SUMMARY AND EVALUATION OF CONCRETE PAVEMENT TEXTURING PRACTICES

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Introduction

Water on the pavement is one of the major causes of highway accidents. It induces hydroplaning, reduces skid resistance, and adversely affects vehicle control. Modern high speed traffic challenges the highway engineer to provide immediate drainage at the tire-pavement interface for rapid removal of pavement surface water during rainy weather.

Proper texturing of concrete pavement for good drainage is one of many elements that need to be recognized in providing and maintaining a safe highway.

Brief descriptions of several texturing methods which have or are being used by several States in the United States are presented. The policy and/or guidelines of American Concrete Paving Association, Portland Cement Association, Federal Highway Administration and American Association of State Highway and Transportation Officials on texturing of portland cement concrete pavement are also given. Findings and conclusions are then summarized to give an up-to-date view of texturing practices.

Texturing of Concrete Pavements in Various States Throughout the U.S.

Arizona placed nine experimental surface texture sections on I-17 in 1973. They consisted of normal burlap drag (longitudinal); 4 ply, 10 oz. burlap drag (longitudinal); 4 ply, 10 oz. burlap drag, threads removed (longitudinal); burlap drag with nails (longitudinal); wire broom (longitudinal); fluted float (longitudinal); fluted float (transverse); burlap drag with nails (transverse); and wire broom (transverse). All burlap drag textures tested produced poor, non-uniform finishes that were significantly less durable than other textures tested. For this reason, the final report suggested that burlap drag texture not be used in the future. When comparing the transverse and longitudinal textures for any particular surface type, it was seen in general that the longitudinal textures had the higher friction levels and the lowest percentage decrease. The reason for this is that the test area receives heavy snowplow and ice removal operations and the transverse textures are being worn away at a rapid rate in comparison to the longitudinal textures which yield little resistance to the snowplow blades. It should be noted, however, that all transverse textures (fluted float, burlap drag with nails, and wire broom) have very little land area to resist the perpendicular movement of the snowplow. Another result from these sections showed that differential friction (at both high and low friction levels) can cause an extremely hazardous condition for a braking vehicle. This is all the more reason for consistency in construction and maintenance techniques.

Arkansas first initiated transverse tine texturing by change order (at a cost of $0.15/S.Y.) on a project near Searcy, Arkansas, on U.S. 67. Special provisions required the tines to be approximately .032 by .083 inch steel flat wire, 4 to 5 inches in length, spaced on 1/2 inch centers. The

groove produced in the concrete was from 1/8 to 3/16 inches in depth. The State has changed to the tine texturing on two major projects and is considering changing to this texture for pavements in the future if results are as expected.

California completed a study in 1975 of longitudinally grooved PCC pavement. A "before and after" technique was used to evaluate 322 lane-miles of grooved pavement on State freeways in Los Angeles. In addition, 750 lane-miles of ungrooved PCC pavement were used as a "control". Accidents (fatal and injury only) were evaluated for a two-year before and after period on both the grooved and ungrooved sections of freeway. Grooving produced an average 69 percent reduction in wet pavement accident rates on the 23 projects studied. Dry pavement accident rates did not change. There was no indication from the data that grooving causes motorcycle accidents. There were five wet pavement motorcycle accidents during the before period and two during the after period on the grooved sections. There were 114 dry pavement motorcycle accidents before grooving and 102 after. A few years ago grooves cut with 1/4 inch wide blades caused riding discomfort to motorcyclists and small car drivers. To remedy this, California settled on grooving blades 0.095 inch wide spaced 3/4 inch on centers. The grooves shall be cut from 1/8 to 3/16 inch deep. Recently, the State has used longitudinal tine texturing in their finishing operations with very little increase in cost. In addition to using a burlap drag initially, final texturing shall be done with a spring steel tine device which will produce grooves parallel to the centerline. The tines are rectangular in cross section, 0.10 inch wide on 3/4 inch centers, 3-1/2 to 5 inches long, capable of producing grooves 1/8 to 3/16 inches deep in the finished pavement.

The State of Florida and the Ballenger Corporation jointly evaluated transverse broom and steel tine texturing methods. As the texturing machine cost approximately $20,000 and can be used to apply curing compound and to carry a roll of polyethylene which covers 1,000 feet of slab, the contractor agreed to use it at no increase in cost. The nylon bristle broom with coarse bristles did not differ too much from the burlap drag method and a uniform surface finish was not evident. The steel comb finish had tines .03 by .08 inch in cross section spaced at one-half inch. The depth of the grooves produced was approximately 1/8 inch. Texturing with the steel comb could be made with one pass, was more uniform, and appeared more durable. As a result of this early work, Florida now specifies a transverse tine texture with tines spaced at one-half inch.

