverse Grooving in Surface Texturing of Concrete Pavement," Transportation Research Board 85th Annual Meeting, Washington, D. C., Jan 22-26.

Purushothaman, N., Heaton, B. S. and Moore, I. D. 1990. "A numerical Analysis of the Friction Mechanism of Grooved Road Surfaces," Surface Characteristics of Roadways: International Research and Technologies, ASTM STP 1031, W. E. Meyer and J. Reichert, Eds., American Society for Testing and Materials, Philadelphia, pp. 127-137.

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