U.S. Department
of Transportation
Federal Highway
Administration

Technical Advisory

Subject
Surface Texture for Asphalt and Concrete Pavements

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T 5040.36	**June 17, 2005**	**HIPT-20**

Par.

1. **What is the purpose of this Technical Advisory?** This Technical Advisory (1) issues information on state-of-the-practice for providing surface texture/friction on pavements and (2) issues guidance for selecting techniques that will provide adequate wet pavement friction and low-tire/surface noise characteristics.
2. **Does this Technical Advisory supersede another Technical Advisory?** Yes. This Technical Advisory supersedes Federal Highway Administration (FHWA) Technical Advisory 5140.10, "Texturing and Skid Resistance of Concrete Pavements and Bridge Decks," dated September 18, 1979.
3. **What are the surface texture components that influence wet-weather friction?** Two types of surface texture affect wet pavement friction: microtexture (wavelengths of 1µm to 0.5mm) and macrotexture (wavelengths of 0.5mm to 50mm). Microtexture is generally provided in asphalt pavements by the relative roughness of the aggregate particles and in concrete surfaces by the fine aggregate. Macrotexture is generally provided in asphalt pavement by proper aggregate gradation and in concrete surfaces by a supplemental treatment such as those listed in paragraph 7(a).
4. **What is the background on pavement surface texture/friction?** The FHWA pavement policy is contained in 23 Code of Federal Regulations (CFR) 626.3, and it states: "Pavement shall be designed to accommodate current and predicted traffic needs in a safe, durable, and cost effective manner." To provide a safe pavement, wet pavement friction should be provided. The characteristics of pavement texture that provide wet weather friction are microtexture and macrotexture. Both microtexture and macrotexture are necessary to provide wet pavement friction at low and high speed conditions. While safety considerations are paramount, tire/surface noise should be considered when specifying pavement and bridge surfaces. Both asphalt and concrete pavements can provide safe, durable, and low-noise surfaces when properly designed and constructed.
5. **How is tire/pavement noise impacted by surface texture?** Texture content of a pavement surface influences tire/pavement noise. Increased macrotexture with wavelengths of 2mm to 10mm has been shown to decrease exterior noise caused by tire/pavement interaction, while increased megatexture (wavelengths of 50mm to 500mm) content has been shown to increase interior noise in vehicles. It may be possible to reduce tire/pavement noise, while providing adequate wet pavement friction, by providing an optimized pavement texture that provides adequate

microtexture and macrotexture, while minimizing megatexture (particularly wavelengths of 50mm to 100mm), to provide a safe, durable, and quiet pavement surface. Methods used to provide macrotexture for concrete surfaces, such as transverse tining and others, also tend to impart some megatexture content. It is important to consider the impact on megatexture of methods to provide macrotexture.

6. **What is the recommended level of surface texture on high-speed (50 miles per hour (mph) or greater) facilities?** Providing adequate texture depth has been shown to improve pavement friction test results at high speeds and reduce crash rates on high speed facilities. Texture depth targets for new and in-service pavement surfaces should be established by owner-agencies based upon project-specific factors as described in paragraph 10. Findings in the references under paragraph 12 should be evaluated for relevancy when establishing texture threshold targets.
7. **What techniques will provide surface texture for concrete and asphalt pavements?**
    a. **Concrete surfaces**. A supplemental treatment is typically required to provide adequate macrotexture on concrete pavements. Paragraph 8 provides a summary of important research findings and recommendations relative to successful application of these texturing techniques. Cost-effectiveness should be assessed prior to specifying a specific texturing technique.

    (1) Tining, preceded by a burlap drag, has been shown to be a low-cost method for providing macrotexture to new concrete pavements. Spacing, depth, width, and orientation of the tine pattern have a significant influence on the friction and tire/surface noise characteristics of the completed surface.

    (2) Exposed aggregate surface has been shown to provide a lower noise surface for Portland Cement concrete (PCC) pavements. Texture depth, aggregate size, and durability of aggregate have a significant influence on the friction and tire/pavement noise characteristics of the completed exposed aggregate surface.

    (3) Broom or artificial turf drag finish for concrete surfaces is recommended for surfaces where the design speed is 50 mph or greater, provided adequate safety performance is demonstrated (see paragraph 11(b))

    (4) Diamond grooving has been shown to be an effective method for providing macrotexture to new concrete pavements. Spacing, depth, width, and orientation of the grooves have a significant influence on the friction and tire/surface noise characteristics of the completed surface.

    (5) Diamond grinding of new concrete pavements for the purpose of imparting macrotexture is recommended, provided adequate safety performance is demonstrated (see paragraph 11(b)) or non-polishing large aggregates are used.