Georgia did extensive research by constructing and texting several surfaces on I-20 approximately 100 miles east of Atlanta. Their work compared various burlap and broom finishes with plastic grooved surfaces. Skid resistance, serviceability, and vehicle noise were the main criteria for the evaluation. Surfaces tested were ordinary burlap with grout build-up, steel comb 1/4 inch spacing, steel comb 1/2 inch spacing, clean burlap finish 17 oz. 3 ply, and smooth transverse broom finish. Textures produced with the steel comb, and especially those with 1/2 inch groove spacing, were more durable because of the surface wear necessary to obliterate them. Plastic grooved surfaces provided the greatest skid resistance and the difference became more pronounced at high speed. The 1/4 inch groove spacing offered slightly better initial skid resistance than the 1/2 inch groove spacing, but the rate of decrease in skid resistance with service offset this advantage causing the 1/2 inch groove spacing to be preferred. There was about a 4 db increase in "A" scale noise produced by tire-pavement interaction on plastic grooved finishes over that produced on burlap finishes. When combined with engine and vehicular noise other than noise from tire-pavement interaction, the 4 db (A) difference in texture noise was less prominent. The serviceability was not significantly reduced by the grooved finishes evaluated. It was concluded from the study that a plastic grooved surface finish can be

constructed which will provide increased skid resistance with no reduction in serviceability and no significant increase in vehicle noise. Georgia now specifies a 1/2 inch plastic grooved transverse steel tine finish on all PCC pavements.

In Louisiana where rainfall intensity often approaches 2.76 inches per hour, a major roadway concern is hydroplaning. To help alleviate the problem, the State adopted transverse tine texturing. The texturing machine uses spring steel tines 4 inches long, spaced approximately 1/2 inch apart, 1/8 inch in diameter producing a depth of 1/8 to 3/16 inch. A burlap drag preceding the transverse tine grooves is required. A major difficulty is the training of field personnel in the techniques of texturing with the steel tines and the inspection of the results. Care must be taken in the determination of when the pavement is ready to be textured. When field personnel become experienced with the method, the desired uniform texture can be achieved. Also, care must be taken not to overlap the strokes made by the comb. This overlapping will produce a weak surface area of thin strips of concrete than can easily be broken away with wear. To prevent this from occurring, it would be better to leave an inch or more gap between strokes. Correction of minor mistakes in surface texturing is impractical and may do more damage than good. If the texture must be corrected, it is better to refinish the surface with the screed and apply the tine comb again than to attempt corrections. Louisiana uses safety grooving on their existing pavements - longitudinally cut .095 inches wide and spaced at 3/4 inch centers. Due to rain intensity, the depth is specified not less than 3/16 inch nor more than 5/16 inch. Studies in California had shown that increasing the depth to 1/4 inch resulted in 50 percent more wear for only a 20 percent increase in cost. Grooving in Louisiana averages about $1.10 per square yard.

New Jersey had an experimental project where they used wire tine constructed with wire tape 0.017 x 0.059 inches wide and projecting 4-1/2 inches from the broom head. These tines were spaced on 1/4 inch centers. Early in 1975, the State modified their standard specifications to require the final finish on PCC pavement be achieved through the use of a wire brush finishing process (similar to the experimental project except that the spacing would be 1/2 inch instead of 1/4 inch). It was anticipated that the change would not increase construction costs.

New York found that textures produced with a wire broom and a fluted magnesium float were generally equivalent in both mean texture depth and initial skid resistance at 40 and 55 mph. Wire brooming and the fluted float surface were superior to those produced by natural bristle brooming or burlap dragging. Considering noise, the texture produced by the fluted float generated no more sound and possibly less than those produced by conventional methods.

Recommendations grew out of a study of 18 Texas highway test sections. The study sought answers to questions about the depth, type, and direction of concrete pavement finishes in relation to safety, durability, changes under traffic loads, and construction costs. The study concluded that: (1) Texture depths deeper than those presently required could be constructured easily and economically in either a longitudinal or transverse direction; (2) all textures - burlap, broom, or metal tine - wear between 25 and 35 percent initially and then abrasion levels off; (3) vehicle speed, more than any other factor, influences skid performance of a concrete pavement; but (4) deep transverse tine texturing permits the greatest improvement in skid values. Texas has now implemented transverse tine texturing in their construction projects.

