public roads

June 1975 Vol. 39/No. 1

A JOURNAL OF HIGHWAY RESEARCH AND DEVELOPMENT

U.S. Department of Transportation Federal Highway Administration

public roads

A JOURNAL OF HIGHWAY RESEARCH AND DEVELOPMENT

June 1975 Vol. 39/No. 1

COVER:

Artist's concept of raised pavement markers leading off an exit ramp and also on an expressway. From an advertisement by the Signal Products Division of Amerace Corporation. Artist: Karl Foster. (Published with permission of the Amerace Corporation.)

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The title sheet for vol. 38 is now available. (See page 36.)

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U.S. Department of Transportation
Federal Highway Administration
Washington, D.C. 20590

Public Roads is published Quarterly by the Offices of Research and Development

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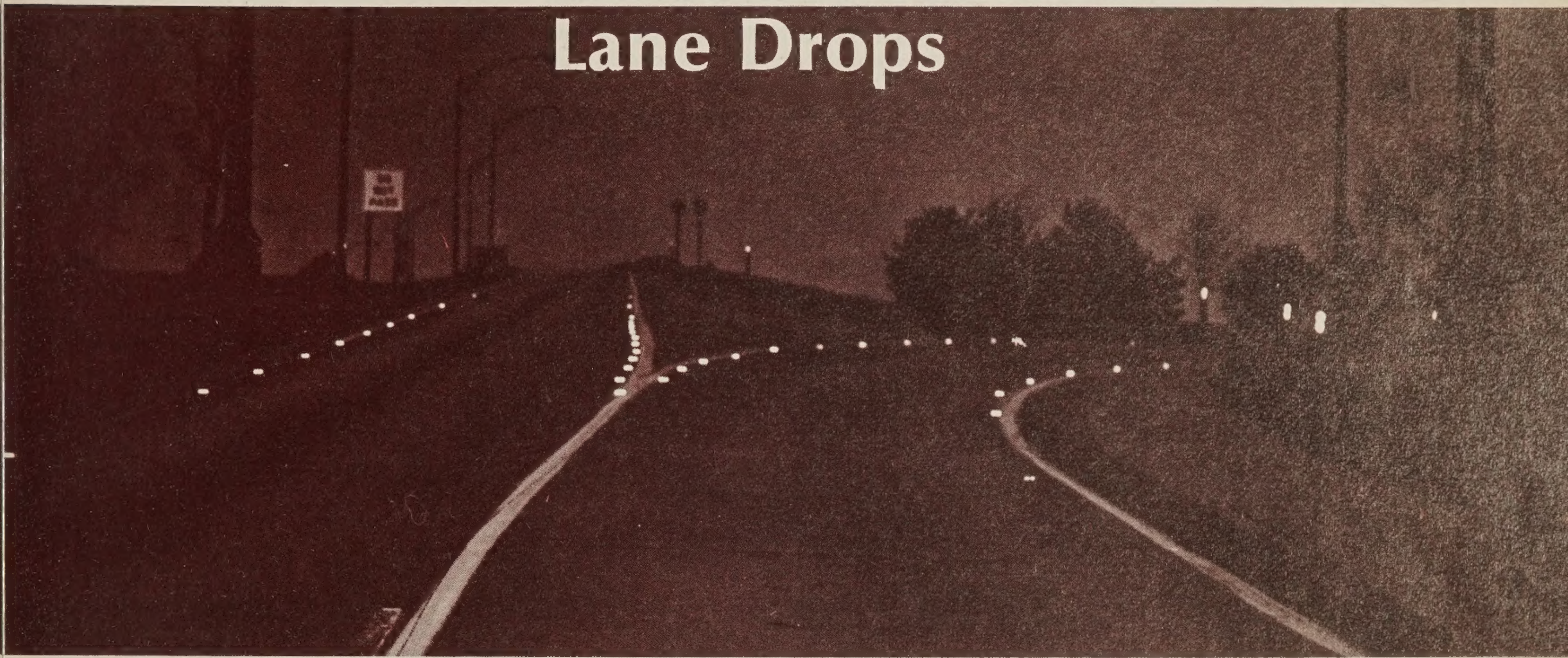
The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through March 31, 1976.

Raised Pavement Markers as a Traffic Control Measure at Lane Drops

by Jerry G. Pigman
and Kenneth R. Agent



Introduction

A previous study conducted by the Division of Research, Kentucky Department of Transportation, investigated the influence of various traffic control measures on the operational characteristics of lane drops *(1)*.[1] Several standard and experimental traffic control devices were selected for application. No single type of traffic control device was found to be significantly effective in reducing conflicts at all the locations. The purpose of this research was to evaluate the effectiveness of raised pavement markers (not used in the previous study) as a traffic control measure at lane-drop sites. One phase of a research study entitled "Evaluation and Application of Roadway Delineation Techniques" *(2)* is reported in this article. In another

Raised pavement markers are an effective means of reducing erratic movements at lane-drop locations, particularly under nighttime driving conditions. The cost of raised pavement markers and their installation is nominal (approximately $150 per lane-drop location). It is recommended that raised pavement markers be installed at other lane-drop locations. Markers installed at locations described in this article have not been in place for a sufficient time to determine their durability; however, reports from other States indicate their durability is sufficient to render them economical. If raised pavement markers are installed routinely, steps should be taken to insure they are not damaged by snowplow operations. Rubber-tipped blades have been used successfully in areas with slushy snow or where chemicals are used in conjunction with snowplows.

[1] Italic numbers in parentheses identify the references on page 6.

phase, an attempt is being made to determine the durability and reflectivity of several types of raised pavement markers over a long period of time. Raised pavement markers have been installed on several test sections and are being monitored by photometer measurements and visual inspection.

Lane drops

A lane drop is defined as a location where the number of lanes provided for through traffic decreases. The broad category of lane drops has been further subdivided into three more specific classes: lane exits, lane splits, and lane terminations. A lane exit refers to a location where the number of through lanes decreases at an interchange on a multilane roadway. A lane split denotes a major bifurcation of a multilane highway where the level of traffic service provided at the terminus of either fork is approximately equal. A lane termination describes a location where a lane ends.

Raised pavement markers

Raised pavement markers are in use in some States as an integral part of the roadway delineation system. They are being used to supplement as well as to replace paint stripes. In addition, they are being placed on horizontal curves, merge and diverge areas, turning lanes, no-passing zones, and stop approaches *(3)*. These markers have proved to be particularly effective for wet, nighttime, and other poor visibility conditions.

A major deterrent to the use of raised pavement markers in snow areas has been marker damage and destruction caused by steel snowplow blades. A study conducted by the State of Washington demonstrated that the rubber-tipped snowplow blade was an effective tool for removing freshly fallen or slushy snows and for protecting raised traffic markers *(4)*. The Federal Highway Administration has requested States in areas where snowfall is common to review their snowplowing and deicing procedures and to carefully consider the use of deicers and rubber snowplow blades so that raised pavement markers could be used *(5)*.

Kentucky receives some snowfall each winter and the seasonal amounts are extremely variable. As a rule, the ground remains covered with snow for only a few days at a time. The average seasonal snowfall at the Lexington weather station for the past 39 years has been 18.5 in. (0.47 m), with a high of 41.7 in. (1.06 m) for the 1950–51 season and a low of 2.3 in. (0.06 m) for the 1949–50 season. Snowplow use varies from an average of 5 to 10 times a year.

Several different types and brands of raised pavement markers have been developed and used by various States. The markers vary in cost, durability, and reflectivity. In this study, five different types of raised pavement markers were used (fig. 1).

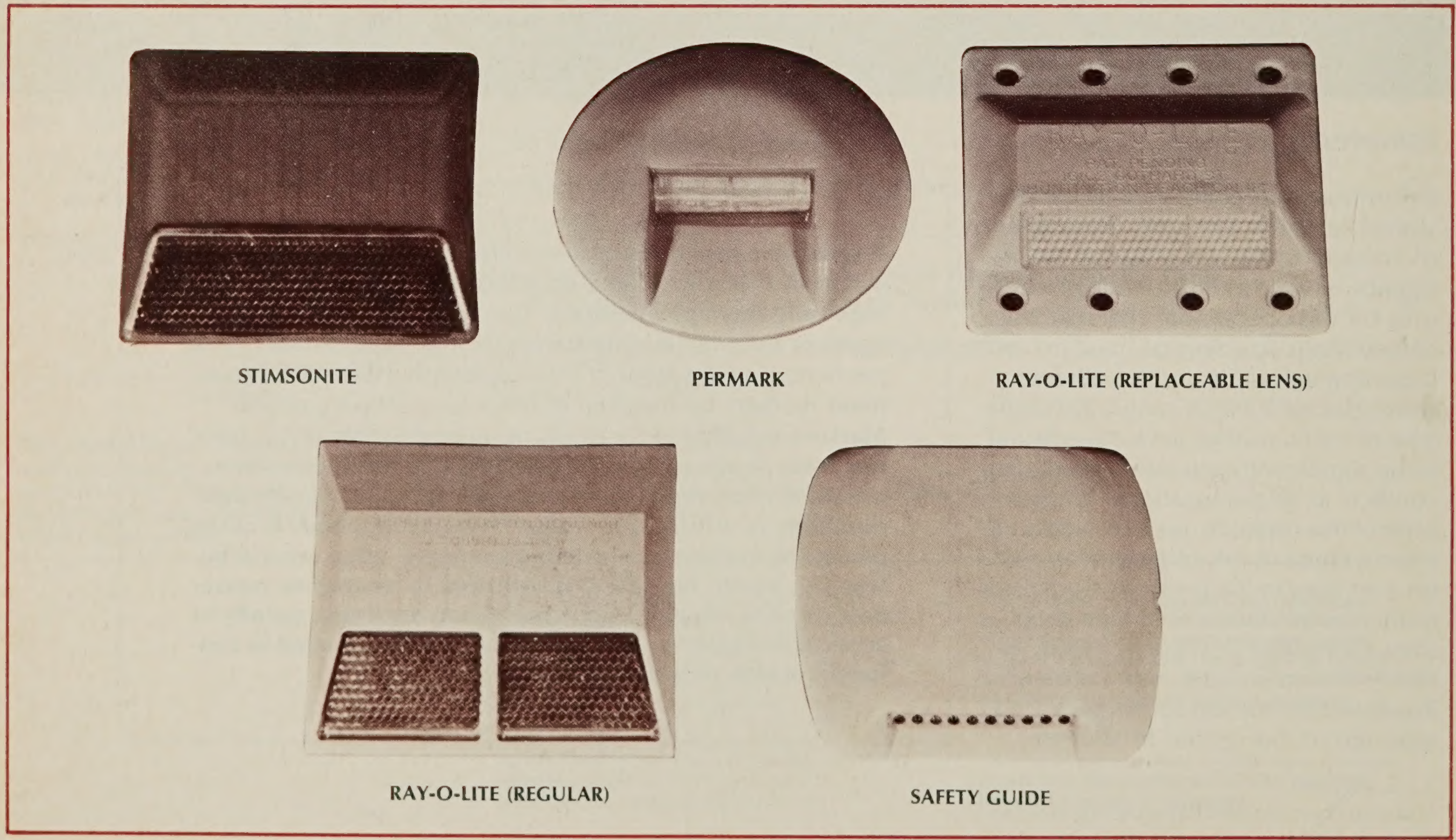


Figure 1.—Types of raised pavement markers.

Procedure

Locations

Studies were conducted at five lane-drop locations, each representing one of the three classes of lane drops. The five sites were:

(1) A single-lane split at I–75 northbound—I–64 eastbound located east of Lexington.

(2) A single-lane split at I–75 southbound—I–64 eastbound located east of Lexington.

(3) A single-lane exit without taper on I–75 northbound at the 5th Street exit in Covington.

(4) A single-lane exit with taper at I–75 southbound—I–71 southbound in Boone County.

(5) A lane termination at US 27—68 (Paris Pike) northbound just north of New Circle Road in Lexington.

One of the lane drop locations is shown in figure 2.

Data collection

Conflict surveys (consisting of erratic movement and brakelight application counts) and lane volume counts were conducted at each of the lane-drop locations. Observations were made before and after installation of the raised pavement markers at all sites for dry pavement conditions. Data were recorded for 6 daylight hours and 3 nighttime hours. Erratic movements were grouped into seven categories: (1) cut across gore area, (2) crowded weave, (3) stopped, (4) slowed drastically, (5) swerved, (6) stopped and backed, and (7) multiple error. Brakelight application rates were summarized for the median, middle, and shoulder lanes. The same observer made all conflict surveys in order to eliminate the bias which often results from varying judgments as to what constitutes a conflict.

Wet nighttime data were collected at one of the sites after installation of the markers to illustrate the relative number of conflicts during wet and dry conditions. It would have been preferable to have before wet nighttime data with which to make a comparison, but it was considered to be an infeasible alternative. This was supported by the belief that it is practically impossible to collect data during inclement weather conditions and expect to duplicate these conditions at some time in the future. Visibility would most likely differ between the before and after conditions since the amount and intensity of rainfall would not be identical. By collecting before and after data under dry pavement conditions, the weather variable was eliminated.

Installations

A different type of raised pavement marker was used at each of the five lane drops. The type of marker and the lane drop at which it was used are as follows:

(1) Ray-O-Lite (regular)—I–75 northbound—I–64 eastbound, east of Lexington.

