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Abridgment

Development of a Porous Lane-Marking System

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The lack of adequate lane guidance at night under wet conditions is a particularly critical highway-safety problem. Water on the pavement surface contributes to increased glare and a general loss in visibility of lane-marking stripes. Recently, significant effort and resources have been devoted to the development of new traffic-control materials, devices, and related delineators to assist the traveling public during adverse weather conditions and night driving (1).

In southern states the problem of wet-night lane marking has been solved largely by supplementing conventional lane stripes with raised reflective markers. In northern states where snowplows are used, however, such markers are impractical, and other solutions are needed.

Open-graded asphalt friction courses (OGAFC) or porous friction courses, although developed primarily for other reasons (2), have helped reduce the wet-night lane-stripe visibility problem. The porous nature of OGAFC minimizes or eliminates the time during which the pavement surface and delineator stripe are inundated. The reflective material is thus more effective and headlight glare is minimized.

There are certain undesirable features in using conventional and hot-applied thermoplastic lane-striping materials and raised pavement markers (RPM) with the porous OGAFC: (a) greater required quantities of striping materials, (b) restriction to lateral flow of water, (c) more rapid loss of RPM, and (d) incompatibility of snowplows with RPM.

PURPOSE OF THE STUDY

It was hypothesized that a better lane-striping system for the increasingly popular OGAFC might be one that uses the same porous, open-graded principle. A research project was therefore initiated to develop and field test a snowplow-resistant lane-delineation system that possessed porosity and texture characteristics similar to that of OGAFC and provided adequate lane-stripe visibility at night under rainy conditions.

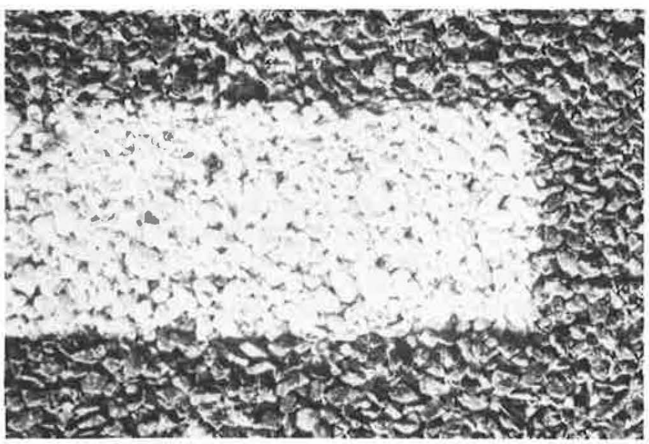
MIXTURE DEVELOPMENT AND EVALUATION

The special delineator system, in order to exhibit a porous, open-graded texture and have appropriate color and light-reflecting qualities, should be composed of the following key ingredients.

1. Aggregate: High porosity is obtained by using a narrow-graded aggregate with no appreciable fines content. The aggregate used in the porous delineator system acts primarily as an inert material that establishes the skeleton of the porous system.
2. Binder material: A very critical component of the porous delineator system is the binder. It must have sufficient strength, durability, and toughness and must adhere to aggregate and glass beads and be able to be pigmented white or yellow.
3. Color pigment: The pigment mixed with the

Figure 1. Magnified photograph showing beaded surface of porous lane marker.

Figure 2. Close-up photograph of porous lane marker 10 cm (4 in) wide installed in OGAFC surface.



binder gives either yellow or white color to the porous delineator system.

4. Glass beads: Glass beads of a high reflective index are placed on the upper surface of the porous delineator system and are held in place by the pigmented binder material.

5. Void space: Void space or porosity allows water to drain both vertically and horizontally. Porosities of about 30 percent were maintained in all porous delineators (similar to OGAFC).

Figures 1 and 2 are close-up photographs of a typical porous delineator system. Mixture proportions by weight for the porous delineators were typically 10 parts binder, 100 parts aggregate, 2-5 parts color pigment, and about 540 grams of glass beads per square meter (13 oz/yd^2) of delineator surface.