The State of Virginia has done extensive work experimenting with different types of PCC pavement textures. Ten textures were used on International Terminal Boulevard in Norfolk on a project in 1972. The ten, in order of giving the best skid resistance, were as follows: (1) 3/4 inch longitudinal tines plus 1 1/2 inch transverse tines;

(2) 3/4 inch transverse tines; (3) 3/4 inch longitudinal tines plus 3 inch transverse tines; (4) 1 1/2 inch transverse tines; (5) sprinkled aggregate; (6) 3 inch transverse tines; (7) washed mortar; (8) 3/4 inch longitudinal tines; (9) dimpled (imprinted); and (10) burlapped. It was interestingly noted that during a steady rain the transverse texture provided excellent drainage such that the pavement appeared dry when compared to the longitudinal texture which still had water on the surface. Virginia found that there were two major areas of concern when designing pavements that would provide enough tire-pavement friction to assure vehicle stability. The first was to fabricate the surface with polish resistant materials so that sufficient friction could be maintained between the tire and pavement surface when thin films of water were present. The second concern was to provide sufficient means for water drainage so that only thin films of water would be encountered. The tire used in ASTM Test Method E274-70 has good tread and provides channels for water passage, but was found inadequate for evaluating the capacity of the pavement surface to provide drainage. To handle this problem, the State performed skid tests with two types of tires--treaded for the evaluation of the aggregates potential for providing skid resistance, and bald or untreaded tires for the evaluation of the surface drainage potential.

When considering noise and roughness, Virginia found that certain textures were objectionable. For trucks and busses, the engine and exhaust noise completely masked tire-pavement noise such that no effect of pavement texture was discernible during roadside observations; for automobiles, while most of the experimental textures were louder than the 3/4 inch longitudinal tined texture, only the sprinkled texture was considered objectionable. During in-the-car observations, the sprinkled, dimpled, and 1 1/2 inch transverse tined texture produced discernibly more intense noise, but only the 1 1/2 inch tined texture was considered objectionable. The sprinkled aggregate texture was the only texture considered undesirable for roughness. With the 1 1/2 inch tined texture being too noisy and the sprinkled aggregate texture being both too noisy and too rough, the two most desirable surfaces tested in Virginia were the 3/4 inch transverse tines and the 3/4 inch longitudinal plus 3 inch transverse tines. Both of these surfaces provide channels for lateral runoff, while the latter also has been credited with providing lateral stability on curves. With the 3/4 inch transverse tines providing the most channels for lateral runoff, it might be that it would be desirable to employ it on tangents and the 3/4 inch longitudinal plus 3 inch transverse tine finish on curves. It was also noted during the study that it took more curing compound and more paint for striping on the tined surface, but the tined surfaces were more durable due to greater land area and in turn showed little signs of wear.

Policy and/or Guidelines of ACPA, PCA, FHWA, and AASHTO on Texturing of PCC Pavement

The American Concrete Paving Association and the Portland Cement Association recommended a minimum average texture depth of 0.020 inches for new pavements in 1969. In March of 1975, the American Concrete Paving Association published a "Guideline for Texturing of Portland Cement Concrete Highway Pavements." The American Concrete Paving Association stated in this guide that plastic groove spacing should average approximately 1/2 inch. Random spacing is acceptable provided grooves range between 1/4 to 1 inch spacing. Width of groove should be 0.08 to 0.13 inch and depth from 1/8 to 3/16 inch. Minimum texture depth by the sand patch method should be an average of 0.03 inch with a minimum of 0.020 inch for individual tests. This plastic grooving should be applied on all mainline pavements and ramps where high speed and rapid acceleration-deceleration are required. In 1976, ACPA also drafted a "Guideline for Retexturing and Restoring Surface Profile in

Existing Portland Cement Concrete Highways." It was recommended that slippery PCC pavements should be corrected through utilization of pavement safety grooving. Longitudinally grooved areas should begin and end at lines normal to the pavement center line and should be centered within the lane width. Groove width should be maximum 0.110 inch minimum .080 inch and be spaced approximately 3/4 inch on centers. The grooves should be cut not less than 1/8 inch nor more than 1/4 inch deep.

Portland Cement Association, in their publication of January 1974 "More Macrotexture in Concrete Pavement for Greater, Longer Lasting Skid Resistance," gave a tentative guideline for grooves of plastic concrete using either a vibrating beam roller or a comb equipped with steel tines, as follows: transverse grooves 0.090 to 0.125 inches wide, 1/8 to 3/16 inch deep, spaced at 1/2 to 1 inch centers. It was further suggested that the minimum average texture depth be 0.030 inch as measured by the sand patch method with a minimum depth limit of 0.025 inch for one test.

