Concrete Pavement Specifications for Reducing Tire-Pavement Noise

Concrete Pavement Surface Characteristics Program

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Introduction

With the goal of providing concrete paving solutions that are safe, comfortable, durable, and cost effective, numerous forms of guidance have been developed under the Concrete Pavement Surface Characteristics Program (CPSCP).

Part of the guidance developed includes specifications to improve pavement surfaces by reducing tire-pavement noise. This Tech Brief summarizes the various specifications that have been developed. Copies of the final specifications are accessible on the National Concrete Pavement Technology Center (National CP Tech Center) website at www.cptechcenter.org.

Summary

Two very different approaches have been adopted in developing guide specifications for reducing tire-pavement noise.

Methods (prescriptive) specifications – Four guide specifications (GS-1 through GS-4) have been developed that correspond to the four most commonly used concrete pavement textures: diamond grinding, drag (artificial turf), longitudinal tining, and transverse tining. The practices described in the specifications have been demonstrated to increase the likelihood of constructing a durable, quieter concrete surface. Central to the specification is guidance for texturing the concrete surface, given that texture geometry has a paramount effect on tire-pavement noise. Guidance is also provided for curing to improve strength and durability of the surface, and thereby improve texture durability.

End-result specifications – A recommended practice (PP-1) has been developed that includes guidance and sample specification language for owner-agencies to evaluate tire-pavement noise of new concrete pavement surfaces. The overall sound intensity level measured

Concrete pavement placement

with the on-board sound intensity (OBSI) test method is designated as the quality characteristic.

While these practices were developed with the intent for use in their entirety, some benefit is possible with partial implementation. Measures should be taken to ensure that implementation is compatible with the friction design policy of the owner-agency. Also recognize, these two types of specifications cannot both be implemented at the same time on the same project. Many aspects of prescriptive specifications conflict with end-result or performance specifications.

CPSCP Specification GS-1 – Diamond Grinding

Diamond grinding has been identified as one of the best options for achieving a quieter concrete pavement. Diamond grinding can be used to texture newly-constructed concrete or to reduce the tire-pavement noise level of an existing concrete pavement surface.

To increase the probability of achieving a quieter surface, the grinding equipment must be a minimum of 35,000 lbs, provide a minimum grinding width of 4 ft, and have a positive means of vacuuming grinding residue. The equipment must also be capable of performing the intended work without causing spalling, raveling, aggregate fractures, or excessive disturbance to the joints, cracks, and other locations. In addition to the equipment being in proper working order, a particular emphasis is given to the runout (roundness) of the match and depth control wheels. Even small deviations in these wheels can introduce unwanted texture in the pavement surface that can lead to an increase in tire-pavement noise.

The construction specifications describe a final pavement surface that must be true to grade and uniform in appearance as a longitudinal-type texture. Successive passes of the grinder must not lead to excessive height differentials, overlap, or holidays (gaps of unground texture). A 12 ft straightedge is used to control the surface, and corrective work is specified if the tolerances are exceeded.

When texturing newly-constructed concrete pavement, diamond grinding is specified to not begin until the concrete has attained sufficient strength to be opened to all types of traffic. Curing compound must be re-applied after grinding if within three days of pavement placement. When diamond grinding an existing concrete pavement, it is specified that concrete pavement preservation activities, except for joint sealing, be completed prior to any diamond grinding.

Regarding the management of grinding residue, Best Management Practices are available from the International Grooving and Grinding Association (IGGA).

Diamond grinding should produce a neat, uniform finished surface. The peaks of the lands should be approximately 1/8 in. higher than the bottoms of the grooves, and the grooves should be evenly spaced. The width of the lands will be determined by the width of the spacers used between the saw blades. The most appropriate combination of saw blade and spacer types and thicknesses should be based on experience (guidance is provided for typical parameters). When diamond grinding newly-constructed concrete pavement, a minimum of 98 percent of the pavement surface must be textured; existing pavements should have a specified minimum of 95 percent.

It is recommended that the American Association of State Highway and Transportation Officials (AASHTO) Standard Practice R 54-10, "Accepting Pavement Ride Quality When Measured Using Inertial Profiling Systems," be considered with a maximum International Roughness Index (IRI) of 65 in./mi. If an inertial profiler is specified for measurement, a line laser (or other wide-footprint sensor) should be used for the height sensor. A single-point laser should not be used, because it can introduce measurement artifacts (error).