A major aspect of mixture development was identification and selection of appropriate binder compounds. Both thermoplastic and thermosetting compounds were considered, including epoxies, polyesters, polyurethanes, acrylics, polyamides, hot-melt glues, and resins. A suite of 20 laboratory screening tests was used to evaluate various properties and characteristics of the numerous special porous delineator mixtures. Based primarily on workability and placement considerations, only thermoplastic binder compounds were selected for field testing.

FIELD TESTING

The most promising candidates were selected from laboratory testing for field testing. White and yellow porous delineator materials composed of four binder compounds were placed on an expressway entrance ramp that has average daily traffic (ADT) of 10 000 and is located about 19 km (12 miles) east of Atlanta, Georgia. The ramp had been previously surfaced with OGAFC.

The porous delineators were placed in a groove sawed at a skewed angle to the direction of traffic. Conventional delineators (beaded paint, thermoplastic and foil-backed tape) were also placed at this location. After installation, the performances of the porous and conventional delineator materials were observed for a period of about six months. Visual, photographic, and telephotometric observations were made.

Two of the porous delineator materials were also placed in the centerline location at a test site on US-50 about 6.5 km (4 miles) west of Winchester, Virginia. In total, about 1060 m (3480 ft) of porous delineator centerline stripe was placed in an OGAFC-surfaced pavement. The conventional 3:5 stripe-to-gap ratio was used. A detailed description of the installation techniques may be found in Robnett and Burrows (3).

Two control sections 760 m (2500 ft) long and consisting of alkyd-base beaded white paint lane stripes were placed adjacent to the test sections. One of these control sections was paint on a conventional dense-graded asphalt surface, while the other was paint on an OGAFC surface.

The serviceability and performance of the porous delineators were examined closely over a period of about a year. The traffic volume was about 5000-6000 ADT, and 24 separate snowplowings were applied to the site during the winter. Periodic monitoring included (a) visual examination, (b) photographic logging (35-mm still and Super 8-mm movie), and (c) telephotometric recording of dry and wet-night retroreflectance. Of particular concern was the night stripe visibility or retroreflectance. Wet conditions were created by spraying the pavement with water from the spray bar of a water truck.

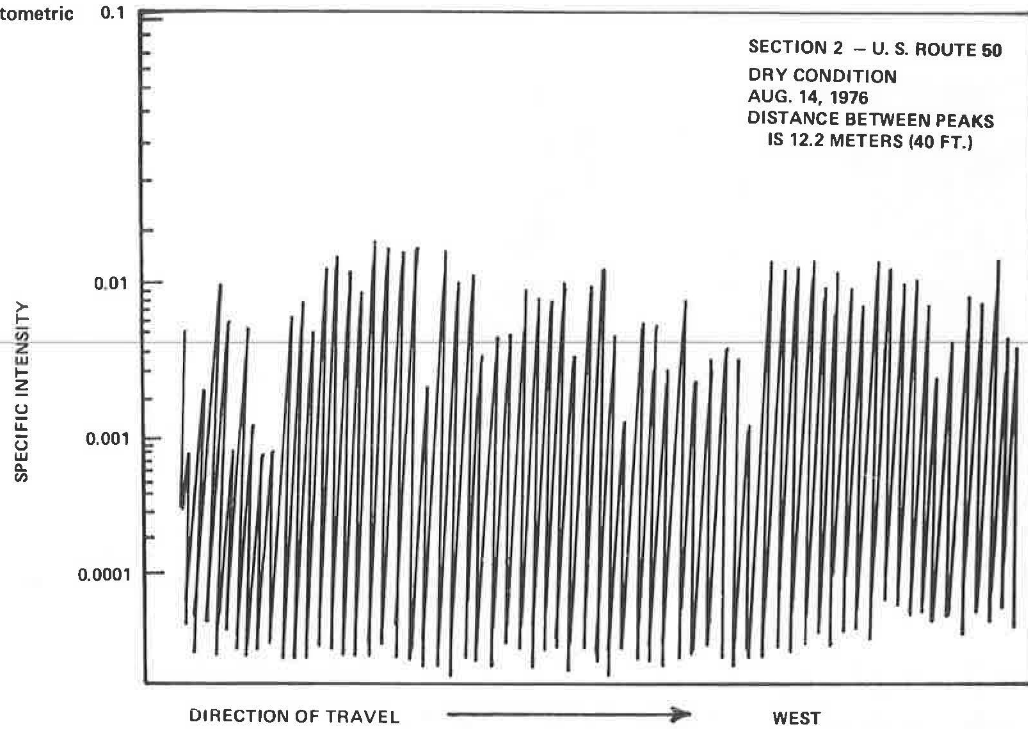
Telephotometric equipment developed by Tooke and Hurst (4) was used at night to evaluate the retroreflectance of the delineator stripes under both dry and wet conditions. Basically, the telephotometer is a fixed-focus fixed-position light transducer attached to and aligned with a spotlight. The telephotometer sensors are cadmium sulfide photocells, Claire CL905, which are centered in the focal plane of an f/1.0, 50-mm lens. The light source is a 12-V, 30-W sealed beam spotlight, whose beam unit is rotated to align the major axis of the filaments vertically. The telephotometer was mounted on the left side of an automobile and the telephotometric readings of the delineators were taken with the automobile traveling at a speed of about 40 km/h (25 mph). Exact details of data acquisition using the telephotometer can be found elsewhere (3, 4).