The Federal Highway Administration issued a notice in September of 1976 concerning "Texturing of Concrete Pavements and Bridge Decks." This notice stated that a burlap or other type of drag finish should not be approved as the sole means of providing surface texture on projects with design speeds of 40 miles per hour or greater unless it can be conclusively demonstrated that safe durable surfaces can be consistently produced by this method. When a broom finish is specified for use on projects with design speeds of 40 miles per hour or greater, specifications that will insure a deep, durable texture must be used. Metal tines are recommended as being the most practical and dependable method of providing positive texture in PCC surfaces. The use of tines 0.03 inch thick, 0.08 inch wide and 4 to 6 inches in length has resulted in good durable surfaces when the grooves were constructed to the maximum depth practical which is normally abour 3/16 inch. Average transverse groove spacings of approximately 1/2 inch are recommended and have been found to produce a more durable surface texture than grooves spaced at 1/4 inch.

"Guidelines for Skid Resistance Pavement Design" were issued by AASHTO in October 1976. Included was texturing of Portland Cement Concrete Pavement. It is stated that burlap drag texturing alone does not provide adequate macrotexture for durability and is therefore not recommended. A skid resistant texture for high speed traffic can be built into concrete by using one or more of the following: (1) plastic grooving with metal tines, grooving drums or other means and (2) steel or plastic fiber brooms. Texturing in the longitudinal direction, while not necessarily producing a large increase in skid number as conventionally measured, improves directional control and has been very effective in reducing accidents on high-speed highways. Transverse texturing produces higher skid numbers and provides faster drainage of water from the surface, but also produces slightly higher tire-pavement noise which would normally be overshadowed by dominant truck and automobile engine exhaust and aerodynamic noises. In plastic grooving, the grooves should be randomly spaced far enough apart to produce durable ridges of concrete between them. Recent experience indicates that a groove spacing of about 1/2 inch is satisfactory but that a spacing of 1/4 inch may result in ridges that will wear rapidly. Maximum groove depths that can be obtained with concrete mixes and equipment normally used are 0.10 to 0.15 inches. Inadequate skid resistance on existing PCC pavements is often corrected by cutting a series of parallel grooves with a bank of diamond or abrasive saw blades. A typical sawed longitudinal groove pattern for highway pavements is slots 0.095 inches wide, 1/8 to 1/4 inch deep on 3/4 inch centers.

Findings and Conclusions

1. Thirty-three States have now used or plan to use transverse tine texturing, at least on an experimental basis.

2. A burlap, artificial grass, or other type of drag finish should not be used as the only means of providing surface texture on projects with design speeds of 40 miles per hour or greater.

3. A broom finish, while usually producing good initial surface texture, may not be durable unless a deep texture is produced by heavy bristles and high pressures. Even then wear may be substantial due to the land area available.

4. Metal tines are recommended as being the most practical and dependable method of providing positive texture in PCC surfaces.

5. Transverse grooving will porovide a pavement surface with good skid resistance characteristics, will reduce splash and spray and headlight glare from wet roadway surfaces, and will continue to facilitate surface drainage until the depth of the wheelpath ruts exceeds the depth of the grooves.

6. Longitudinal grooving assists vehicle control at curves and sites involving lateral movements. It has been found to be a very effective means of reducing accidents at sites having high, wet weather accident rates.

7. Optimum specification might be the use of tines 0.03 inch thick, 0.08 inch wide and 4 to 6 inches in length with the grooves being constructed from 1/8 to 1/4 inch in depth with 3/16 inch being normal. Random spacing from 1/2 to 3/4 inch would be preferable.

8. It would be preferable for transverse grooving on tangents and a combination of longitudinal (3/4 inch spacing) and transverse (3 inch spacing) on curves.

9. Sawed grooving of existing pavements should have blades 0.095 inches wide spaced on 3/4 inch centers cutting from 1/8 to 3/16 inches deep.

10. Cost of plastic grooving has run from nothing to $0.08 a square yard while sawed grooving has been averaging from $0.75 to $1.25 a square yard.

11. Grooving of PCC pavements has very little effect on roughness, if any.

12. Noise measurements up to this time have shown a slight increase for transverse grooving (up to 4 db on A scale) which is usually masked by the tire-pavement noise and is not considered objectionable. More research is needed in this area.

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