Diamond-ground pavement

CPSCP Specification GS-2 – Artificial Turf Drag

Drag textures using artificial turf represent another alternative with an excellent probability of achieving a quieter concrete pavement. To achieve this, final texturing should be completed as soon as possible after finishing, but before the concrete has attained its initial set.

To assure uniformity, the turf must be mounted on a work bridge or a movable support system that allows for adjustment of the area of turf in contact with the pavement. A single piece of turf spanning the full width of the pavement must be used. To achieve the desired texture, a minimum length of 5 ft of turf must be in contact with the concrete at all times.

Turf is artificial grass, which comes in many types. For this specification, the material must be strong, durable, and not subject to rot. It must have a molded polyethylene pile face with 0.6 to 1.3 in. long curled and/or fibrillated blades (no straight, smooth monofilament blades). The minimum weight of the turf material is 60 oz/yd^2.

Turf dragging operations should be delayed if there is excessive bleed water. Furthermore, measures must be taken to prevent the turf from getting plugged with grout or dragging larger aggregates through the pavement surface. Turf should be cleaned or replaced as needed to ensure a surface of uniform appearance and free from deep striations.

To assure that adequate texture has been achieved, either Mean Texture Depth (MTD) per ASTM E965 or the Estimated Texture Depth (ETD) calculated from the Mean Profile Depth (MPD) per ASTM E1845 can be used. Verification testing is conducted after the concrete has hardened sufficiently at points located in the outside wheel path. Excessive curing compound may affect the results, so the surface can be brushed prior to testing. The current specification recommends that the running average of three sequential test results result in a texture depth of no less than 0.03 in.

CPSCP Specifications GS-3 and GS-4 – Longitudinal and Transverse Tining

Both longitudinal and transverse tining are routinely used by owner-agencies, particularly for high-speed facilities. Achieving a quieter concrete surface is possible, but requires additional control, particularly for transverse tining, which is often associated with some of the loudest concrete pavements.

When specifying both longitudinal and transverse tining, texturing should be applied as soon as possible after finishing, and before the concrete has attained its initial set. This is accomplished by applying a drag pre-texture followed by subsequent tining.

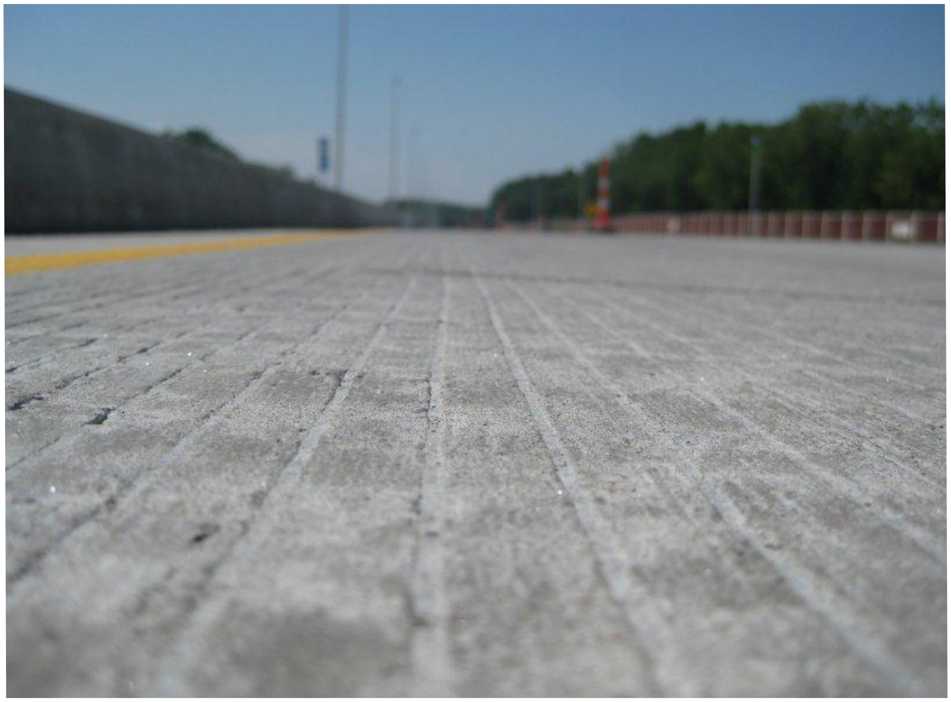
Drag Pretexture

To create needed texture on the lands (the areas between the tined grooves), artificial turf or burlap must be dragged longitudinally along the concrete pavement surface after finishing. The turf or burlap must be mounted on a work bridge or a movable support system that allows the area of turf or burlap in contact with the pavement to be modified.