(2) Ray-O-Lite (replaceable lens)—I–75 southbound—I–64 eastbound, east of Lexington.

(3) Stimsonite—I–75 northbound—5th Street exit in Covington.

(4) Permark—I–75 southbound—I–71 southbound in Boone County.

(5) Safety Guide—US 27—68 (Paris Pike) northbound, just north of New Circle Road in Lexington.

The markers were applied using a two-component epoxy. Surfaces were prepared prior to application of the epoxy by scrubbing with a wire brush. Traffic was maintained during application, but traffic cones were used to prevent vehicles from touching the markers until the epoxy had hardened.

Markers outlined the gore area as well as the edgelines. The markers started

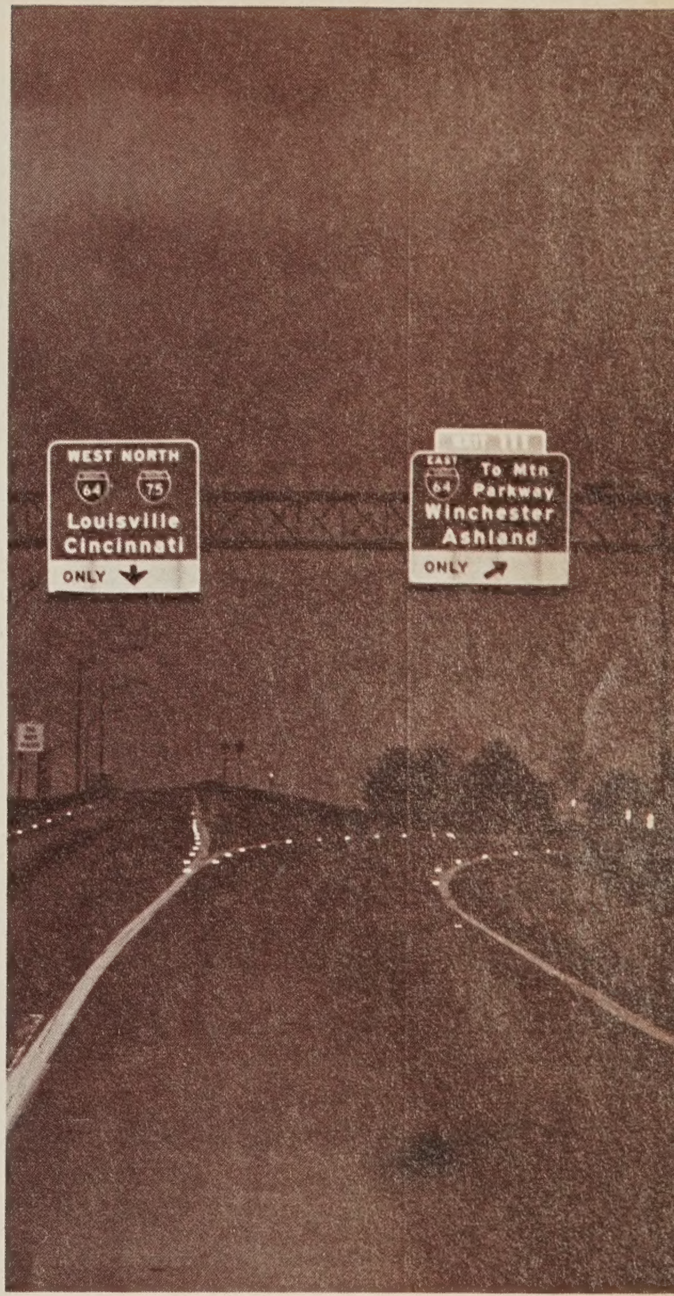


Figure 2.—I–75 northbound—I–64 eastbound lane split.

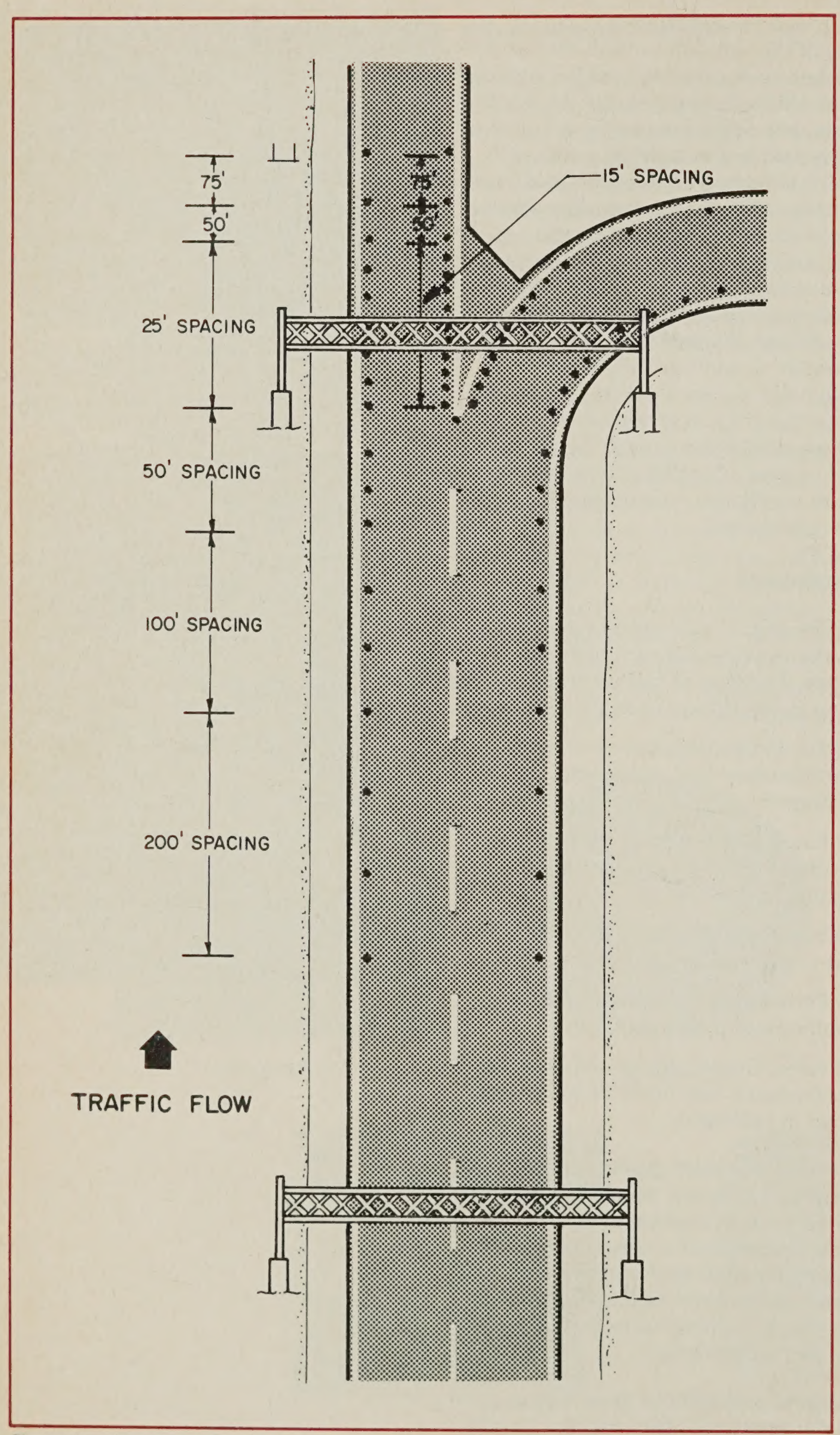


Figure 3.—Arrangement of raised pavement markers at I–75 northbound —I–64 eastbound lane split east of Lexington.

approximately 1,100 ft (335 m) in advance of the gore and continued approximately 150 ft (45 m) past the base of the striped gore area. At the Paris Pike location, markers were placed on the right edgeline as well as the left side of the section where the two lanes merged into one. A schematic which provides details of the marker arrangement at one of the study locations where 61 markers were installed is shown in figure 3.

Data analysis

Erratic movement and brakelight rates were calculated. Rates before and after installation of the markers were calculated for both daytime and nighttime conditions and for the total study period. Rates were obtained by dividing the number of erratic movements or brakelight applications by the applicable traffic volumes and expressing this quotient as a percentage. Statistical tests were then used to determine whether a significant difference existed between the before and after conflict and brakelight rates *(6)*.

Results

Erratic movement rates, brakelight rates, and average hourly volumes for all five lane-drop locations were calculated, and the data before and after installation of the raised markers were summarized by total study period, daytime conditions, and nighttime conditions, respectively.

Results of the statistical analysis of the difference between the before and after conflict and brakelight rates are presented in table 1. The words *increase* and *decrease* mean that the particular erratic movement or brakelight rate difference was found to be statistically significant at the 95-percent confidence level. For more detailed information refer to the research report *(2)* from which this article was written.

A statistically significant decrease in the total erratic movement rate occurred in nearly all cases. Exceptions were I–75 northbound at the 5th Street exit under daytime conditions and Paris Pike under nighttime conditions. There was not a significant increase in any type of erratic movement at any of the locations. From table 1, it can be seen there was a significant decrease in the total erratic movement rate for daytime, nighttime, and combined conditions. It should be noted that, while the erratic movement rate decreased for all conditions, the nighttime rate showed the greatest decrease. There was a total reduction in the overall erratic movement rate of 27 percent (from 2.07 to 1.52). This resulted from a 20 percent reduction (from 2.15 to 1.71) for daytime conditions and a 44 percent reduction (from 1.78 to 0.99) for nighttime conditions. This indicated the raised pavement markers were particularly effective in reducing the erratic movement rate for nighttime conditions.

A study of brakelight rates produced different results. Some locations showed a significant increase while others showed a significant decrease. From table 1, it can be seen that no significant change occurred in the total brakelight rate.

At the I–75 northbound—I–64 eastbound site, wet, nighttime data were collected. A comparison was made of the nighttime data for dry-before, dry-after, and wet-after conditions. Results indicate that the wet-after, nighttime erratic movement rate decreased by 29 percent from the dry-before, nighttime rate and increased by 25 percent from the dry-after, nighttime rate. Neither the reduction nor the increase in erratic movement rates was significant at the 95-percent confidence level.

The increase in erratic movements was somewhat expected due to the larger number of conflicts which occur during wet, nighttime conditions—that is, when visibility is usually impaired.

Cost of the raised pavement markers and their installation was relatively inexpensive compared to their potential benefits (table 2). The average cost was approximately $150 per lane-drop location.

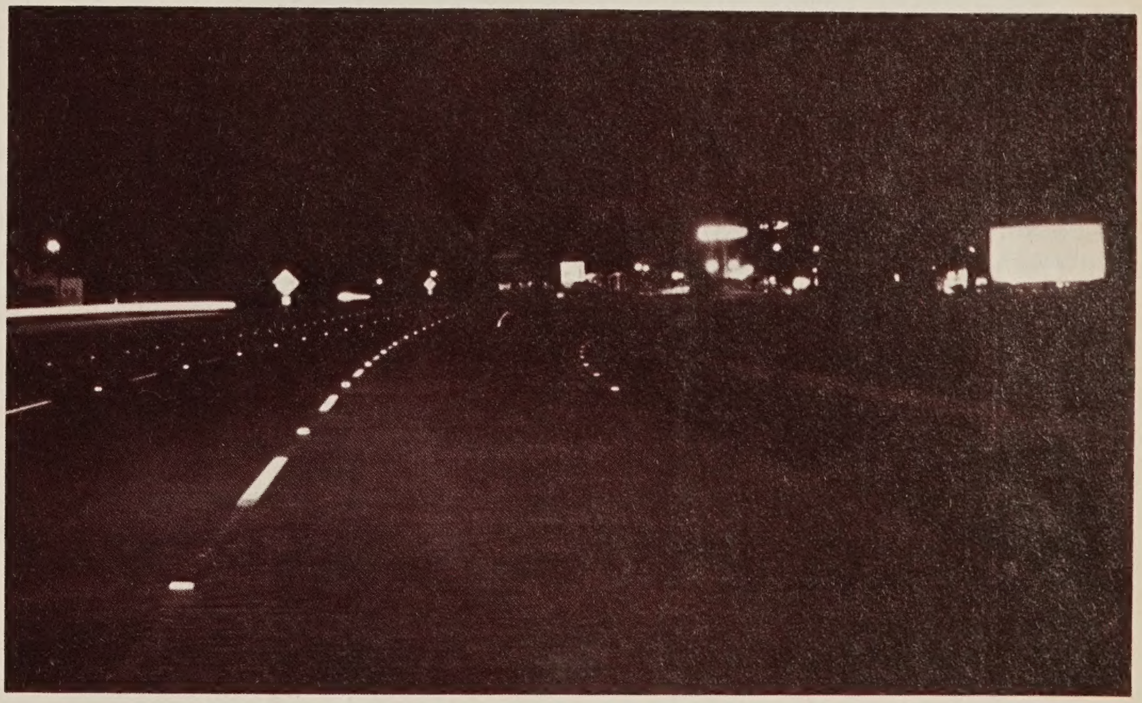


Table 1.—Significant erratic movement and brakelight rate differences—summary for all locations

