

Texturing Concrete Pavements

Reported by ACI Committee 325

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The importance of the need for skid-resistant pavement has been known for many years. Increased traffic volumes and speeds have increased the need for an improved skid-resistant surface. The emphasis has been to improve skid resistance by creating new surface textures that increase the "macrotexture" of the concrete pavement. These textures are created by forming the deeper textures in the plastic concrete during the finishing operations. Skid resistance has also been improved in existing concrete pavements by sawing grooves in the hardened concrete with cutting heads composed of a number of circular diamond saw blades. The traveling public may better understand this as a process of placing a "tread" in the pavement surface, which complements the tread on the car tires, and stops the vehicle without skidding or loss of control by permitting the rapid escape of water.

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CHAPTER 1 - NEED FOR TEXTURE

1.1- Development of textures

The importance of the need for a uniform surface texture to increase skid resistance of both highways and airport pavements has been recognized for many years.^{1,2}

The problem of skidding vehicles is not considered to be critical when low volumes of traffic and low speeds are prevalent.³ During the late 1940s and early 1950s, civil engineers raised serious concerns about pavement safety on the highway system. Increasing traffic volumes and speeds, which were contributing to a constantly increasing number of accidents and fatalities in the United States, were the two main factors that led engineers to believe that pavement skid resistance needed to be improved if skidding accidents were to be reduced.

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During the same period, aircraft runways were being more critically examined in terms of pavement slipperiness. The advent of jet-powered aircraft quickly established that high-performance airplanes, with accompanying higher takeoff and landing speeds, were much more difficult to control on wet runways than were piston-type aircraft.⁴

Published reports on the adverse effect of pavement slipperiness on vehicle control go back to the late nineteenth century. The first concrete street in the United States, built in Belfontaine, Ohio, had 4 X 4 in. (102 X 102 mm) squares formed in the plastic concrete to provide traction for horses' hooves.

Grooving hardened concrete pavement appears to have been a British innovation that was used in 1956 on a number of airfield pavements in England. In the United States in the early 1960s the California State Division of Highways started sawing grooves in pavements to reduce hydroplaning on curves.⁴

Textures have also been constructed on bridges and parking-deck ramps by building up a multicomponent epoxy coating system, as indicated in ACI 503.3-79. For many years, pavement texturing in plastic concrete had been accomplished with a burlap drag or a belt drawn longitudinally along the pavement surface. During the late 1960s, deeper texturing efforts were initiated. Textures on pavements have been made with both longitudinal and transverse patterns using brooms, tining combs or rakes, roller imprints, and a longitudinally drawn, coarse polyethylene artificial-turf drag inverted to provide texture.

The concerns of engineers in developing new deeper textures in concrete whether in the plastic state or in the hardened state were:

1. The possibility of objectionable pavement noise.
2. The possibility of increased roughness, which would cause objectionable vehicle handling characteristics.
3. Problems associated with vehicles, particularly motorcycles, experiencing sensations of "tracking" or loss of handling control of the vehicle on longitudinal grooves.
4. Increased aircraft-tire wear associated with high-speed landings on deeper textured pavements.
5. Increased pavement wear and rutting.

Highway and airport designers have no control over vehicle speed and tire characteristics, and therefore must pay attention to the skid resistance of the pavement surfaces in their designs. Specifications should be adopted for constructing new portland cement concrete pavements with satisfactory surface textures and crowns for existing older pavements that have lost their skid resistance.

Cross slopes (or crowns) built into concrete pavements, airport runways, and high-speed turnoffs provide for draining the water from the surface rapidly. Generally, a minimum cross slope on highways of 1 percent is recommended. Slopes greater than this can be used provided they are consistent with road safety and driveability of the vehicles using them. Cross slopes on

airport runways and taxiways vary from 1 percent to a maximum of 1.5 percent. The cross slopes enhance the skid resistance of textures by providing a good drainage characteristic.

1.2 – Benefits of texturing

The results of testing with a standard skid trailer (ASTM E 274) indicate that transverse textures produce higher friction numbers than longitudinal textures (higher friction numbers indicate greater skid resistance). However, it does not necessarily follow that transverse textures should be used throughout the highway system, since friction numbers, as measured with the locked-wheel device, are not sensitive to cornering friction. It is apparent from studies of grooved pavement that longitudinal grooving increases cornering friction significantly, whereas transverse grooving increases mainly longitudinal braking friction.⁵ Transverse grooves provide a path perpendicular to the direction of travel for the escape of water under the tire, which is an important factor in reducing hydroplaning.

The Edens Expressway in Cook County, Ill., was constructed as a jointed portland cement concrete pavement in the early 1950s. The pavement was resurfaced with a bituminous concrete mix in the late 1960s. Between 1979 and 1980, it was reconstructed as a continuously reinforced concrete pavement. The texturing technique used in the reconstructed pavement was a longitudinally drawn artificial turf drag followed by a transverse tine device. The positive benefits of surface tining are reflected in a comparison of the accident statistics compiled for the four years before and after its reconstruction, as shown in Table 1.2. The northbound lanes were installed in 1979 with tining combs that had tines spaced at 1/2 in. (13 mm). In 1980, the southbound lanes were constructed; however, the tine spac-

Table 1.2 – Statistics compiled by Illinois Department of Transportation, District 1 Bureau of Traffic

Safety impact of Edens Expressway reconstruction - Four years before-after comparison of Edens Expressway versus System*

Accident type	Accidents before reconstruction: 1974 to 1977	Accidents after reconstruction: 1981 to 1984	Change, percent
Total accidents			
System	62,282	59,869	- 3.9
Edens	4216	3249	- 22.9
Fatal accidents			
System	196	181	- 7.7
Edens	12	11	- 8.3
Injury accidents			
System	15,016	13,677	- 8.9
Edens	1296	1001	- 22.8
Wet, snow/ice road surface conditions			
System	15,122	16,470	+ 8.9
Edens	1438	851	- 40.8
Off-road, one-vehicle collision with fixed object			
System	7590	7769	+ 2.4
Edens	861	510	- 40.8

*Chicago Metropolitan Expressway System accident experience, excluding Edens Expressway.