A single piece of turf or burlap drag is used that spans the full width of the pavement. A minimum of 4 ft of drag material must be in contact with the concrete being placed. This is slightly less than the requirement for the drag texture described in GS-2, because the tining process will provide additional texture in this instance.

If a turf material is used for the drag, the material should meet the same standards as described previously in GS-2. If burlap is used instead, it must meet the Class 3 or Class 4 requirements of AASHTO M 182, "Standard Specification for Burlap Cloth Made from Jute or Kenaf." In this case, too, the trailing end of the burlap that is in contact with the concrete

Turf drag texture



Longitudinal tining

surface must be frayed by removing yarns perpendicular to the direction of paving. The resulting burlap frays must be 2 to 6 in. long, and uniform in length across the width of the pavement.

If there is excessive bleed water, turf or burlap dragging operations should be delayed. Measures must be taken to assure that the drag material does not get plugged with grout or begin to drag larger aggregates. The drag pretexture should result in a uniform surface that is free from deep striations.

Tining

When using tined textures, grooves are imparted in the surface of a pavement while the concrete is plastic. This can be done either longitudinally (as specified in CPSCP GS-3) or transversely (as specified in CPSCP GS-4). Tining must be done with a mechanical device, such as a wire comb with a single row of tines, each nominally 5/64 to 1/8 in. wide. For longitudinal tining, the nominal spacing of the tines is 3/4 in. For transverse tining, nominal spacing of 1/2 in. is specified. The nominal depth of the tined grooves in the plastic concrete is 1/8 in.

Longitudinal tining must use equipment that has automated horizontal and vertical controls to ensure straight tined grooves with a uniform depth. For transverse tining, the texture must be uniform across the width of the comb, and between successive passes of the comb. Furthermore, successive passes of the comb must only be overlapped by the minimum necessary to achieve a continuously-textured surface.

The timing of the tining operation is important. Tining must be performed such that the intended surface texture geometry is imparted. The tining operation must minimize displacement of the larger aggregate particles and, of course, be conducted before the surface permanently sets.

Tines should be thoroughly cleaned at the end of each day's use and damaged or worn tines replaced as needed.

Curing Specifications

For both drag (CPSCP GS-2) and tined textures (CPSCP GS-3 and GS-4), the protection of the concrete surface is of paramount importance. Unless proper methods of curing are adopted, the texture can deteriorate prematurely under the influences of traffic and climate.

To control this, curing should begin immediately following the texture operation by spraying the concrete surface uniformly with two coats of membrane curing compound at an individual application rate not to exceed 180 ft^2/gal. If the evaporation rate during paving operations does not exceed 0.1 lb/ft^2/hr, only one coat of membrane curing compound at an individual application rate not to exceed 180 ft^2/gal is allowed.

It is important not to allow the concrete surface to dry before the curing compound is applied. Standing pools of bleed water that are present on the surface should be removed before applying the curing compound. The first coat of curing compound must be applied within 10 minutes after completing texturing operations and, if applicable, the second coat applied within 30 minutes.

The evaporation rates cited in the specification should be evaluated using the Menzel nomograph or its underlying equations. For more information, refer to the American Concrete Institute® (ACI) 308R-01 "Guide to Curing Concrete," available at www.concrete.org.

It is important that the curing materials be properly maintained, and any damage promptly repaired. This should be done for at least three curing days, or until the pavement is open to the traveling public, whichever occurs first.

CPSCP Recommended Practice PP-1 – Accepting New Concrete Pavement Surfaces for Tire-Pavement Noise

A recommended practice was developed that is intended to facilitate the adoption of an end-result specification for tire-pavement noise. The trend to use end-result type specifications is recognized. However, by simply adopting better practices, it is highly likely that a quieter concrete pavement will be constructed. The methods specifications highlighted in this Tech Brief can be used to encourage adoption of these better practices, which make an end-result specification unnecessary.

That said, if this practice is to be adopted, a critical first step is to minimize (or eliminate) the use of prescriptive language that describes how the surface texture is to be imparted. This language could be in direct conflict with the intent of the end-result specification to encourage innovation and an emphasis on quality control.