	Daytime conditions	Nighttime conditions	Total study period
Erratic Movement			
Cut across gore	NSC[1]	Decrease	NSC
Crowded weave	Decrease	Decrease	Decrease
Swerve	Decrease	NSC	Decrease
Slowed drastically	Decrease	NSC	Decrease
Stopped	NSC	NSC	NSC
Stopped and backed	NSC	NSC	NSC
Multiple error	NSC	Decrease	Decrease
Total	Decrease	Decrease	Decrease
Brakelight Rate			
Median lane	NSC	NSC	NSC
Middle lane	Decrease	NSC	Decrease
Shoulder lane	Increase	NSC	Increase
Total	NSC	NSC	NSC

[1] No significant change

Table 2.—Materials and installation costs for five lane-drop locations

Marker type	Markers used	Unit price	Marker cost per lane-drop location
	Number	*Dollars*	*Dollars*
Ray-O-Lite (regular)	61	1.28	78.08
Ray-O-Lite (replaceable lens)	57	1.00	57.00
Stimsonite	79	1.045	82.56
Permark	63	0.45	28.35
Safety Guide	41	0.60	24.60
Marker costs	..	....	270.59
Labor (site preparation and placement of markers)	..	....	420.00
Epoxy (3 gallons)	..	....	42.00
Total installation costs	..	....	732.59

Reflectivity test results at the 0.5-degree divergence angle on the five soft-white markers are summarized in table 3. The comparative reflectivity measurements indicate that two distinct categories of markers were used. All markers used were monodirectional with white reflective lens. The Stimsonite and Ray-O-Lite markers have highly reflective prismatic reflectors which are considerably larger in area than those of the Permark and Safety Guide markers. The Permark and Safety Guide markers have less reflectivity. The Permark marker has an acrylic rod-lens reflector, and the Safety Guide marker has a reflective strip consisting of 10 glass beads. The Stimsonite and Ray-O-Lite markers had a specific reflectivity five or six times greater than Permark and Safety Guide. There were no conclusive results which indicated that the lower reflectivity of the Permark and Safety Guide markers affected their ability to reduce conflicts. Since the five types of markers were installed at different lane-drop locations, a valid comparison of marker types is not available. The markers have not been installed for a sufficient period of time to justify a complete evaluation of their durability. With the exception of the Ray-O-Lite (replaceable lens), all markers appear to have sufficient durability. The Ray-O-Lite (replaceable lens) marker failed to remain intact under traffic and has since been discontinued by the manufacturer.

Table 3.—Summary of reflectivity tests

Type	Specific reflectivity[1]
Stimsonite 88	1.9
Ray-O-Lite (regular)	1.8
Ray-O-Lite (replaceable lens)	2.0
Permark	0.36
Safety Guide	0.30

[1] Candlepower per foot candle (1.08 lux) per unit reflector (at 0-degree incidence angle).

Conclusions and Recommendations

The objective of this study was to determine the effectiveness of raised pavement markers as a traffic control measure at lane drops. Major conclusions, which were drawn from the analyses, and recommendations are as follows:

- Raised pavement markers are an effective means of reducing erratic movements at lane-drop locations.

- No significant change in brakelight rates resulted from the installation of raised pavement markers.

- While the raised pavement markers proved to be generally effective under both daytime and nighttime conditions, the reduction in erratic movements under nighttime conditions was the major benefit derived.

- The cost of the raised pavement markers and their installation was nominal, and their use at any lane-drop location is recommended.

- Conclusions concerning the long-term durability of the raised pavement markers are not appropriate on the basis of only limited exposure to traffic. However, experience in other States suggests that some markers possess the desired characteristics to make them economically feasible.

- Studies have shown that rubber-tipped snowplow blades have been used successfully. The potential benefits of raised pavement markers at the types of locations investigated indicate that overall safety provided the driving public would be enhanced by using raised pavement markers. It is recommended that use of steel snowplow blades be discontinued on a trial basis where raised markers have been installed.

- Since different marker types were used at each of the lane-drop locations, it was not possible to compare their relative effectiveness.

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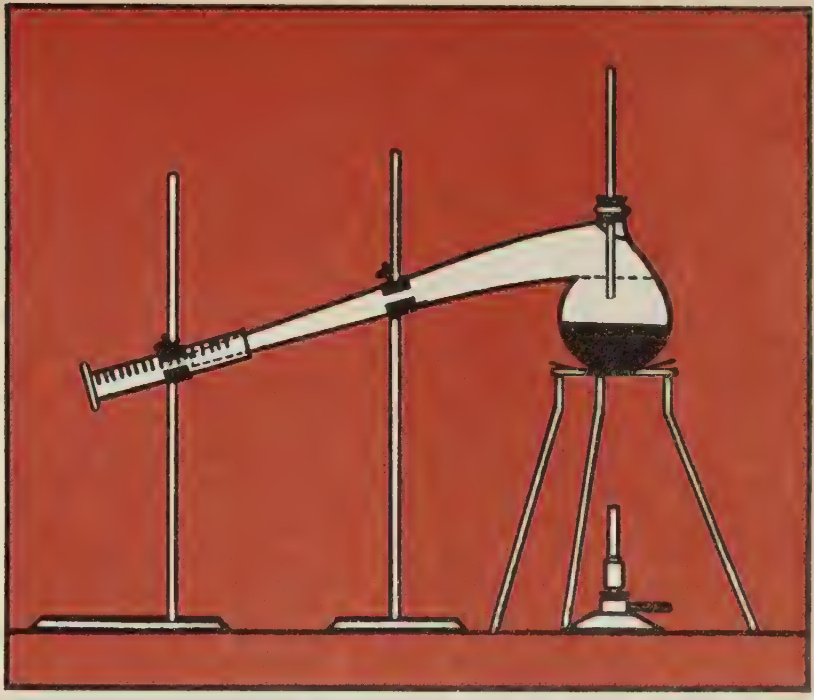
Development of Asphalt Tests and Specifications in the United States

by Woodrow J. Halstead and J. York Welborn



In February 1974 at its annual meeting, the Association of Asphalt Paving Technologists (AAPT) observed its fiftieth anniversary. During the session of the meeting devoted to a history of asphalt paving, the authors of this article presented a paper on the "History of Asphalt Testing Apparatus and Asphalt Specifications." This article is excerpted from the AAPT paper and is published here to illustrate the strong role the forerunners of the Federal Highway Administration played in developing and standardizing asphalt testing in the United States. The article also includes the *folklore* surrounding the development of some of the early tests.

Introduction

Roadbuilding dates back to ancient times, and the use of *asphalt* dates back to the days of Babylon (600 B.C.). However, the modern paved highway as we know it first appeared in the United States just before the beginning of the twentieth century. Records for that period show that in 1904 there were 6,000 miles of improved roads in the United States *(1)*.[1] However, the term *improved roads* implied only that the roads had been graded, drained, and surfaced with a hard material or combination of materials, or that some preparation had been applied. By this definition *gravel* roads were classified as improved. Except in urban areas, paved roads as we recognize them today were few and far between.

[1] Italic numbers in parentheses identify the references on page 15.

Today, there are over 2.9 million miles of improved roads, of which 52 percent (about 1.5 million miles) are improved by some type of bituminous treatment. The remainder includes concrete (4 percent) and select soil and aggregate materials (44 percent). Excluding the latter, bituminous types of pavements comprise about 93 percent of the mileage of all-weather surfaces.

The degree to which bituminous or asphalt construction has grown during the twentieth century is illustrated by statistics for the State of Virginia. In 1904 the total highway mileage in Virginia was estimated to be 52,000 miles, of which 1,600 miles were improved by hard surface, sand-clay, or combinations of materials *(2)*. Only 4 miles of these roads were bituminous pavement as compared to nearly 36,000 miles of bituminous pavements in 1971. Many other States have comparable increases in mileage of asphalt roads.

The specifications and tests used for controlling the construction of the early roads were generally created for specific projects and often were merely on-the-spot judgments by the engineer as to what would be satisfactory. As the asphalt paving industry grew, the need for definite specifications and test methods became apparent. Representatives of industry, consulting firms, and Federal, State, and municipal governments all made significant contributions. This article traces some of those developments with special emphasis on the contributions of the Federal government agencies that were the forerunners of the Federal Highway Administration.

Advantages of Early Asphalt Pavements

In the United States, the first asphalt pavements were built during the 1870's, using natural asphalt and aggregate. The most famous of these was constructed on Pennsylvania Avenue in Washington, D.C., around 1876–1878.

These early pavements were built solely in urban areas and had some obvious advantages over the blocks or cobblestones they replaced. The April 16, 1879 Transactions of the American Society of Civil Engineering (ASCE) contain an article by Edward North in which he discusses these advantages at some length. A summary of several pamphlets issued by the Barber Asphalt Company around 1893 shows that the following were the major claims being made at that time *(3)*:

- *More durable.*

- *Smoother,* particularly compared with Belgian block, cobble, and wood block. Asphalt pavements did not disintegrate under impact or attrition, consequently producing neither mud nor dust.

- *More healthful.* Joints in block and cobblestone pavements were receptacles for horse urine and manure. Asphalt pavements provided good surface drainage and were easily cleaned by flushing with water.

- *Less noise.* Physicians claimed that the noise from horses' hoofs on block or cobblestone was a leading cause of nervous disease in large cities.

- *Safer.* In a survey in 1885 on streets in 10 cities, 800,000 horses were observed for 192 days. The results showed that a horse traveled an average of 585 miles before falling on *asphalt* and 413 miles before falling on block or stone. Asphalt did not polish. Brick was observed to be slippery.

- *Lower cost,* compared with granite Belgian block and wood block on concrete foundation. Another economic advantage of sheet-asphalt pavements over the rough types was evident in an 1885 report by the City of Philadelphia, Pa., showing that by using such pavements the cost of repairs to vehicles in that city could be reduced by $1 million annually *(4)*.

Even though some of the health hazards have changed with full development of the automobile and methods of measuring skid resistance are no longer dependent on how far a horse will travel before falling, most claims of advantages of asphalt pavements have been proved and are features of good design and construction practice today.

Early Sources of Asphalt

From 1878 to 1900 most of the asphalt used in the construction of sheet asphalt, penetration macadam, and mixed macadam (now called asphalt concrete) was obtained from the surface of an asphalt lake on the island of Trinidad. It was cut out in chunks and water and excess organic material were removed, leaving a solid asphalt containing approximately 52 percent bitumen (soluble in carbon disulfide), 39 percent mineral matter, and 9 percent insoluble organic matter.

Because the refined product was a solid, the asphalt had to be softened to the desired consistency by adding fluxes, which were usually residual materials obtained from the distillation of crude petroleum. The fluxed asphalt was heated and added to hot aggregates usually consisting of sand or blends of sand and crushed stone most of which passed a No. 10 screen. The dust passing the No. 200 screen ranged from 10 to 15 percent. The bitumen content ranged from 10 to 11 percent. The resulting mixtures were very similar to the sheet asphalt mixtures still used today in Washington, D.C., and other cities.

Bermudez Lake asphalt found in Venezuela came into use during the 1890's and was a major source by 1901. Like the Trinidad Lake asphalt, the Bermudez asphalt had to be mined and the water and extraneous inorganic and organic matter removed. The crude asphalt was composed of about 66 percent bitumen, 31 percent water, and 3 percent insoluble organic and inorganic matter. It was softer than the Trinidad Lake asphalt, but it still had to be softened by adding petroleum fluxes. Both lake asphalts had remarkable uniformity. The suppliers claimed the lake asphalts from Bermudez and Trinidad had superior ductility, tenacity, and cementitious qualities not found in other asphalts.

Until 1900 the promoters of lake asphalts from Trinidad and Bermudez exercised a monopoly and controlled the development of the bituminous paving industry. Petroleum asphalt—the residual material from asphaltic petroleum after the volatile gasoline and other distillates have been removed—came into use in the United States about 1900. Some of the asphalt suppliers and contractors considered the petroleum asphalts to be inferior to Trinidad and Bermudez asphalts and attempted to restrict their use. In 1902 only 20,000 tons of asphalt were refined from petroleum in the United States, but today almost all of our so-called *black top* roads are made using this material as the binder.

The introduction of the automobile at the beginning of the twentieth century created the need for pavements in rural areas to be dust free and serviceable under all weather conditions. Until then, the only improvement made to country roads was a surfacing with gravel or water-bound stone macadam. Such surfaces helped prevent getting stuck in the mud, but it was soon found that they would not withstand the destructive action of automobiles. The need for serviceable pavement led to the dust palliative and surface treatments for low-cost roads, with the accompanying development of liquid asphalt materials for cold applications.

Early Specifications and Test Methods

The early specifications for asphalt in the United States were based on the appearance of the crude Trinidad asphalt and on analytical tests to determine amounts of bitumen (soluble in carbon disulfide), insoluble organic matter, and inorganic matter (fig. 1). Such specifications and tests were devised merely to identify the source of asphalt, to the exclusion of other source materials. Much of the early asphalt construction was entirely a matter of *rule of thumb,* resulting in some excellent pavements and some partial or total failures. As the asphalt industry grew, the need for better tests and standardization became evident. This led to a number of empirical tests, some of which became the standards of the industry. One example is the *penetration test*—until recently the worldwide standard for asphalt consistency.

Figure 1.—The BPR laboratory about 1915. Apparatus for determining bitumen content is essentially same today as then; however, trichloroethylene is used instead of carbon disulfide because of fire hazards with carbon disulfide.