RESULTS

Visual Observations

The primary porous delineator system used at the Virginia site exhibited negligible raveling under traffic action. Records show that the test site was snowplowed

Figure 3. Typical profile of telephotometric readout for test section.



24 times and deicing chemicals were applied 17 times during the winter months. Although the OGAFC pavement surface suffered some snowplow damage, only very small, isolated areas of damage were observed for the porous delineator stripes.

Telephotometric Readings

The telephotometric data obtained for each test and control section at each site visit were expressed in terms of specific intensity (SI), which is a measure of the intensity of a reflecting surface for a given amount of illumination at a given point of observation and has units of candela per square meter (Equation 1).

SI = intensity of projected area/illuminance on projected area (1)

Figure 3 represents a typical recording for an evaluation run for a given test section. Each peak represents the SI for a particular 4.6-m (15-ft) long stripe within the test section.

After all visits had been made to the Virginia test site during the one-year observation period, extensive telephotometric data, expressed as peak SI, were available for each of the test sections. These data were subjected to a statistical analysis with regard to

1. Time effects, the influence the exposure had on the relative retroreflectance of the various delineator materials, and
2. Material effects, the influence the various delineator materials had on retroreflectance, in particular, whether the porous delineator materials were better than the beaded paint delineators.

The effects of time and material were determined by using Duncan's new multiple-range test at a 0.05 level of significance.

Concerning the influence of time of exposure, all test items in general exhibited a loss of night visibility under both dry and wet conditions. The rate of loss of SI or retroreflectance during exposure was greatest for the paint-on-OGAFC stripes.

Concerning the influence of materials, at all observation periods, retroreflectance of the paint-on-OGAFC stripes under dry conditions was the lowest. Although the paint-on-dense-asphalt surface had the highest retroreflectance under dry conditions, when wet these stripes exhibited significantly lower retroreflectance than either the porous delineator stripes or the paint-on-OGAFC stripes. The paint-stripe test sections were repainted toward the end of the observation period because visibility of paint stripes had become so poor. The porous delineator stripes that had been in service almost a year still had retroreflectance under wet-night conditions that was equal to or greater than that of the newly painted stripes.

CONCLUSIONS AND RECOMMENDATIONS

This paper has described very briefly the development and preliminary testing of a snowplow-resistant porous lane-marking system for use with open-graded asphalt friction courses. A complete description of the research study methods and findings can be found in Robnett and Burrows (3).