At the core of this practice is the evaluation of tire-pavement noise, with the overall sound intensity level designated as the quality characteristic used for pay adjustment. A quality assurance model has been adopted, based in part on the recently adopted AASHTO Standard Practice R 54-10, "Accepting Pavement Ride Quality When Measured Using Inertial Profiler Systems."

Measurement Method

Overall sound intensity level is measured using on-board sound intensity (OBSI) in general conformance with AASHTO TP 76. Prior to testing, the concrete surface should be cleaned, and the contractor permitted to operate construction traffic on the surface to further condition the surface.

Because OBSI measurements are still a relatively new test method, the recommended practice describes quality controls for both equipment and operators. For example, systems should be demonstrated through comparative testing as sanctioned by the Tire/Pavement Noise Research Consortium, TPF-5(135), or the Tire/Pavement Noise Technical Working Group, sponsored by the Federal Highway Administration (FHWA) Office of Pavement Technology. Qualified operators must also participate in these activities and meet the education and experience requirements for becoming a full member of the Institute of Noise Control Engineering of the USA (INCE/USA).

OBSI microphones

CPSCP PP-1 recommends 528 ft test segments; however, owner-agencies can adopt other lengths that are more compatible with their existing standards and practices. Gaps between test segments are permitted to avoid structures, manhole covers, utility covers, and areas of pavement that do not comply with the criteria for valid testing per AASHTO TP 76 (including steep grades).

Pavement with cure applied

Quality Assurance Process

The recommended practice includes four types of testing:

- Quality control (QC)
- Acceptance
- Verification
- Independent Assurance (IA)

QC testing is conducted by the contractor per an approved QC plan. Testing can be conducted using OBSI measurements or via pavement texture measurements using a relationship that is provided and demonstrates a proven relationship between texture and tire-pavement noise evaluated using OBSI. The correlation must be developed and documented from data measured on concrete pavements of the same nominal texture type (such as diamond grinding or longitudinal tining). The as-predicted OBSI level (using texture measurements) versus the as-measured OBSI level must have a standard error of no greater than 1.2 dBA.

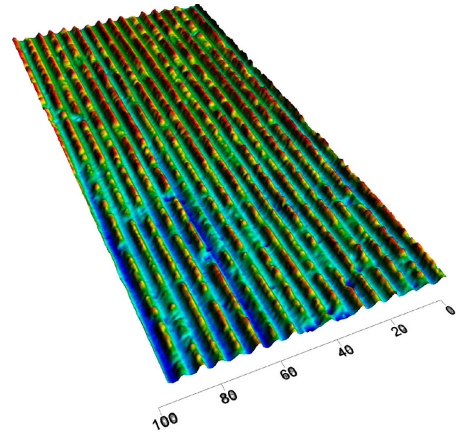
Acceptance testing is also conducted by the contractor, but it is necessary in this case to use the OBSI method. Testing is conducted on the surface of the completed project, or at the completion of a major stage of construction. Ideally, a standard test speed of 60 mph should be used, but other speeds are permissible. Given the sensitivity of OBSI level versus speed, pay factors and other limiting values must be selected to correspond with the test speed that is used.

Verification testing can be conducted by the owner-agency as desired. If the verification testing demonstrates an overall sound intensity level greater than 3.0 dBA different from Acceptance testing, the differences should be resolved to a mutual satisfaction.

Independent Assurance (IA) testing is specified if differences cannot be resolved. This testing is conducted by an operator with a higher order of qualifications. Comparisons are made to both the Acceptance and Verification test results to determine the validity of each. If the overall sound intensity level is within 1.5 dBA of the IA testing, the test results are confirmed valid.

Pay Adjustments

While not a required feature, a pay adjustment schedule is provided in the recommended practice. A target set of OBSI sound intensity level limits is provided, for which a corresponding pay adjustment can be determined. Incentive is offered for constructing quieter sections, and disincentive for louder sections. Table 1 shows just one possible example of a pay adjustment schedule. In this table, overall sound intensity level limits and pay adjustment factors should be selected based on the specific project requirements and the specific test speed that is used on the project. The final pay factor is determined by taking the values in column 2 and multiplying them by column 3. The results are shown in column 4, which are then summed and divided by 100 to obtain the Final Pay Factor (incentive or disincentive).



Correlation of pavement texture with OBSI levels

The pay adjustment schedule is flexible and can be modified in a variety of ways. The number of OBSI limit steps and their ranges are adjustable (column 1), as well as the scale of the pay adjustment factors (column 2). This allows flexibility in targeting specific noise ranges that may vary by agency, region, and road design. It allows flexibility in setting the priority of noise performance for the specific project.