In 1888 H. C. Bowen of the Barber Asphalt Paving Company invented the first penetrometer which he called the "Bowen Penetration Machine." Its main purpose was to determine consistency and the proper degree of fluxing the asphalt cement. Before Bowen's invention, the method of testing the proper degree of softening of the asphalt cement was by chewing. If the material crumbled on chewing, it was too hard. If it stuck to the teeth, it was too soft. If it was pliable like chewing gum, the consistency was correct. Even after the invention of the penetration machine, the chewing method—crude as it may appear to the uninitiated—served as a valuable check. An "asphalt man" prided himself on the fact that by chewing the material he could very closely estimate the results obtained by the machine. Clifford Richardson, one of the leading asphalt technologists of his time, expressed his doubt that the penetrometer was absolutely necessary except as a matter of record *(4).*

In 1903 A. W. Dow, Inspector of Asphalt and Cements for the District of Columbia, described another machine of this type which he developed *(4).* Later, another penetrometer was designed by the New York Testing Laboratory to overcome some of the deficiencies of the other machines (fig. 2).

All these machines measured consistency by the depth to which a No. 2 sewing needle would penetrate the asphalt under certain specified conditions of load, time, and temperature. Since the needle most often used was the No. 2 needle manufactured by R. J. Roberts, the American Society for Testing and Materials (ASTM) in 1915 adopted the following recommendation:

> The needles for this test shall be R. J. Roberts Parabola Sharps No. 2. The needles for this test shall be carefully selected by the use of a hand glass, rejecting all that are manifestly of unusual shape or taper. Needles thus selected shall be compared with a standard needle and further rejections made of those which vary by more than one point from that obtained with the standard needle, on a sample having a penetration of approximately 60 *(5).*

In practice, the *standard* needle was the original needle furnished with the penetrometer. In a report published in 1916, Charles S. Reeve and Fred P. Pritchard of the Office of Public Roads and Rural Engineering (OPR and RE) showed the inadequacies of this approach because the examination of

Figure 2.—Penetration test apparatus as used in BPR laboratory from about 1915 to 1940. The penetrometer was the New York Testing Laboratory Model.

many needles was required to select only a few giving the same results *(5)*. This difficulty in obtaining standard needles led to the development by the OPR and RE of a needle with a cone-shaped end of specific dimensions that could be easily duplicated. The dimensions established at that time remain standard today with one exception: Present specifications call for a needle having a *truncated-cone* point, not one honed to a sharp point as originally specified.

An interesting account of how the truncation came about was told to the authors of this article by R. H. Lewis, one of the early pioneers in asphalt testing who worked closely with Pritchard and Reeve during this time. Pritchard—working with his own small lathe in the Office of Public Roads and Rural Engineering's laboratory—designed and sharpened the needle to the dimensions stated in his report. However, after publication of the final report and acceptance of the dimensions, the job of making the needles was given to one of the skilled toolmakers in the Bureau's shop. After discovering that his equipment produced a sharper point, and consequently a different result, than the original tapered needle, it was necessary to determine by trial and error the degree of bluntness required to duplicate the needles prepared to match the No. 2 Roberts sewing needle. The small diameter of the *truncated cone* was then defined.

In addition to the penetration test for consistency (viscosity), other tests that were normally used to determine the properties of the residual petroleum fluxes included flash point, specific gravity, loss on heating at various temperatures and times (fig. 3) , character of the residues from loss tests, bitumen insoluble in 88° Baumé naphtha, and paraffin scale. Some reports published as early as the 1890's showed that the amount of volatile reported by 29 cities ranged from 1.4 percent to 12.3 percent, indicating that the fluxed asphalts varied widely in their resistance to hardening during plant mixing and service and that the control of the volatility of the fluxes was very important. The wide range in volatility probably overshadowed any other quality characteristics that might have been associated with asphalt and pavement performance.

During this same period, methods to control asphalt paving mixtures were also developed. Sand screens became generally available and were used to determine and control the grading of sands prior to use and during construction.

By 1895 the asphalt industry recognized the need for laboratories at or near the asphalt mixing plants *(6)*. Such laboratories were equipped to determine penetration at 78° F (instead of at 77° F, the present test temperature), asphalt composition (insolubility in carbon disulfide), and bitumen content of mixtures, by dissolving the asphalt in carbon disulfide and separating the solution from the aggregate by a percolation method or by a centrifuge machine (fig. 4). To assist in judging whether or not the proper amount of asphalt was being used during construction, *pat-stain* tests were made on the sand-asphalt mixtures. In these tests, a small *pat* of asphalt was pressed between several layers of filter paper and a judgment made on the basis of the number of layers of paper that became stained with asphalt.

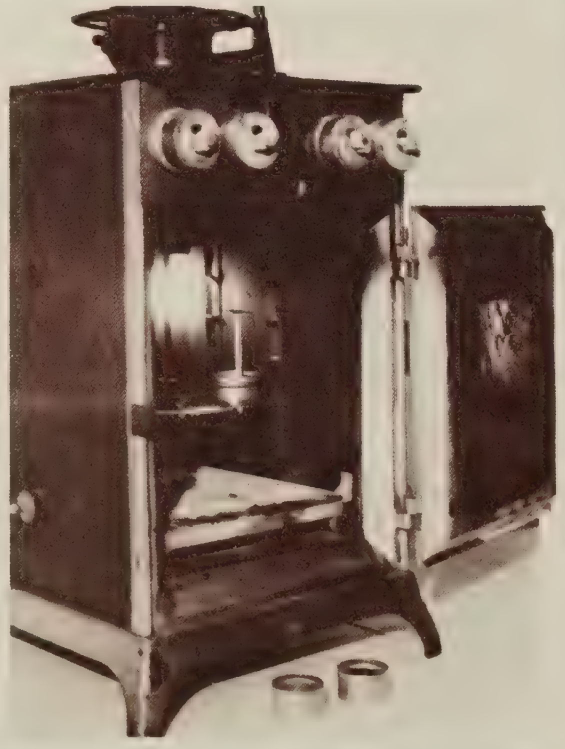


Figure 3.—Loss on heating oven was used in BPR laboratory about 1920–40. The original work to develop the Thin-Film Oven Test was done with this oven.

As early as 1898, A.W. Dow recognized the importance of the viscosity of the liquid asphalts used for such purposes as dust palliatives, prime coats, or surface treatments. The earliest viscometer that came into use was the Engler, which was a German development. Although its main use was in the tar industry, it was used to a limited extent for determining the consistency of liquid asphalts. The *Furol* orifice was developed in the 1920's by the ASTM Committee D–2 on petroleum products and for a

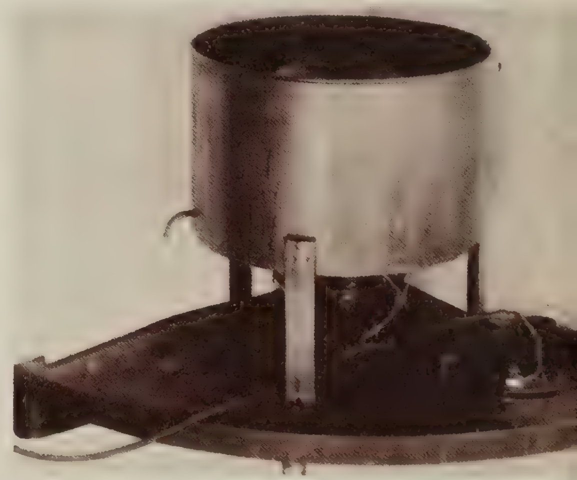


Figure 4.—One of the original asphalt extractors used in the BPR laboratory. The inverted bowl was a BPR innovation and was used by BPR for a number of years.

long time the *Furol* viscometer was the standard instrument for measuring viscosity of liquid asphaltic materials. *Furol* is a contraction for fuel and road oils.

The exact origin of the float test could not be determined. It was devised sometime after 1900 and is referred to by Hubbard and Reeve *(7)*. It was used mainly for measuring the consistency of asphalts too viscous to measure with the Engler viscometer and too soft for the penetration test. One story that could not be verified is that the dome-like top of an ether can was used as the float in the first tests, but apparently the float and plug mold, as we know it today, was standardized very early.

By 1903 the pattern of required tests began to emerge. In that year A. W. Dow presented a paper that described the penetration test for measuring consistency; the ductility test—Dow's invention—for measuring adhesion and cementing characteristics; the loss on heating test and the penetration of the residue to determine the stability of asphalt during heating and mixing; solubility in carbon disulfide and petroleum naphtha; and a water resistance test *(8)*.

In addition to the above tests, Richardson recommended tests for fixed carbon, sulfur, paraffin scale, specific gravity at 78° F, flash point by closed cup and open cup methods, and flow *(4)*. Many of these tests as listed by Dow and Richardson became the major requirements of early specifications and a number of them are still in use today.

Until 1903 there was little or no effort to develop standards for tests and specifications for asphalt, asphalt paving mixtures, or construction practices. The large asphalt paving companies such as Barber and Warren-Scharf developed their own control standards and methods to determine the suitability of materials for use in pavements. Working individually, the pioneers in the development of test methods and schemes of analysis of asphaltic materials had accomplished much in providing an understanding of asphalts and their function in paving mixtures. They apparently discussed their various viewpoints in technical society meetings or through personal correspondence, but each was acting as an expert in his own right.

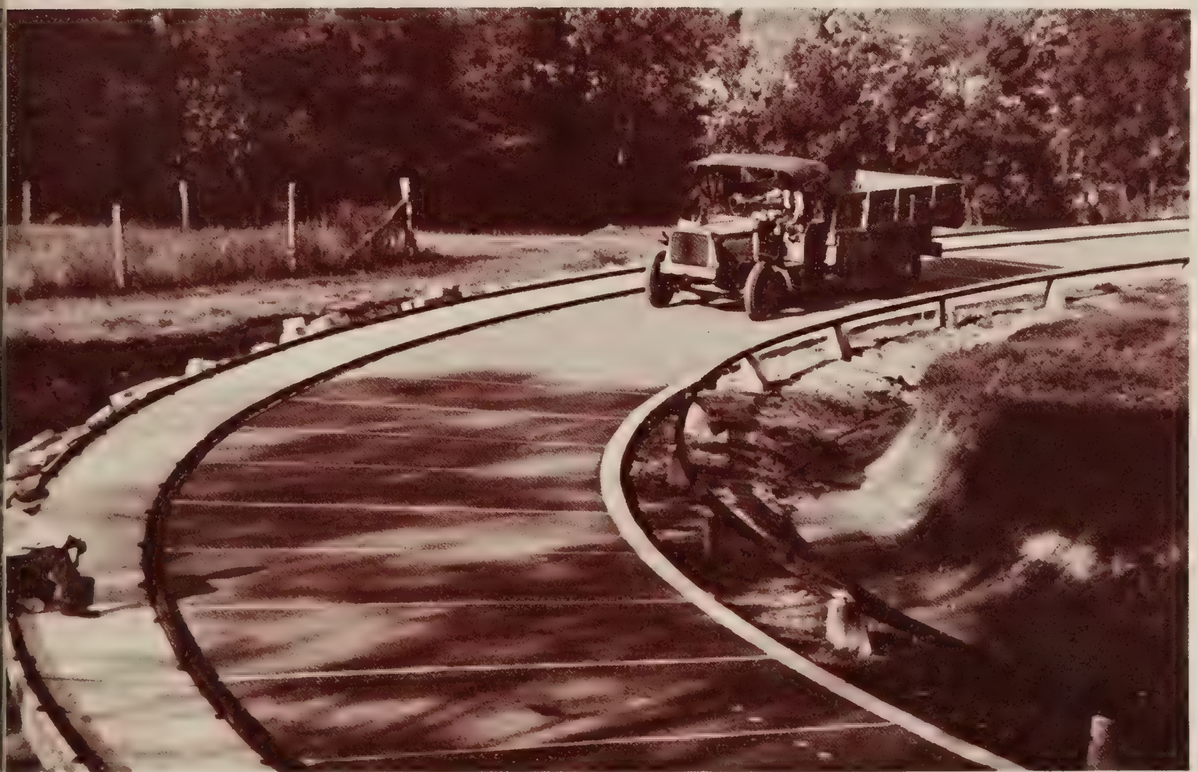


Figure 5.—View of the circular track at Division of Tests site in Arlington, Va., in early 1920's. This track was used to establish a number of the principles of pavement and base course design and was probably the first accelerated testing system used in the United States. "Traffic" was provided by the truck driven continually in circles for 8 hours each day. Note the solid tires on the truck.

The Federal Government's Role

Although the Office of Road Inquiry was established within the U.S. Department of Agriculture (USDA) in 1893, until 1901 the Federal Government had taken a minor role in roadbuilding. In that year, Congress established the Office of Public Roads and appropriated funds to establish a mechanical and chemical laboratory for testing, without charge, road materials from all parts of the United States. Logan Walter Page of Harvard University was in charge of the laboratory *(9)*. By 1911 the Office of Public Roads consisted of 11 employees. Prevost Hubbard, Charles S. Reeve, Albert T. Goldbeck, and Edwin C. Lord made up a laboratory staff that undertook the investigation of materials for highway construction and the standardization of test methods and specifications.

The Division of Road Material and Research was created in July 1915 (figs. 5 and 6). Shortly after this date (probably in 1918) the laboratory became known as the Division of Tests. It was this division that evolved, through many reorganizations, into the Offices of Research and Development of the Federal Highway Administration. Today the Materials Division in the Office of Research retains the responsibility of test method standardization and materials specifications that made up the major portion of the work of the Division of Tests. It is of interest to note that the FY

1915 annual report of the Office of Public Roads showed that during that fiscal year the laboratory tested 1,453 samples which came from every State except Wyoming. This number included 338 bituminous materials, 115 metals, and about 1,000 samples of rock, slag, sand, soils, etc.