Based on the results of this study, we concluded that the combined system of an OGAFC surface and a porous lane-marking stripe can provide superior centerline, wet-night marking compared to conventional beaded paint on a dense-graded asphalt surface. The results also demonstrated that, for the one-year test period, porous lane-marking systems provided better delineator performance under wet-night conditions than the conventional beaded paint on the OGAFC surface.

An estimate of the total installation cost of the porous lane-marking systems was not determined. Apparently the initial cost would be substantially more than that of conventional lane-marking materials. To be economically attractive, the porous lane-marking system would thus have to exhibit a much longer service life. Because of a limited time frame, this study did not examine or attempt to estimate the life expectancy of optimally designed and efficiently installed porous lane-marking systems.

Thus, before final decisions can be made regarding overall economy of the porous systems, additional field installations and comparative studies are needed. The economic attractiveness would undoubtedly be improved if appropriate installation equipment and techniques were developed.

ACKNOWLEDGMENT

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The contents of this paper reflect my views, and I alone am responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration.

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Measurement of Stress in Concrete Pavements

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Sudden compressive failures of concrete pavements (blowups) are a serious problem for highway maintenance departments. In an effort to predict when blowups will occur, a method of measuring residual stresses within a concrete pavement has been developed. In the procedure, electrical strain gauges are attached to the wall of a corehole by means of a specially designed installation tool. The corehole is overcored and the relief strains are measured. Available theory has been adapted to allow computation of longitudinal stress at the level of the gauges. Laboratory tests have validated the procedure, but results from tests on actual pavements have proved to be somewhat erratic.

A blowup in a concrete pavement is a buckling failure, usually at a transverse joint and is due to compressive forces in the pavement. Seasonal variations in temperature and moisture content cause the pavement slabs to expand and contract. During contraction of the slabs, the joints open and, if improperly sealed, may receive charges of detritus from the pavement surface, subbase, and shoulder. Subsequent expansion is prevented at these filled joints and compressive stresses result. Blowups rarely occur in new pavements. Such failures usually begin in pavements 5-10 years old and continue for the life of the pavement, whether overlaid or not.

An unusually large blowup, which occurred on June 24, 1975, on OH-21 in Summit County, is shown in Figure 1. This blowup was 0.53 m (21 in) high and involved both northbound lanes for approximately 4.57 m (15 ft).

Blowups usually occur at contraction joints; sometimes they happen at transverse cracks. Joints are particularly susceptible to infiltration by deicers, water, and debris and undergo more severe stress patterns due to traffic than the rest of the pavement. These stress patterns are repetitive and dynamic. Load-transfer devices, such as dowels, that are improperly installed or not functioning properly can cause spalling of the faces of the joint. Many joints inspected after being involved in blowups demonstrate prior deterioration of as much as half of the joint faces. Figure 2 illustrates such disintegration.

The combination of joint deterioration and high compressive stresses in the pavement leads to blowups. Blowups may be gradual or sudden and can involve both large and small areas.

To repair a blowup, full-depth saw cuts are made just outside the zone affected and the concrete is replaced (in Ohio) with bituminous concrete, usually without rebuilding of the subbase. This procedure is expensive and delays traffic, often for several days. The state of Ohio, after waiving its immunity to lawsuit in 1975, has been successfully sued by at least one motorist who was injured by a pavement blowup (Arthur E. Knickel v. State of Ohio Department of Transportation, Court of Claims No. 750329).

Preventive maintenance involves plowing out the sealant and routing or sawing joints in areas suspected of possible blowups. The joints are then resealed. If the progressive formation of high compressive forces could be anticipated and measured, temporary relief could be furnished by simply sawing a new joint in the pavement and filling it with an appropriate sealant.

Some of the variables that have been studied in conjunction with the blowup problem are ambient tempera-