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Skid Resistance of Concrete Pavers

The previous *Engineer's View* highlighted slip resistance, a major factor in walking safely. Similarly, skid resistance, contributes to driver safety through secure tire/pavement interaction. Just as coefficient of friction quantifies pedestrian surface slip resistance, friction measurement also plays a like role in characterizing vehicular pavement surfaces.

What pavement factors affect the friction coefficient?

The main factors are the type and condition of pavement surface, the type and condition of tire, the type of vehicle and environmental conditions such as temperature and moisture. While pavement designers have no control over vehicles and the weather, they do influence the pavement surface. Two surface conditions play an important role in determining pavement friction coefficient and ultimately skid resistance—microtexture and macrotexture.

Microtexture

Microtexture primarily influences skid resistance of tires traveling less than 25 mph (40 kph), particularly in wet conditions. It is typically defined by smaller deviations in the surface, those less than 0.2 in. (0.5 mm), or those often characterized by "grittiness" on the pavement's surface. For concrete pavers, microtexture can be affected by coarse and fine aggregates in concrete. Specifically, the hardness of the aggregate plays an important role since its polishing under traffic influences microtexture and skid resistance. Harder aggregates resist polishing under concentrated braking or accelerating tires thus maintaining a high degree of surface texture variation. State and Provincial Departments of Transportation (DOTs) typically select aggregates on their initial roughness and on their ability to retain roughness when exposed to polishing from tire traffic.

Typical North American tests for aggregate hardness include the Los Angeles abrasion test and the Micro Deval test. In the Los Angeles abrasion test (see Figure 1), dry aggregates are placed in a horizontally mounted cylindrical drum with a shelf inside that lifts and drops the aggregate. Steel balls are added and the drum rotates for a number of revolutions. Abrasion and attrition of the aggregate occurs due to tumbling, but primarily from the aggregate impact (or dropping) in the apparatus. The Los Angeles abrasion test is defined by ASTM C 131, ASTM C 535 and AASHTO T 96. It is best used to evaluate coarse aggregates or those larger than 1/4 in. (6 mm).

The Micro-Deval test induces degradation of aggregates by tumbling them in a rotating steel drum with water and steel balls. This test is harsher than the LA abrasion test and is a better indicator of service when exposed to weather and moisture in pavement. The Micro Deval test can be used to evaluate coarse and fine aggregates including bedding sand. It is defined by CSA A23.2-23A for fine aggregates, and ASTM D 6928, or AASHTO TP-58 for coarse aggregates. Another test is ASTM D 3319, Standard Practice for Accelerated Polishing of Aggregates. This test method is used by some state agencies to evaluate coarse aggregates for polishing characteristics.

In most cases, concrete pavers conforming to ASTM or Canadian (CSA) standards generally do not require special aggregates to maintain skid resistance equal to that of asphalt or PCC pavement surfaces. Like other paving materials, aggregates (hardness, sharpness) and surface texture can be controlled in the mix design and manufacturing process for concrete pavers.

Figure 1. Hardness of aggregates for bases and pavements are often assessed using the Los Angeles Abrasion machine. Photo source: Southern Illinois University Edwardsville

Figure 2. Chamfers on concrete pavers offer water drainage, increasing skid resistance and can decrease vehicle stopping distances.

Macrotexture

Macrotexture refers to the large-scale roughness of a pavement surface and is typically defined by surface deviations 0.2 in. (0.5 mm) or greater (from a true planar surface). A pavement with good macrotexture contributes to skid resistance of vehicles traveling over 25 mph (40 kph) in wet conditions. The shape, size and gradation of coarse aggregates can sometimes influence macrotexture. It can also be introduced through pavement designs that incorporate small surface channels or grooves. Those in asphalt and poured-in-place concrete pavements are created by scoring the surface (also known as "tining"). Concrete pavers, however, automatically offer a unique macrotexture from their chamfers that can benefit skid resistance at these speeds (see Figure 2). The chamfers form small drainage channels on the pavement surface, and have been shown to help disperse water under moving tires and were likely influential in a Japanese study that demonstrated decreased vehicle stopping distances at an intersection compared to asphalt.

Current paver manufacturing practices emphasize the control of aggregate quality and, therefore, the control of microtexture. Additional research demonstrates that pavement macrotexture greatly influences skid resistance. This has been difficult to measure in the past and the challenge for researchers is to develop technologies that allow the simultaneous testing and measuring of macrotexture and microtexture. Methods are being investigated that use laser beams or light strobes.

How is friction quantified for a pavement?

In North America, the frictional resistance of a paved surface is typically quantified as a skid number (SN). Defined as "the ratio between the frictional resistance acting along the plane of sliding and the load perpendicular to this plane," the skid number is often used by DOTs when selecting and evaluating in-service pavements.

To test for SN, many DOTs use the test procedure described in ASTM E 274, *Standard Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire*. In this procedure a standard test tire is towed by a trailer behind a moving vehicle. Water is applied ahead of the tire while moving and the tire is braked and locked at constant speed, usually 40 mph (65 kph). The resistance between the tire and wet pavement is measured at very small time increments while the tire skids. The force required to slide the tire is divided by the wheel load at each increment. The values are averaged and multiplied by 100. The averaged measurement from the surface is expressed as a skid number (SN) or friction number (FN). A higher value indicates better skid resistance.

No universal, minimum standard for skid resistance has been established. Typically, pavement engineers utilize the skid number measured using test method ASTM E 274 at 40 mph (65 kph) (i.e., SN 40) as a reference value. A SN 40 value of 30 for interstate and other divided highways, and a minimum SN 40 value of 40 for two-lane highways have been suggested by some studies.

In 1997, ICPI engaged The Pennsylvania Transportation Institute (PTI) to conduct skid measurements on two sections of new interlocking concrete pavement. Each section was 2 ft (0.6 m) wide by 150 ft (45 m) long and laid in a 90° herringbone pattern. Five skid resistance measurements were performed at three speeds; 25, 40 and 50 mph (40, 65, and 80 km/h) using the test method described in ASTM E 274. The test used a standard grooved test tire described in ASTM E 501, *Standard Specification for Standard Tire for Pavement Skid Resistance Tests*. The average results from the two sections are shown in the table below and indicate SN skid values between 40 and 57. These values are well above the typical minimum requirements expected by DOT's. Figure 3 shows the device testing the skid resistance and Table 1 show the test results for the two paver sections.

Since 1980, there have been several skid resistance tests on concrete pavers using various types of testing equipment. These have demonstrated that interlocking concrete pavements can maintain adequate skid resistance during their service life. For more information on pavers and skid resistance visit the ICPI web site at www.icpi.org, follow the link to Design Professionals and Tech Specs and download *ICPI Tech Spec 13 Slip and Skid Resistance of Interlocking Concrete Pavements*.❖

Figure 3. Skid resistance measured on concrete pavers at Pennsylvania Transportation Institute in 1997 according to ASTM E 274 that includes a trailer and tire that locks or skids over a wet surface.

Test Section	Speed mph (kph)	SN	Standard Deviation
A	25 (40)	51.9	0.5
A	40 (65)	46.5	1.1
A	50 (80)	40.0	1.5
B	25 (40)	57.2	1.1
B	40 (65)	49.6	3.0
B	50 (80)	43.1	0.5

Table 1—Average SN Values for Interlocking Concrete Pavement Sections