In 1903 the American Society for Testing and Materials took the first step toward standardizing highway materials tests and specifications by forming a major committee to provide these tests and specifications. The Office of Public Roads played an important role in this activity. Page, Director of the Office of Public Roads, was appointed acting chairman of the organizing group, and served until 1919 as chairman of Committee D–4 on Road and Paving Materials. Bureau of Public Roads and Federal Highway Administration personnel have continued to contribute toward national standardization by providing leadership in ASTM.

In 1911 the Office of Public Roads published Department of Agriculture Bulletin No. 38 *(7)*, which presented the methods then used by that office for examining bituminous road materials. At that time, no standard methods had been adopted and the need for such standards was imperative. The bulletin included test methods and schemes of analysis to classify and determine the suitability of various types of bituminous materials for use in road construction.

For the purpose of examination bituminous road materials may be classified under the following headings:
1. Petroleums and petroleum products, including residual petroleums, fluxes, oil-asphalts, and fluxed or cut-back oil-asphalts.
2. Malthas.
3. Asphalts and other solid native bitumens, and asphaltic cements produced by fluxing them.
4. Tars and tar products.
5. Mixtures of tar with petroleum or asphalt products, bituminous emulsions, and factitious asphalts.
6. Bituminous aggregates, including rock asphalts or bituminous rocks, bituminous concrete and asphalt or other bituminous topping *(7)*.

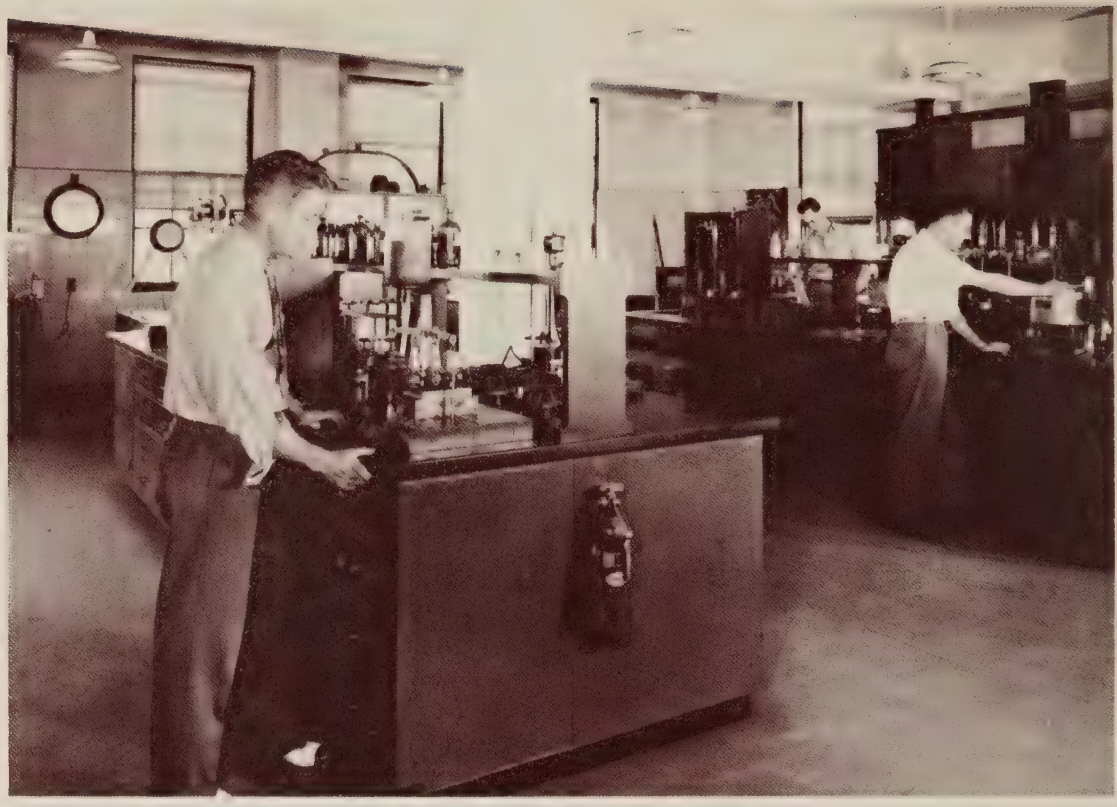


Figure 6.—The BPR Bituminous Laboratory at Gravelly Point, Va., near National Airport, in 1947.

The recommended tests for each type of material were described in the bulletin in detail. In general these included tests for specific gravity, volatilization, bitumen soluble in carbon disulfide, bitumen insoluble in 86° Baumé naphtha, fixed carbon, Engler viscosity, penetration, float, melting point, flash point, and paraffin scale.

In 1915 Hubbard and Reeve published a professional paper on methods of test that expanded on the information in Bulletin No. 38. Their intent was to present the methods for examination of road materials "in such a form that with little practice and proper equipment, such examinations may be made by any intelligent person" *(10)*.

The Federal Aid Road Act of 1916 initiated the joint participation of the Federal Government and the States in the construction of highways. Thus, it became necessary for the Office of Public Roads and Rural Engineering to cooperate with the States in materials and methods being used in construction. Until then, less than one-half of the States had proper testing facilities and many had none at all.

The first general conference between State and Federal engineers on highway materials was held in February 1917 at the request of the Office of Public Roads and Rural Engineering. The Federal representatives met with those from 21 States to develop recommendations on highway materials. The major purposes of the conference were to encourage the establishment of well-equipped State highway laboratories; to recommend adoption of standard methods of sampling, testing, and reporting of results; and to outline a plan for cooperative research on the chemical and physical tests for materials related to use. The recommendations of the conference were published in USDA Bulletin No. 555, "Standard Forms for Specification Tests, Reports, and Methods of Sampling for Road Materials" *(11)*.

Typical Specifications for Bituminous Road Materials

New specifications published by Hubbard and Reeve in 1918 superseded all prior specifications *(12)*. Their purpose was to provide the engineers with information: (1) To secure a suitable grade of material, (2) to insure reasonable uniformity of supply, and (3) to sufficiently identify the material by type.

In 1918 Hubbard and Jackson published specifications for *broken-stone* surface treatment, penetration macadam, coarse and graded bituminous concrete, and sheet asphalt *(13)*. In their publication, specifications also were given for gravel, sand, and mineral filler. Requirements for stone included French coefficient of wear, toughness, and grading.

Origin of AASHO Standard Specifications and Methods of Test

The American Association of State Highway Officials (AASHO) was organized in 1914, and in 1919 answered the need for uniform standard methods of testing for use by all testing laboratories affiliated with the association by forming a Committee on Tests and Investigations. In 1920 this committee met in Washington, D.C., with representatives of the Bureau of Public Roads[2] to standardize the work of the State highway departments and the Bureau's laboratories. Although this was the second such conference to develop standard and tentative methods of sampling and testing highway materials, it marked the beginning of the AASHO Committee on Materials that later developed the AASHO Standards.

USDA Bulletin 949, published in October 1921, was the first publication of *recommended* standards endorsed by an AASHO committee *(14)*. The introduction of this bulletin stated that, when available, test methods developed by the American Society for Testing and Materials were adopted with or without minor revisions. Other tests that had not been standardized by ASTM were adopted from USDA bulletins contributed by the Bureau of Public Roads. Bulletin 949 was superseded in 1924 by Bulletin 1216 *(15)*. These test methods were adopted as standard by AASHO and approved by the Secretary of Agriculture for use in Federal Aid Road Construction. Bulletin 1216 remained the AASHO *standards* until 1931 when AASHO published the first edition of "Tentative Standard Specifications for Highway Materials and Methods of Sampling and Testing." Bureau of Public Roads (and later, Federal Highway Administration) personnel have assisted in the publication and served as editor of each edition of the Highway Materials Standards. The 11th edition of the standards, entitled "Highway and Transportation Materials," was issued in September 1974 and reflects AASHO's name change to the American Association of State Highway and Transportation Officials (AASHTO).

The AASHTO developments have been basically consumer or Government oriented, but at the same time many of those involved in AASHTO—both State and Federal employees—have worked with ASTM Committee D–4 and others in developing ASTM standards that recognize significant cooperation and inputs from industry and universities.

[2] The title of the Office of Public Roads and Rural Engineering was changed to Bureau of Public Roads by Congress on July 1, 1918.

Standard Specifications for Asphalt

The publication of Bulletin 949, and later 1216, did much to standardize test methods. But, except for the publication of Bulletins 691 and 704 by the USDA, little progress was made with respect to national standardization of specification requirements until 1923. In that year, a joint conference of representatives of producers, distributors, users, and other interests drafted a simplified practice recommendation for asphalt *(16)*. The conferees were faced with 88 different specifications or grades of asphalt and 14 types of asphalt joint filler. The deliberations of the conference resulted in a unanimous recommendation that the number of grades of asphalt used in all types of bituminous pavement construction be reduced to nine with definite penetration limits. Asphalt joint filler specifications would be reduced to four. The recommended penetration grades of asphalt cement were:

25–30	50–60	100–120
30–40	60–70	120–150
40–50	85–100	150–200

Recommended practice R4 was reaffirmed in 1926 and again in 1936 at which time a 70–85 penetration grade was added to satisfy its widespread use in western States.

Specifications similar to those given in the simplified practice recommendation were first adopted by AASHO in 1926 except that AASHO did not include the 25–30 and 150–200 grades. The General Services Administration adopted a similar Federal Specification in 1943 and ASTM adopted it in 1947. However, with the supply of asphalt from new sources, and with different refining methods, many of the States and other government agencies wrote special requirements in an effort to maintain a limited number of approved sources and to exclude other than steam- or vacuum-refined materials. The extent to which such limitations are needed has always been controversial, even among knowledgeable asphalt technologists and highway engineers.

The stipulation that petroleum asphalt must be steam or vacuum refined has now been removed from all national specifications. Two requirements based on tests developed after the initial standardization have attained general recognition and have been adopted by many agencies. These were the Oliensis Spot Test in the 1930's to identify asphalts produced by thermal cracking and the Thin-Film Oven Test in the 1950's to identify asphalts which harden excessively during hot mixing. The Thin-Film Oven Test was developed by the Bureau of Public Roads in 1940, but more than 15 years were required before its general acceptance. AASHO modified its petroleum specification in 1959 to drop the 50–60, 70–85, and 100–120 grades, thus establishing the *skip grading* system. AASHO also first adopted the Thin-Film Oven Test in 1959.

The next major change in specifications for asphalt cements was in 1970 when AASHO and a number of State highway departments adopted a specification based on viscosity grading at 140° F. Today AASHTO has retained penetration grading as an alternative. About 37 States now use viscosity grading or accept either viscosity or penetration grading as alternatives depending on the supplier's choice. It is expected that ultimately all States will shift to a viscosity grading. In this effort, the Bureau of Public Roads conducted in-house research, supported research by States, and worked closely with industry groups and AASHO in arriving at the final specification. Considerable controversy surrounded this change and a number of papers and symposia on the subject can be found in ASTM, Highway Research Board, and AAPT literature as well as in literature from other organizations.

Liquid asphalts

Various types of liquid asphalts came into extensive use during the 1920's for low-cost construction of pavements. The principal purpose of liquid asphalts was to provide materials that could be applied or mixed cold or slightly warmed without the use of expensive plant equipment. They were used primarily with local aggregates such as pit and raw sands and gravels. Liquid asphalts are classified as slow, medium, and rapid curing.

The slow-curing materials are asphalts dissolved in high-boiling petroleum distillates that do not evaporate at normal road temperatures or would do so very slowly; the medium-curing materials use kerosene or its equivalent as the diluent or solvent; and the rapid-curing materials use gasoline. Each of these materials was used in the following types of construction:

- Dust laying
- Surface treatment
- Mix-in-place (road mix)
- Pre-mix (plant mix)

Because of the use of liquid asphalts in local areas, engineers devised many specifications for them, and new tests were developed to measure and control their properties. Each State and community often worked independently. In 1930 the Asphalt Institute and the Bureau of Public Roads made a cooperative study of the specifications and tests and found that in 33 States, 125 different specifications were being used. The cooperative study was later expanded to include State highway departments. After extensive study of the properties of rapid- and medium-curing cutback asphalts and road oils and numerous asphalt user–producer meetings, a set of simplified specifications for each of the three types of materials was developed. With the simplification of specifications in the 1930's, a new distillation test was developed for use in identifying and controlling the type of liquid asphalt.

Deficiencies in the simplified specification were corrected and the revised rapid curing (RC) and medium curing (MC) specifications were adopted by AASHO in 1942 and the slow curing (SC) specifications in 1949. The development of the kinematic viscosity method for measuring the consistency of liquid asphalts prompted a further change in specifications for the RC, MC, and SC materials. The number of grades was reduced from six to four for RC and SC materials and from six to five for MC materials. The limits of the viscosity grades were changed from Saybolt Furol to kinematic viscosity at 140° F.