Note: Edens Expressway under construction 1978 to 1980.

ing was changed to $\frac{3}{4}$ in. (19 mm) to reduce tearing of the concrete surface. Although a slight increase in noise level was anticipated, it was negligible when measured and actually screened out by other noises. The $\frac{3}{4}$ in. (19 mm) tine spacing is now standard in Illinois."

The reduction of the "wet, snow/ice road surface conditions" accidents in Table 1.2 shows a very impressive safety impact has been achieved by reducing accidents. This improvement has been attributed to the improved surface texture.

Additional benefits observed on pavements with the deeper textures are: 1) a reduction in water spray from traffic due to improved surface drainage, by providing channels for the expulsion of water at the tire-pavement interface into the grooves or deeper striations; 2) a reduction in headlight glare due to the rougher surface of the pavement; and 3) a slower buildup of rubber on runways due to airplane touchdowns on grooved airport pavements.

1.3 — Factors affecting skid resistance

Skid resistance of pavements is affected by both the "microtexture" of the pavement as related to the sand in the mortar portion of the concrete mixture; and by the "macrotexture," which is defined as the measurable deeper striations or grooves formed in the plastic concrete during the finishing operations, or the shallow grooves cut in the hardened pavement with cutting heads composed of uniformly spaced circular diamond saw blades. This report will not discuss microtexture.

The term "hydroplaning" refers to the separation of tire contact from the pavement surface by a layer of water. This separation causes a loss of steering and braking control of the vehicle. Hydroplaning is a complex phenomenon that is affected by 1) water depth; 2) pavement texture; 3) tire-tread depth; 4) tire-inflation pressure; 5) tire-contact area; and 6) vehicle speed. An approximate relationship exists between the speed at which hydroplaning will occur and the tire inflation pressure

$$\text{Hydroplane speed} = 10.35 \sqrt{\text{tire pressure}}$$

when speed is in mph and pressure is in psi.

Some of the earliest investigations and technical reports on loss of vehicle control, which came from the National Aeronautics Space Administration (NASA), were primarily concerned with hydroplaning of aircraft during wet weather operations. The U.S. Army Air Corps, and its successor the U.S. Air Force, also did valuable work on this subject. Later, the Road Research Laboratory in Great Britain began investigations related to hydroplaning of automobiles. Concurrent with this research, the Americans and Germans studied tires and road surfaces to seek their own theories of the factors contributing to skidding.⁵

CHAPTER 2 — TEXTURE TYPES

2.1 — Texturing plastic concrete

2.1.1 Artificial turf texture — This finish (Fig. 2.1.1) may be accomplished by using artificial turf inverted and suitably attached to a device that will permit control of the time and rate of texturing. A transverse artificial turf with approximately 2 ft. in contact with the pavement surface and operated longitudinally in the direction that the pavement is being placed should be required. The artificial turf may be weighted to produce a deeper and more uniform texture.

One artificial turf that provides a satisfactory texture is made of molded polyethylene with turf blades approximately 0.85 in. (21.6 mm) long, and containing 7200 individual blades per ft² (930 cm²).

2.1.2 Transverse tine texture — This finish (Fig. 2.1.2) may be obtained by using a single pass of an artificial turf or burlap followed by a mechanically operated transverse-texturing device. The texturing device consists of a single line of flat, slightly flexible, tempered spring steel tines, spaced at not less than $\frac{1}{2}$ in. (12.7 mm) nor more than 1 in. (25 mm) centers. Closer centering of the tines will lead to early raveling while larger spacing may lead to objectionable road noise. Random spacings have been used on some projects due to the concern for noise developing from a uniform spacing. The tine width should be $\frac{1}{8}$ in. (3.2 mm). Texturing is applied while the concrete is still plastic

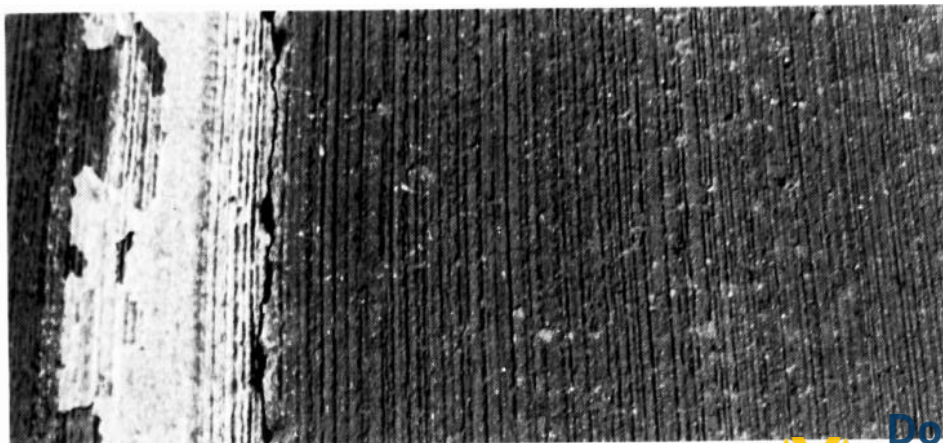


Fig. 2.1.1-Artificial turf texture