    (6) Burlap drag surface texture should only be considered for surfaces where the design speed is less than 50 mph.

    (7) Other techniques may be utilized if research indicates long-term safety performance is achieved (see paragraph 11(b)).

    (8) The fine aggregate fraction of the aggregate concrete matrix provides microtexture. As such, the fine aggregate should be wear and polish resistant. A minimum 25% of the fine aggregate for concrete should be siliceous material. More information on concrete mix design is contained in FHWA Technical Advisory T 5080.17, dated July 14, 1994.

    (9) Thin asphalt overlays may be used to provide a surface on PCC pavement. Typically, asphalt surfaces include dense graded mixes, gap-graded mixes, and open graded asphalt friction courses. Paragraph 7(b) provides guidance on design of asphalt surfaces.

    b. **Asphalt surfaces**. Hot-mixed asphalt pavements designed in conformance with Superpave mix design will generally provide adequate macrotexture and microtexture without supplemental treatments. In areas where supplies of durable non-polishing aggregates are limited, an agency may choose to construct an asphalt pavement using high durability aggregates optimized for friction properties only in the top layer.

(1) **Asphalt surface course**

(a) Dense graded asphalt mixtures designed using appropriate material and design techniques as discussed below will typically provide adequate surface texture.

(b) Open Graded Friction Courses should be designed and constructed in conformance with FHWA Technical Advisory T 5040.31, dated December 26, 1990.

(c) Stone Matrix Asphalt Courses should be designed and constructed in conformance with American Association of State Highway and Transportation Officials (AASHTO) specifications MP8 and PP41.

(2) **Surface treatments and other methods**

(a) Asphalt-based surface treatments such as microsurfacing.

(b) Thin epoxy-bonded laminates.

(3) **Mix-related characteristics**

(a) Proper texture characteristics of asphalt surfaces are very much influenced by asphalt content, voids in the mineral aggregate, dust to binder ratio, and void content. Proper mix design, following Superpave procedures, should be performed to ensure the needed ratio of these elements. It is recommended that test procedures listed in AASHTO specifications PP28 and M323 be used in performing Superpave volumetric mix design.

(b) Surface characteristics of asphalt surfaces are also dependent on aggregate characteristics. This is particularly important after the surface is exposed to wear from traffic and weather conditions.

1. **Aggregate angularity.** Frictional resistance of the wearing course is improved when angular aggregates are used in the Hot Mix Asphalt (HMA) mixture. Increasing fractured faces of the coarse aggregate (reducing or eliminating rounded gravels) will improve stability of the HMA mix. Coarse aggregate angularity is defined as the percent by weight of aggregates larger than 4.75 mm with one or more fractured faces. Similar to coarse aggregates, performance is also related to the angularity of fine aggregates. It is recommended that the aggregate meet the requirements specified in AASHTO specification M323.

2. **Aggregate soundness.** Soundness is an indication of an aggregate's resistance to weathering. It is recommended that sodium or magnesium sulfate tests use the limits described in the AASHTO specification M 29. The recommended range for sodium sulfate soundness is 12-15% maximum and for magnesium sulfate soundness is 15-20% maximum for 5 cycles. Other methods may be used to characterize aggregate soundness.

3. **Aggregate toughness.** Toughness is an indication of an aggregate's resistance to abrasion and degradation during handling, construction, and in-service. It is recommended that specifications require toughness tests and tests should be performed in accordance with AASHTO specification T96. The recommended specification value for a Los Angeles abrasion loss ranges from 35 to 45 percent maximum. (Consideration should also be given to utilizing the Micro-Deval Abrasion Test (AASHTO specification TP58).)

4. **Polish resistance.** The use of aggregates that polish easily should be avoided. It is recommended that polishing resistance of aggregates be measured in the laboratory, prior to use. An appropriate test and value for the specific pavement should be established. A set of tests for evaluating aggregate polish value is Accelerated Polishing of Aggregates Using the British Wheel (AASHTO specification T-279) and Surface Frictional Properties Using the British Pendulum Tester (AASHTO specification T-278). AASHTO specification T-278 may also be used to evaluate the polishing condition (BPN) of pavement surfaces. Other methods may be used to characterize polish-resistance of aggregates.

8. **How is adequate texture provided on concrete pavements over the performance life of the pavement?** In order to provide the desired texture over the performance life of the pavement and minimize objectionable level of tire-pavement noise, the following techniques are recommended.
   a. **Transverse tining**

      (1) A width of 3mm (+/- 0.5mm) and a depth of 3mm maximum are recommended. Narrower, deeper grooves are better than wider, shallower grooves, within the limits indicated, for minimizing noise.