The Asphalt Institute and the Bureau of Public Roads cooperated in a series of user–producer workshops held in all areas of the country during 1960–65. These meetings provided a forum for discussing the advantages of grading by kinematic viscosity at 140° F and potential problems involved in changing specifications. As a result, relatively rapid acceptance of the new specifications was attained. They have now been adopted as standard by all national materials groups and by most States. Although not advertised as such, this activity was a highly successful implementation effort.

Emulsified asphalts

Emulsified asphalts were developed initially to provide liquid materials that could be used with little or no heating in the construction of pavements. The emulsions now generally in use are the oil-in-water type. They are prepared with asphalt cements, emulsifying agents, and water. Petroleum distillates may also be present as a part of the dispersed phase.

One of the earliest known uses was a road-oil emulsion manufactured in 1903 to lay dust on roads and streets in Philadelphia, Pa. The emulsion used was prepared from a patented process. In 1911 an experimental pavement was constructed near Washington, D.C., in which a mixing grade emulsion was used. In 1914 Headley developed a mixing grade emulsion using clay and other chemicals as emulsifying agents. The clay emulsions were used to prepare dense asphalt concrete until about 1928. Soap and other types of emulsifiers came into use during the 1920's and 1930's to manufacture rapid and medium setting emulsions.

Rapid setting emulsions were first used in surface treatment and seal coat construction about 1920 and in pre-mix and hot plant mixtures about 1928. Slow setting emulsions came into use in the early 1930's to stabilize soils and sands, and in 1958 for slurry seals. Cationic emulsions were used on an experimental basis in 1949 and were in general use after 1957.

The earliest tests for emulsified asphalts were limited to the determination of water content, oil, and asphalt residue by distillation. The asphalt in the emulsion was recovered by breaking the emulsion with calcium chloride and kneading out the water. Penetration and other tests were made on the recovered asphalt. In some cases, the asphalt was tested prior to emulsification to determine its characteristics.

With the development of rapid, medium, and slow setting emulsions, additional tests came into use in the 1930's to establish requirements for specifications. These usually included Furol viscosity, demulsibility, miscibility with water, sieve, settlement, and stone coating tests. The residue from distillation was tested for penetration, ductility, solubility in carbon disulfide, ash content, and specific gravity.

ASTM adopted tentative specifications for five grades of emulsified asphalt in 1934. AASHO adopted specifications for the same materials in 1935.

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This development activity was conducted in the acoustic laboratory of the Federal Highway Administration's Region 9, San Francisco, Calif., under the sponsorship of the Implementation Division, Office of Development, FHWA.

Noise Produced by Open-Graded Asphaltic Friction Courses

by William L. Williams, Robert A. Kay, and Jerald K. Stephens

Test vehicle at midpoint of test course with tripod-mounted microphone 50 ft from edge of lane.

Field tests were made comparing noise properties of open-graded asphaltic friction courses with surfaces made of portland cement concrete, chip seals, and asphalt-coated dense-graded materials. Three types of tires were used: (1) Standard rib tires, front and rear; (2) standard rib tires, front, and mud and snow tires, rear; and (3) radial retreads, front and rear. Field test results indicate that open-graded asphaltic friction courses generally produce slightly lower noise levels than the other surfaces. Radial rib treads were slightly less noisy than standard rib tires and both were noticeably less noisy than mud and snow tires.

Introduction

The use of open-graded asphaltic friction courses has been increasing. This new design provides a smooth ride and an anti-skid surface at reasonable cost. The noise properties of open-graded asphaltic friction courses were compared with those of surfaces made of portland cement concrete, chip seals, and asphalt-coated dense-graded materials.

Statistical tests were not performed as application of valid statistical procedures would require a much larger data sample than is presented here.

Test Sites and Equipment

Test sites

Roadway surfaces were tested at 16 field sites—five in Arizona, six in California, and five in Nevada (table 1). At each location a 200-ft (61-m)-long test lane was established and microphones and sound-level measuring equipment were installed (fig. 1).

Table 1.—Number and location of test sites

Type of surface	Number of locations			
	Arizona	California	Nevada	Total
Open-graded asphaltic friction course	1	2	2	5
Asphalt-coated dense	1	2	1	4
Portland cement concrete	1	2	1	4
Chip seal	2	0	1	3
Total	5	6	5	16

Certain criteria were necessary for each test-site location. Field tests required a dry, clean pavement surface and a low wind velocity. Test sites had to be level with no obstructions and had to have a quiet period so that the vehicle tire noise level was at least 10 dBA above the ambient noise level.

Test vehicle

The test vehicle was a 1973 Plymouth station wagon weighing approximately 4,600 lbs (2,087 kg).

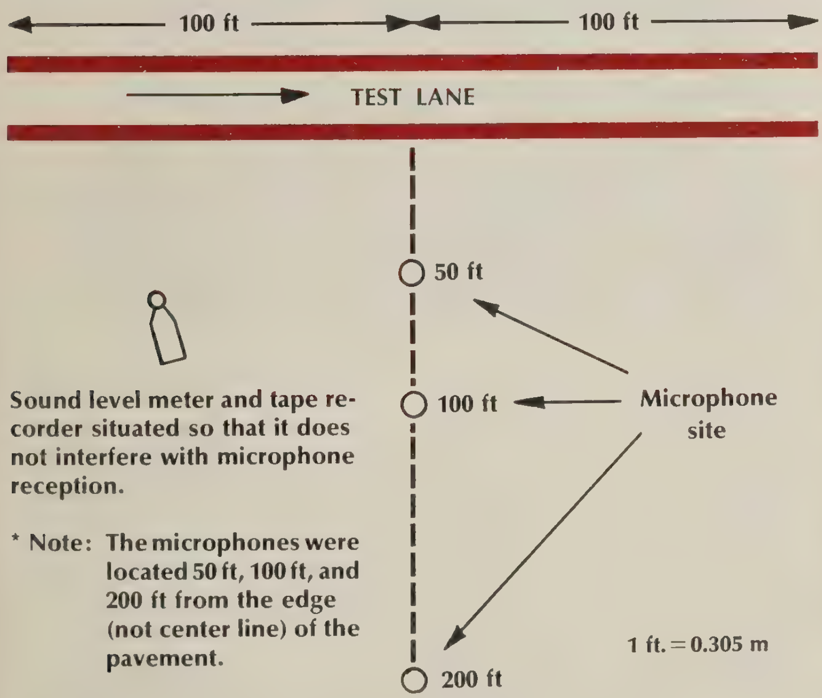

Figure 1.—Typical overall test course setup.

Tires

Three tire-tread designs (fig. 2) were selected for study because they represent automobile tires most commonly in use:

■ Mud and snow tire
Tread depth started and remained at 15/32 in. (1.19 cm) throughout the testing period.

■ Standard tire
Tread depth measured 12/32 in. (0.95 cm) when new; the Nevada testing tread depth averaged 11/32 in. (0.87 cm); the Arizona testing tread depth averaged 10/32 in. (0.79 cm); and the California testing depth averaged 8/32 in. (0.64 cm).

■ Radial tire
Tread depth started and remained at 9/32 in. (0.71 cm) throughout the testing period.

Mud and Snow *Standard Rib* *Radial Recap*

Figure 2.—Tire treads used in field tests.

All the tires were dynamically balanced before testing. The tires were warmed before each series of tests to eliminate vibrations caused by flat spots.[1]

Sound-recording equipment

The noise level generated at the roadway surface/tire interface was measured on a precision sound level meter and recorded on magnetic tape using a portable scientific tape recorder and a remote 1-in. (25-mm), free-field condenser microphone. The microphone was fitted with a wind screen during testing. The recordings, through the sound level meter, were made on the linear scale so that a frequency analysis of the noise could be made later in the laboratory. A real-time ⅓-octave analyzer and a level recorder were used to analyze the field data.

Test Procedure

The test vehicle was coasted through the 200-ft test course at each test site—called a pass-by—at 35, 50, and 65 mph (56, 80, and 105 km/h). The vehicle was coasted in neutral with the engine off which minimized all noises except tire noise.

Two people performed the testing; one drove the vehicle and verified the speed of the pass-by with a stopwatch; the other monitored the equipment and recorded the maximum overall noise levels. One complete series of tests was run for each of the three sets of tires.

Since only one measuring and recording system was available and since measurements were desired at perpendicular distances of 50, 100, and 200 ft (15, 30, and 60 m) from the lane, it was necessary to run three pass-bys at each speed. For each pass-by, the measuring system was relocated. In all, 27 separate measurements were taken at each test site.

The microphone was mounted on a tripod approximately 4 ft (1.2 m) above ground level. Because of the microphone's free-field characteristic, it was positioned to point horizontally toward the midpoint of the test course. The calibration of the equipment was checked after each change in microphone setup.

The field data were electronically analyzed by playing the tape recordings of the vehicle pass-bys through the real-time ⅓-octave analyzer. As the test vehicle passed through the course, the sound level in each ⅓-octave band rose to a peak and then diminished. The analyzer was set to hold the maximum level in each ⅓-octave band, even though these maximum levels were not necessarily reached at exactly the same instant. The maximum A-weighted sound level was also recorded. The data were then plotted by a level recorder. The plot was a ⅓-octave band linear frequency response followed by an overall dBA level for each pass-by (fig. 3). The pistonphone signal tone (123.9 dB at 250 Hz and corrected for barometric pressure) recorded at the beginning and end of each tape provided the calibration for the real-time analyzer.

A. Precision sound level meter, with windscreen
B. 1/3 band octave analyzer and level recorder
C. Tape recorder

Field Test Results

The sound level data from the individual test sites have been averaged and are shown in table 2 for each type of tire tread on each type of surface. The 35-mph test at the 200-ft microphone location was eliminated because the dB levels were too near the ambient level causing the data to be of questionable value.

[1] There is a slight error in the procedures since the tire tread depth was not held constant. It has been found that tire noise tends to increase as tread depth decreases, and increases proportionately as tread wears away.

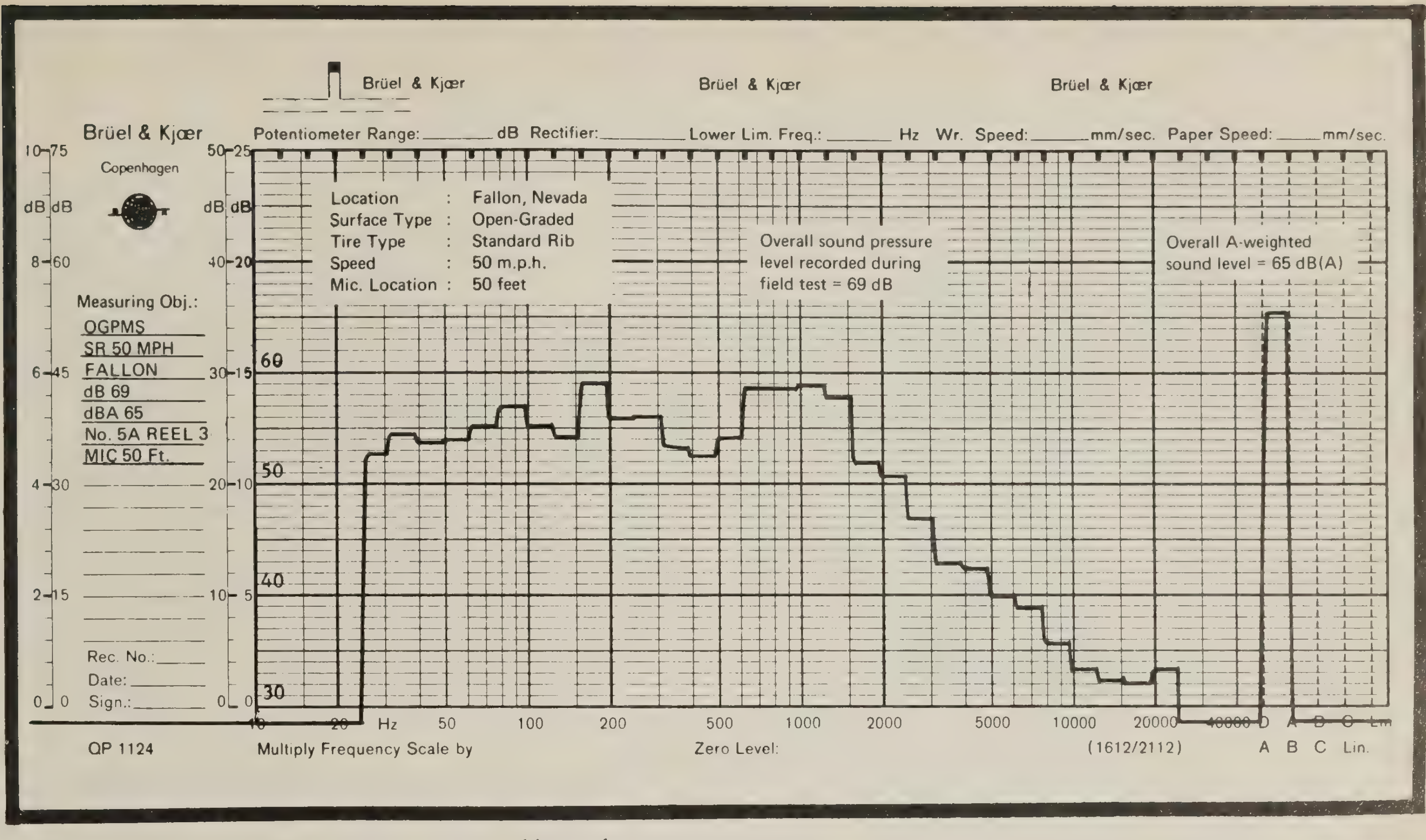

Figure 3.—Typical noise level recorder printout of linear frequency response.