Table 1. Sample pay adjustment schedule

Overall Sound Intensity Level Limit for Testing at 60 mph (dBA) (1)	Pay Adjustment Factor (2)	Percentage of Test Segments within Overall Sound Intensity Level Limit (%) (3)	Pay Adjustment (4)
<102.0	1.##	#.#	##.#
102.0-103.9	1.00	#.#	##.#
104.0-106.0	0.##	#.#	##.#
>106.0	0.##	#.#	##.#
Final Pay Factor (PF)=Sum of Column (4)/100=#.### or 0.###			

Deficiencies and Corrective Action

For test segments designated as defective segments, corrective actions can be recommended. A plan should be developed that identifies the methodology to identify and correct defective segments. Corrective action should be done with the purpose of correcting the pavement surface to decrease the tire-pavement noise level to acceptable limits. Diamond grinding is an example of a commonly-accepted methodology.

Recommendations for Implementation

To implement the practices summarized in this Tech Brief, use of a stepwise sequence is recommended.

Phase 1A: Develop a "shadow" specification—Specific language should be developed for a specification that is compatible with existing specifications and standard practices of the owner-agency. As such, a review of existing concrete pavement texture specifications is warranted. Regardless of which type of specification is being considered for adoption, it should be noted that prescriptive language will likely conflict with an end-result specification, and measures should be taken to modify or eliminate existing language as needed.

As a best management practice (BMP), a shadow specification (and any requisite changes to existing standards) should be developed through a cooperative effort with the owner-agency and industry stakeholders, such as local representatives of the American Concrete Pavement Association (ACPA). If the end-result approach is adopted, another BMP is to begin implementation with relatively small deviations from a pay factor of 1.0. For example, extreme pay factors could initially be established at 1.05 and 0.95, respectively.

Phase 1B: Field trial of the "shadow" specification—A field trial of the shadow specification should include use on a job that would be typical for more widespread implementation. All aspects of the specification should be in force, except for any relevant provisions of independent assurance, pay adjustments, and/or corrective action. From this field trial, a report should be prepared by the owner-agency that documents the test methods and test results. If relevant, and while not in force, instances that could have required Independent Assurance (IA) testing should be documented, as well as the pay adjustments and/or corrective actions that would have been applied.

Phase 2: Special provision—Based on the outcome of the shadow specification field trial, revisions should be made as appropriate to the specification language. A special provision should be developed that is gradually implemented on projects that are typical for more widespread implementation. Early projects should be closely monitored, and additional revisions to the special provisions made as needed to reflect the lessons learned. If relevant, specific changes could include modifications to the pay adjustment schedule.

Phase 3: Standard practice—As the specification matures during subsequent field trials, it can subsequently be adopted as a standard practice, along with requisite changes to other aspects of the concrete pavement texturing standards to ensure compatibility.

For More Information

- American Association of State Highway and Transportation Officials, "Standard Method of Test for Measurement of Tire/ Pavement Noise using the On-Board Sound Intensity (OBSI) Method," AASHTO Specification TP 76-10, 2010.
- Institute of Noise Control Engineering of the USA. 1 Jan. 2011. http://www.inceusa.org
- Robert O. Rasmussen, et al., "How to Reduce Tire-Pavement Noise: Better Practices for Constructing and Texturing Concrete Pavement Surfaces," National Concrete Pavement Technology Center, Ames, Iowa, 2011.
- Tire/Pavement Noise Research Consortium, "Questions and Answers about Quieter Pavements," Transportation Pooled Fund TPF-5(135), January 2011.

About the Concrete Pavement Surface Characteristics Program

In December 2004, a coalition was formed between the National Concrete Pavement Technology Center (National CP Tech Center), the Federal Highway Administration (FHWA), the American Concrete Pavement Association (ACPA), and the International Grooving and Grinding Association (IGGA).

The mission of the program was to help optimize concrete pavement surface characteristics—more specifically, it was to find innovative solutions to make concrete pavements quieter without compromising safety, durability, or cost effectiveness.

The current program is now operating under Pooled Fund TPF-5(139) with the additional support of state Departments of Transportation (DOTs), including California, Iowa, Minnesota, New York, Texas, Washington, and Wisconsin.

Recent focus is on identifying specific guidance to properly design and construct quieter concrete pavements. Innovative concrete pavement surfaces are also being evaluated to assess their potential as viable solutions.

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