      (2) Random spacing of either 13mm or 26mm average tine spacing is recommended. The 13mm random tine spacing shall have the following tine pattern (in millimeters): 10/14/16/11/10/13/15/16/11/10/21/13/10. The 26mm random tine spacing shall have the following tine pattern (in millimeters): 24/27/23/31/21/34.

   b. **Longitudinal tining**

      (1) A width of 3mm (+/- 0.5mm) and a depth of 3mm maximum are recommended. Narrower, deeper grooves are better than wider, shallower grooves, within the limits indicated, for minimizing noise.

      (2) Straight, uniformly spaced grooves spaced at 19mm have been shown to provide adequate handling characteristics for small vehicles and motorcycles.

   c. **Exposed aggregate**

      (1) Exposed aggregate is normally constructed in two layers

      (2) The top layer consists of 30% siliceous sand of 0-1mm, and 70% high-quality chips of 4-8mm

      (3) A water-cement ratio of 0.38 maximum is recommended.

      (4) A mean texture depth of 0.7mm is recommended.

   d. **Diamond grinding.** Diamond grinding typically provides grooves of approximately 3mm width, spaced at 5-6 mm intervals. Specific groove depth and spacing is dependent on hardness of the aggregate.
   e. **Diamond grooving.** Diamond grooving, transverse and longitudinal, can provide adequate friction characteristics. Groove geometry should be consistent with recommendations for tining in paragraphs 8(a) and 8(b).
   f. **Burlap drag.** This is typically produced by trailing a moistened, course burlap from a construction bridge that spans the pavement. Striations of 1.5 - 3mm depth are typical.
   g. **Artificial turf drag.** This is typically produced by trailing an inverted section of artificial turf from a construction bridge that spans the pavement. Striations of 1.5 - 3mm depth are typical when using turf with 77,500 blades per m^2.
   h. **Transverse broom.** This is typically obtained using a hand broom or mechanical broom device that lightly drags stiff bristles across the surface. Striations of 1.5 - 3mm depth are typical
   i. **Other methods**

(1) Thin, epoxy-bonded laminates. Aggregates are typically 4-6mm.

(2) Asphalt-based surface treatments such as micro-surfacing.

9. **What techniques will restore desired surface texture to in-service pavement surfaces?** To restore adequate texture to an in-service pavement, the following techniques can be utilized in addition to overlays.
   a. **Restoration of concrete surfaces.** Restoration techniques have been shown to provide adequate friction characteristics. The rate of decrease in friction properties after treatment is typically dependent on the polish-resistance of the course aggregate.

      (1) Diamond grinding has been shown to restore frictional characteristics of concrete pavement for 8-10 years.

      (2) Transverse or longitudinal diamond grooving can provide adequate friction. However, random spacing is recommended to provide adequate noise performance.

      (3) Other methods

         (a) Thin overlays of asphalt such as dense graded asphalt and open graded friction courses or thin concrete overlays can be used to restore friction to concrete pavements.

         (b)Asphalt-based surface treatments such as micro-surfacing.

         (c)Thin, epoxy-bonded laminates.

   b. **Restoration of asphalt surface.** The most common techniques for restoration of adequate surface texture on hot mix asphalt pavement are surface treatments or thin asphalt overlays. See paragraph 7(b) for mixture and aggregate recommendations. Concrete overlays may also be considered to restore adequate surface texture on asphalt pavements.

10. **What factors should be considered when selecting pavement surface techniques or thresholds?** The selection of the surface texture type to be provided at a specific location should be based upon existing conditions at that site. When selecting a texturing method or establishing a threshold value for a friction-related parameter, an agency should consider many factors including splash and spray, climate, traffic, speed, geometry, conflicting movements, materials and costs, and presence of noise sensitive receptors. Due to widely varying conditions at individual project locations, it is unlikely that one surface type or texturing method will always be the best choice for all projects within a State or jurisdiction. References in paragraph 12 should be evaluated for current reported US and international texture or friction-test targets.
    a. **Splash and spray.** Reduced visibility caused by splash and spray may increase the probability of wet-weather crashes. Adequate pavement cross-slope or use of porous surfaces will provide surface drainage and has been shown to reduce splash and spray.
    b. **Climate.** An increased probability of wet-weather conditions would justify a higher level of texture or higher threshold value for a friction-related parameter. Research in Sweden concluded that, for worn pavements, crash rates increase on days with rainfall of 10mm or greater.
    c. **Traffic volume and composition**. Pavements with higher traffic volumes would justify a higher level of texture or higher threshold value for a friction-related parameter. Increased traffic would decrease the reaction/recovery time in the event of loss of control of a vehicle. Facilities with higher volumes of passenger cars will realize greater benefits of low-noise pavement characteristics than facilities with higher truck volumes.
    d. **Speed limit.** Higher speed facilities may justify a higher level of texture or higher threshold value for a friction-related parameter. Friction test results will decrease with increasing speed, reaching a minimum at approximately 60 mph. Friction on surfaces with low texture falls more rapidly with speed than on high textured surfaces.
    e. **Roadway geometry.** Curves may justify a higher level of texture or higher threshold value for a friction-related parameter. Research in France and Great Britain has shown that curves with a radius of curvature less than 500 m have significantly higher crash rates.