Table 2.—Average sound level, dBA, of each type of tire tread on each type of surface

Surface	Microphone location								
	50 feet			100 feet			200 feet		
	35 mph	50 mph	65 mph	35 mph	50 mph	65 mph	35 mph	50 mph	65 mph
Mud and Snow Tire									
Open-graded asphaltic friction course	63	71	74	57	64	67	—	55	59
Asphalt-coated dense	66	72	77	59	66	70	—	60	64
Portland cement concrete	66	72	78	58	65	70	—	58	62
Chip seal	67	72	76	59	66	69	—	58	62
Standard Rib Tire									
Open-graded asphaltic friction course	60	64	68	53	58	62	—	50	53
Asphalt-coated dense	62	68	72	55	60	64	—	56	59
Portland cement concrete	63	67	71	55	61	63	—	54	56
Chip seal	64	70	73	57	62	67	—	54	60
Radial Recap Tire									
Open-graded asphaltic friction course	57	63	67	52	56	60	—	47	52
Asphalt-coated dense	61	66	69	53	58	63	—	54	55
Portland cement concrete	60	65	70	53	58	63	—	52	55
Chip seal	64	69	72	57	62	66	—	53	57

Effect of tread design on the noise-producing characteristics of the various surface types is demonstrated in figure 4. Analysis of this figure indicates that the radial recaps are the quietest of the tires, the standard ribs a close second, and the mud and snow tires are several dBA louder on all four surfaces. The radial recaps and standard ribs are quietest on the open-graded asphaltic friction course, a little louder on the two dense surfaces, with the highest sound level reading obtained on the chip seal. At higher speeds, the characteristics of the mud and snow tires caused them to form a significantly different pattern from the other two test tires. They are quietest at 65 mph on the two porous surfaces—open-graded asphaltic friction courses and chip seals—even though the chip seal was found to be the noisiest surface overall. The mud and snows were noisiest on the portland cement concrete with the asphalt-coated dense surface just 1 dBA lower. It should be noted that the open-graded asphaltic friction course is less noisy than the other three surfaces for each combination of speed and for each combination of tread design.

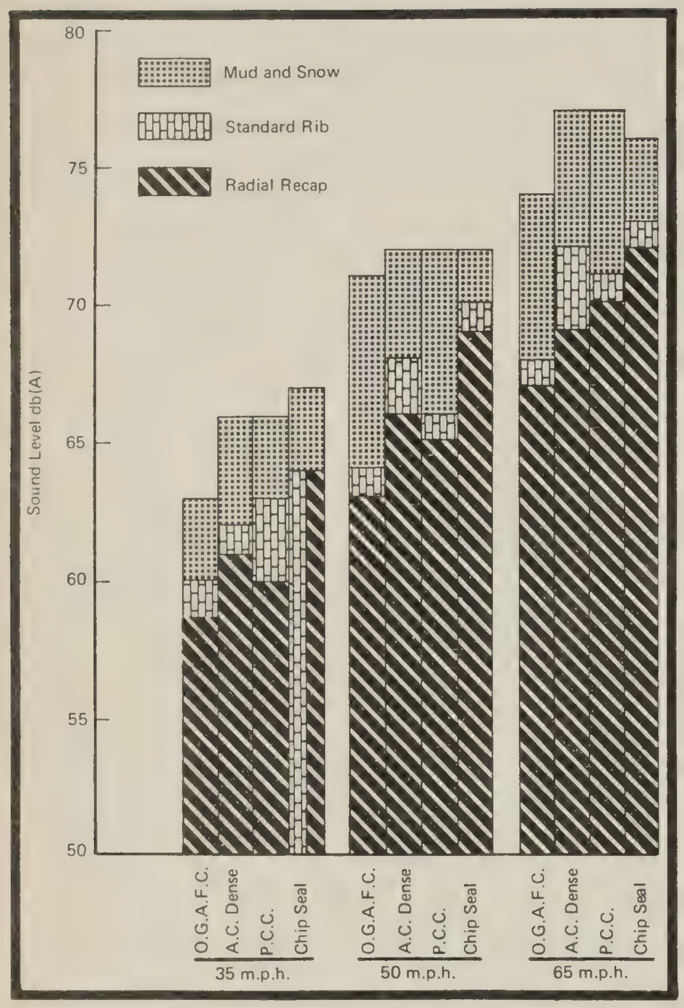

Figure 4.—Sound level, dBA, for each type of tire tread on each type of surface (microphone at 50 feet).

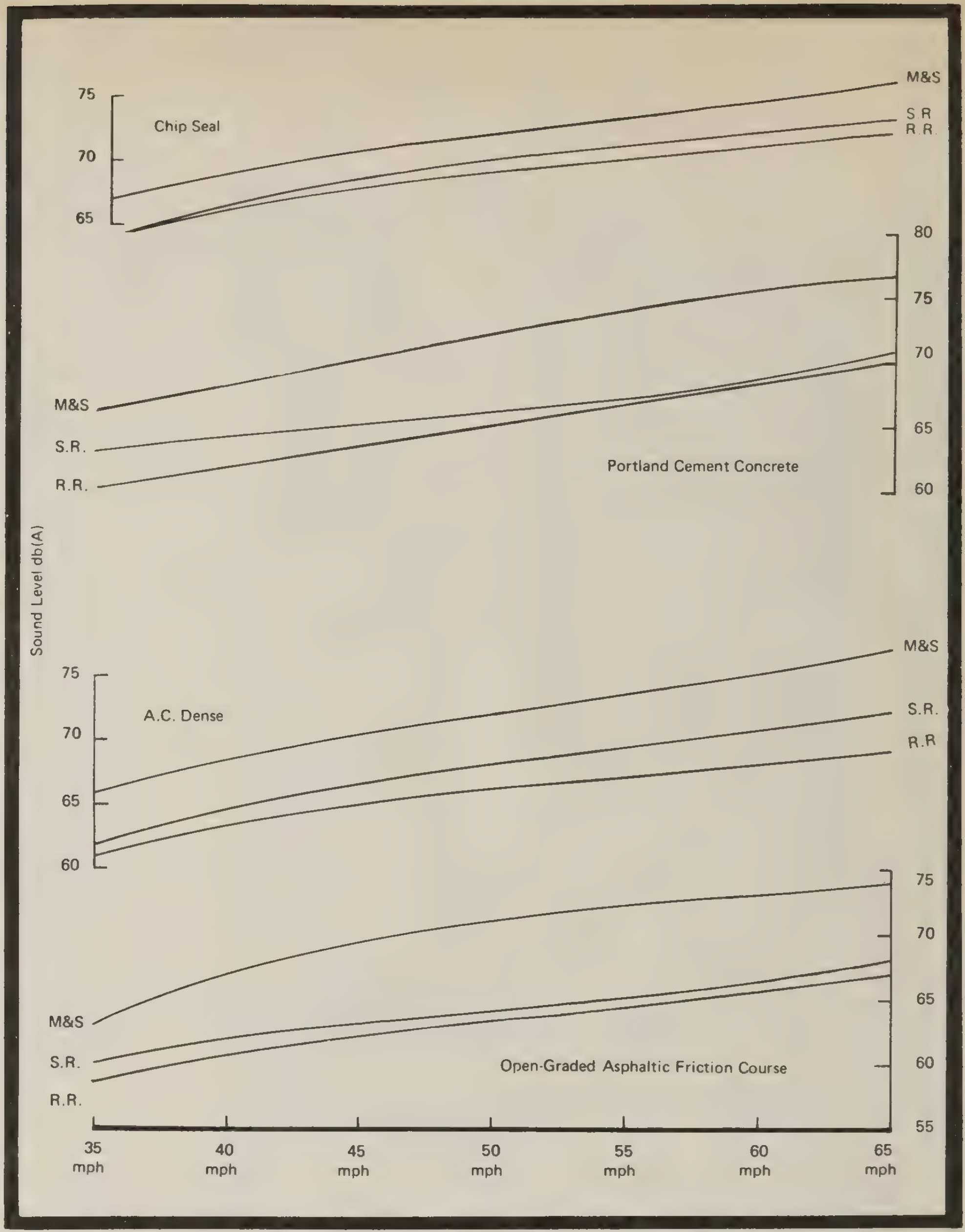

Figure 5.—Sound level-speed relationships for each type of tire tread (microphone at 50 feet).

The effect of speed on the sound level of each of the pavements studied is shown in figure 5. The noise level of the two porous surfaces—open-graded asphaltic friction course and chip seal—is affected less by speed than the portland cement concrete but only slightly less than the asphalt-coated dense roadway surface. The rate at which the sound level increased was approximately the same for each set of tires on any one of the pavements tested. For example, if one tire had a difference of 6 dBA from 50 to 65 mph, the other two sets of tires would show nearly the same difference on that surface.

Conclusions

- The open-graded asphaltic friction course generally produces slightly lower noise levels than the other three pavement surfaces tested. This holds true for all combinations of tire tread design and vehicle speeds.
- The use of an open-graded asphaltic friction course to increase pavement skid resistence also tends to slightly lower tire-pavement noise.
- Since the radial rib and standard rib treads were similar in design, their sound-generating characteristics were found to be similar. Throughout the entire test series, the radial tire was on the average 1½ dBA quieter than the standard tire. The heavily cleated mud and snow tire was found to be 4 dBA louder than the standard tire. It is therefore concluded that although the noise difference between standard and radial rib tread designs would not be perceptible in normal on-the-street usage, the conversion to snow tires during the winter months could result in a discernible increase in tire-pavement noise.

ACKNOWLEDGMENTS

The Federal Highway Administration gratefully recognizes and thanks the following organizations for their significant contributions to this project:

- The Arizona Highway Department.
- The California Department of Transportation.
- The Nevada Highway Department.

Single-Vehicle Accidents Involving Utility Poles

—courtesy, Washington, D.C. Metropolitan Police.

by Nicholas L. Graf, James V. Boos, and James A. Wentworth

From the limited data available it appears that utility poles constitute one of the major roadside hazards on our Nation's highways. The data indicate that utility poles are one of the most frequently struck fixed objects along the roadside. It is estimated that utility pole accidents account for more than 5 percent of the national traffic fatalities, or more than 15 percent of the fixed object traffic fatalities.

Assessing and resolving the utility pole accident problem presents a formidable task. Contributing factors which make the problem difficult include sketchy accident statistics, lack of uniform standards and enforcement for locating utility poles, insufficient legal authority for States to undertake corrective action, inadequate right-of-way in many areas, and the high cost of current solutions to the problem. It is the purpose of this article to highlight the severity and complexity of the utility pole accident problem and recommend further specific actions.

Introduction

The magnitude of the utility pole accident problem is difficult to determine as there are relatively few accident statistics presently available with the necessary degree of detail to accurately make such a determination. In addition, attempts to resolve the problem must consider the fact that, unlike other fixed objects occupying highway rights-of-way, utility facilities are not owned by and under the absolute control of either the State or local highway agency. Thus, technical, legal and political issues must be addressed in any program to reduce the magnitude and severity of the utility pole accident problem.

The Problem

Utility poles are generally metal or timber structures used primarily by the electric power companies and the telephone industry for supporting overhead wires and cables. These poles are frequently used jointly by the electric power and telephone industries, and in urban and suburban areas may also provide space for police and fire signal systems, street lighting, cable TV, and other community utility services. Because of their varied use, accident reports may be inconsistent in referring to utility poles, sometimes identifying them as a light pole, telephone pole, or simply as a pole. The majority of utility poles in use are timber, and come in a variety of strengths, wood species, preservative treatments, and lengths.

An attempt was made to estimate the total number of utility poles that are presently located on the right-of-way of public roads and streets. The best information available on the total number of timber poles in service nationwide is from a 1958 report in which it was estimated that there would be 140 million utility poles in service in 1975 *(1)*.[1] A conservative estimate of the number of poles located on public roads and streets would be 60 percent or more of those in service. That would mean more than 80 million utility poles occupy highway right-of-way.

In order to develop an effective program to relocate, rearrange, or convert existing overhead utilities that presently occupy hazardous locations along roadsides, it is necessary to overcome certain legal obstacles involved, primarily who is to pay for such work. When a utility occupies highway right-of-way by permit, the cost of relocation is usually the responsibility of the utility owner. Thus, the States may be reluctant to force utilities to modify, remove, or relocate their facilities when the State cannot participate in the cost.

Federal law sets forth the provisions for Federal fund reimbursement for the relocation of utility facilities under the Federal-aid highway program *(2)*. This legislation is an extremely important fact to consider in any federally funded program to correct roadside utility pole hazards. It provides that when a State pays for the cost of relocation of utility facilities necessitated by the construction of a Federal-aid project, Federal funds may be used to reimburse the State for such cost in the same proportion as Federal funds are expended on the project. Federal funds cannot be used to reimburse the State when the payment to the utility violates the law of the State or violates a legal contract between the utility and the State.

[1] Italic numbers in parentheses identify the references on page 26.

There are presently 38 States which have laws permitting the State to pay for the cost of utility relocation, but such laws contain various types of limitations. For example, several of these States limit the payment of such cost to Interstate projects. Other States authorize payment only for relocating municipally owned facilities. Consequently, there are many instances under present legislation where Federal funds may not participate in the cost of utility relocations or adjustments.