f. **Potential conflicting movements or maneuvers (frictional demand).** Intersections and presence of pedestrians will justify a higher level of texture or higher threshold value for a friction-related parameter. Intersections and pedestrians will increase the likelihood of sudden braking movements.
g. **Materials quality and cost.** The availability and cost of high-quality durable, non-polishing materials will influence the choice of materials and techniques to provide friction.
h. **Presence of noise-sensitive receptors.** A pavement located near a school, hospital, or other noise-sensitive receptor may justify a higher consideration of noise effects when selecting the appropriate surface treatment for a pavement.

11. **What factors should be considered when evaluating new or innovative texturing methods for concrete pavement?**
    a. The primary purpose of adequate surface texture is to reduce wet-weather and total vehicle crashes. Where a State Highway Agency (SHA) has time-history data to show a specific surface treatment or texturing method results in similar or improved safety performance compared to transverse tining texture, the proposed method should be allowed.
    b. **Safety performance.** Safety performance shall be based upon long-term performance monitoring of either wet-weather crash performance or friction test results. In the absence of long-term safety performance data for alternate texturing methods or treatments, alternative methods may be used on an experimental basis provided safety performance is monitored and reported. This approach may also be utilized to evaluate the impact of changes to asphalt pavement surfaces on pavement safety performance.

    (1) **Wet weather crash performance.** Reduced wet-weather and/or total vehicle crash rates at the same or similar locations.

    (2) **Friction test results.** Similar or improved friction test results and speed gradient when tested in conformance with American Society for Testing and Materials (ASTM) E-274 (skid trailer) using the smooth tire (ASTM E-524), or International Friction Index (IFI) ASTM E-1960.

12. **Are there any reference materials on pavement surface texture/friction?** Yes. The following references apply to pavement texture and friction.

a. P.G. Poe, A.R. Parry, and H.E. Viner, "High and Low Speed Skidding Resistance: The Influence of Texture Depth," TRL367, Transport Research Laboratory, Wokingham, UK, 1998
b. P.G. Poe, D.C. Webster, and G. West, "The Relation Between Surface Texture of Roads and Accidents," Research Report RR296, Transport Research Laboratory, Wokingham, UK, 1991.
c. J. Nichols and D. Dash, "Australian Developments to Reduce Road Traffic Noise on Concrete Pavement," 5th International Conference on Concrete Pavement Design and Rehabilitation, Purdue University, April 1993, Volume 2, pages 99-106.
d. A.P. Hewitt, P.G. Abbott, and P.M. Nelson, "Alternative Textures for Concrete Roads: Results of M18 and A50 Trials," TRL291, Transport Research Laboratory, Wokingham, UK, 1997.
e. B. Hibbs and R. Larson, "Tire Pavement Noise and Safety Performance: PCC Surface Texture Technical Working Group," FHWA-SA-96-068, Federal Highway Administration, Washington, DC, 1996.
f. P. Wetling, "Relationship Between the Functional Properties of Road Surface and Traffic Safety: A State-of-the-Art Report," Swedish National Road and Transport Research Institute, Linkoping, Sweden, April, 1996.
g. World Road Association (PIARC), "Report of the Committee on Surface Characteristics," XVIII World Road Congress, Brussels, Belgium, 1987.
h. J.J. Henry, "Evaluation of Pavement Friction Characteristics," NCHRP Synthesis 291, Transportation Research Board, Washington, DC, 2000.
i. S. Rao, H.T. Yu, L. Khazanovich, M. Darter, and J. Mack, "Longevity of Diamond-Ground Concrete Pavements," Transportation Research Board, Washington DC, 1999.
j. D.A. Kuemmel, R.C. Sonntag, J.A. Crovetti, Y. Becker, J.R. Jaekel, A. Satanovsky, "Noise and Texture on PCC Pavements - Results from a Multi-State Study," SPR 0092-45-91, Wisconsin DOT, Madison, WI, 2000.

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