The single-vehicle utility-pole accident problem is not well defined at the national level.[2] Also, statistics identifying the object struck in fatal and nonfatal injury fixed object accidents have been reported by only five States—Kansas, Oklahoma, Pennsylvania, Massachusetts, and Michigan—in their State Summaries of Traffic Accidents for 1972. Moreover, other important factors such as the distance pole was set back from edge of roadway, roadside environment (business, residential or rural), average traffic volume, and operating speeds were not included in State Summaries of Traffic Accidents.

Available information does, however, indicate that utility poles constitute one of the major roadside hazards on our Nation's highways. In some areas of the country they are the most frequently struck objects in run-off-the-road accidents. Data from State Summaries of Traffic Accidents and from an unpublished survey conducted in North Carolina show that the frequency of utility pole fatalities varies from approximately 1 percent of the annual traffic fatalities in Oklahoma to more than 8 percent in Massachusetts. Based on the limited data reported, it is estimated that utility pole accidents account for more than 5 percent of the national traffic fatalities reported annually, or over 15 percent of the fixed object traffic fatalities. That is, utility pole accidents account for an estimated 2,750 fatalities and 110,000 injuries annually. In addition, there are an estimated 250,000 utility pole accidents each year involving property damage only.

[2] J. A. Wentworth, "Motor Vehicle Accidents Involving Utility Poles: Summary of Data Availability," *Offices of Research and Development, FHWA,* February 1973. (Unpublished)

Based on preliminary contacts with a limited number of States, it is believed that a substantial amount of detailed data has been collected that is not reported in the State Summaries. For example, North Carolina did not identify the object struck in fixed object accidents in its 1972 and 1973 State Summaries of Traffic Accidents. However, on investigation it was found that they do have this information for the past several years and it is readily available. All reported traffic accidents are categorized and entered in a data processing system. Using this system, data on any accident category in the system can be recalled quickly and efficiently.

From data available in the aforementioned State Summaries and additional information from North Carolina, the following assumptions regarding utility pole accidents can be drawn:

- Utility poles are one of the most frequently struck roadside fixed objects.
- Sufficient data exists to identify the utility pole accident problem and to establish relationships between accident severity and frequency, and roadside environment.
- A detailed analysis of utility pole location and spacing, traffic density, and average speed vs. frequency and severity of collisions is beyond the scope of the data currently available.
- The magnitude of the utility pole problem dictates that serious attention must be given to this area in a balanced attack on the rigid obstacle problem.

Existing Practices and Programs

Historically, it has been in the public interest for public utility facilities to use and occupy the rights-of-way of public roads and streets. This practice has generally been followed nationwide since the early formation of utility and highway transportation networks.

State and local highway agencies regulate the use of highway rights-of-way by utility facilities in accordance with State and local law. In some cases, this regulation is minimal, while in others, standards for locating utility facilities are well established. These standards vary depending on the functional class of highway involved and the degree of control exercised by the responsible highway authority. Utilities have various degrees of authority to install their lines and facilities on the rights-of-way of public roads and streets. Their authority also depends upon State laws and regulations which differ from State to State. Over the years, State and local highway agencies, in cooperation with the utility industry, developed their own policies for regulating utility use of public roads and streets.

In 1956, at the onset of the Interstate Highway Program, Federal and State highway officials recognized that the access control feature of these important highways could be materially affected by the extent and manner in which public utilities cross or otherwise occupy Interstate freeways. For this reason, in 1959 the American Association of State Highway Officials (now AASHTO) in cooperation with the Federal Highway Administration (FHWA) and the utility industry, issued "A Policy on the Accommodation of Utilities on the National System of Interstate and Defense Highways."

—courtesy, California Association of Highway Patrolmen.

This policy was later extended for application to all freeways. Essentially, the policy does not permit utility facilities to be installed longitudinally along and within freeway rights-of-way, except where frontage roads are provided or in extreme cases under strictly controlled conditions. In addition, the policy contains specific criteria for horizontal clearances of above-ground utility supporting structures. Developing this policy was a landmark decision for it was the first time a national policy had been developed for accommodating utilities on any highway rights-of-way.

During the 1960's, utility and highway transportation networks continued to grow in complexity as modern society expanded and intensified its organization of facilities for service and communications. As these networks grew, the frequency of occasions for them to occupy a common right-of-way or to intersect one another continued to increase as well as the problems stemming from common use. It was evident that there should be some national policy to provide reasonable uniformity in the engineering requirements employed by highway agencies for regulating utility use of highway rights-of-way. On February 15, 1969, FHWA issued a policy on "Accommodation of Utilities" and on October 25, 1969, AASHO issued "A Guide for Accommodating Utilities on Highway Right-of-Way."

The only national standards available for installation and maintenance of electric supply and communication lines are those contained in the National Electrical Safety Code. The Code is voluntary but has been adopted by various governmental agencies and utility organizations.

All the above documents have provided a basis for State and local highway agencies to follow in developing new or modernizing existing accommodation policies. They do not, however, adequately deal with the problem of existing utility pole hazards for the following reasons:

- FHWA policy on utility accommodations primarily concerns new utility installations that are to cross or otherwise occupy highway right-of-way and the relocation and accommodation of existing utility facilities that fall in the path of proposed highway projects. In general, it does not apply to existing utilities along existing highways. Also, its application is limited to active or completed Federal-aid projects.

- FHWA policy requires that each State develop its own utility accommodation policy, which is subject to approval by FHWA. There is no specific criteria prescribed to be used by the States in their policy such as minimum offsets from the roadway for utility poles. This is left up to the individual State, which must necessarily develop a policy in conformity with its laws regarding utility placement on the public right-of-way.

- The AASHO Guide provides only broad criteria relative to the placing of utility poles within highway rights-of-way, and does not establish the relative hazards for such installations.

- The National Electrical Safety Code has only limited reference to utility pole clearances. The present edition specifies that supporting structures should not be less than 6 inches from the street side of the curb. No provision is made for pole clearances where there is no curb.

There is a provision in the FHWA policy on utility accommodations which states that where existing utility facilities are likely to be associated with injury or accident to the highway user, the responsible highway authority is to initiate appropriate corrective measures to provide a safe traffic environment. Federal fund participation in the cost of adjusting or relocating utility facilities in accordance with this provision is subject to Federal law. Federal funds can be used to correct these hazards, but only to a very limited degree, as many States are hampered by lack of appropriate legal authority to pay for such corrective action.

The Highway Safety Act of 1973 contains several new programs for highway safety improvements. Section 210 (23 U.S.C. 153) is a program for the elimination or reduction of hazards caused by roadside obstacles on the Federal-aid system other than the Interstate System. Section 230 (23 U.S.C. 405) is a program for the elimination or correction of safety hazards in several categories, including those under Section 210, on highways not on any Federal-aid system. Relocation of utility poles identified as a traffic hazard is an example of the type of project which is eligible under these programs.

A continuing engineering survey of all highways to develop a procedure to detect high accident locations through accident analysis has been a requirement of Highway Safety Standard 9 since 1967. The Federal-Aid Highway Program Manual sets forth the details for carrying out this survey for Federal-aid highways. A survey is required by Section 210 to identify hazardous roadside obstacles *(3)*.

Among the types of hazardous obstacles to be identified in this survey are utility poles within 30 feet of the edge of traveled way except those installed in protected locations. A protected location is considered to be a location behind bridge rail, guardrail, or up on a non-traversable slope. Where the posted speed is 40 mph or less, utility poles would be counted only if located within 10 feet of the edge of traveled way. Also, if the posted speed is 40 mph or less, the area behind a curb designed to inhibit or discourage vehicles from leaving the pavement is considered to be a protected area. These criteria for protected location are applicable only for the purposes of making this survey. It is not intended to imply that a roadside obstacle occupying a protected location, as described above, does not present some degree of hazard to traffic, but rather that those obstacles not in a protected location present a greater hazard and should receive higher priority for correction.

These safety programs can be effective in eliminating hazards on highways both on and off the Federal-aid system. However, as only a few States and political subdivisions have broad authority to pay for utility pole adjustments or relocations under these programs, the effective implementation of any such projects is seriously hindered.

There are several methods now being used for reducing utility pole hazards. Joint use single pole construction offers an effective way of increasing safety by reducing the number of utility poles along the roadside. Joint use of poles should be encouraged where more than one utility or type of facility is involved. This is of particular significance at locations where right-of-way widths approach the minimum needed. While joint use of poles is now a common practice by the electric power and telephone industries, more extensive use of this practice can result in significant safety benefits.

The use of more attractive, self-supporting utility poles with vertical alinement of cables and wires should also be encouraged, perhaps as a compromise between undergrounding and conventional wood poles with cross arm clutter and guy wires. Self-supporting poles with vertical alinement of utility lines have advantages from both a safety and esthetic standpoint as exposure to hazards and unsightly clutter are reduced.

Another effective method of elimination of utility pole hazards is the conversion of overhead lines to underground. Conversion up to this time has primarily stemmed from beautification programs rather than safety reasons. Undergrounding new facilities has also been done by individual utility companies where it is found to be an economical alternate to overhead construction. For example, the Bell System has done a significant amount of undergrounding in recent years. It is reported that their inventory of owned poles is decreasing at a rate of ½ million per year and may be expected to decrease even faster in the future.

Undergrounding of electric power lines is mainly confined to low voltage distribution circuits in new residential subdivisions. Where direct burial of electric cable can be used, the cost of undergrounding may be as little as 1.5 times the cost of conventional overhead lines. However, it has been estimated that the cost of converting all existing overhead distribution lines would be a staggering $150 billion.

Undergrounding of high voltage transmission lines can be accomplished only after a number of economic and technological problems have been overcome. Underground transmission lines are many times more costly than overhead lines and are feasible today only in special areas, such as metropolitan centers having high demands for power. Underground transmission lines have the advantage of freedom from aboveground weather problems, and would have fewer interruptions than overhead lines. Continued research on underground materials and installation methods could result in a substantial reduction in the overall cost of undergrounding electric transmission lines.

Many utility pole hazards exist today because right-of-way acquired for public roads and streets was inadequate to meet future demands for additional use by public utility facilities. When a new highway facility is to be constructed, the responsible highway agency must necessarily contact any utility company which has facilities that might be affected by the roadway construction. It is important that consideration also be given to future planned utility facilities that may eventually occupy the highway right-of-way. If utility use of the right-of-way is authorized by law, the right-of-way so acquired must be adequate to safely accommodate those utility facilities.

In designing local roads and streets, AASHTO *(4)* suggests that right-of-way width should be sufficient to accommodate the ultimate planned roadway, including space for public utility facilities. In addition, it suggests that the use of the right-of-way by utilities should be planned to cause the least interference with traffic using the street. If utility facilities are crowded onto highway rights-of-way, the utility consumer and the highway user both suffer the consequences from the standpoint of safety, inconvenience, and added costs.

The breakaway concept has been used for roadside sign structures *(5)* and lighting supports *(6)* since the mid-1960's with well documented success. Research conducted at Southwest Research Institute (SwRI) *(7)* suggests that breakaway concepts can also be applied to utility poles. While the work conducted at SwRI must be considered preliminary, it encourages the idea that breakaway designs for utility poles are technically feasible. More comprehensive research is proposed in the near future.

Recommendations

Based on information currently available, recommendations for further action regarding the utility pole problem are as follows:

■ In the interest of carrying out an effective safety program for the elimination of roadside obstacles under 23 U.S.C. 153 and 405, each State should seek whatever legislation it may need to permit relocation or adjustment of existing utility poles from hazardous locations along roadsides.

■ Where appropriate, State Utility Accommodation Policies, and practices thereunder, should be modified and strengthened as necessary to ensure that:

1. New pole line installations along roadsides will be permitted only at locations that are conducive to a safe traffic environment.

2. More extensive use of joint-use single-pole construction will be made at locations along roadsides where more than one utility or type of overhead facility is involved, particularly where the right-of-way widths approach the minimum needed for a safe traffic environment.

3. Self-supporting utility poles will be utilized as appropriate to eliminate the need for guy poles and guy wires to encroach upon roadside areas.

4. On highways with narrow rights-of-way or on urban streets with closely abutting improvements, self-supporting, armless, single-pole construction with vertical configuration of overhead wires and cables (as opposed to conventional cross-arm construction) will be employed where needed to permit pole installations as close as possible to the right-of-way line.

■ Available accident data from the States should be collected, validated, and analyzed. Utilizing this data, recommended utility pole setbacks from the traveled way, taking into account available right-of-way widths, should be established for each type and class of highway (i.e., urban or rural, major or minor arterial, collectors, and so forth) and incorporated in utility accommodation policies.

■ The undergrounding of wire and cable facilities should be encouraged and location standards established.

■ Studies should be undertaken to determine the feasibility of developing breakaway utility pole designs, giving due consideration to:

1. Structural feasibility.

2. Devices to minimize electrical hazards.

3. Legal constraints.

If the studies are encouraging, an in-depth program of concept development should be undertaken.

■ Measures should be taken to assure that needed field performance information be reported in a timely manner through either future State Summaries of Traffic Accidents or by other means.

ACKNOWLEDGMENT

The authors wish to thank James E. Kirk, Office of Engineering, FHWA, and John G. Viner, Office of Research, FHWA, for their help and guidance during the preparation of this article. The authors also wish to thank Glenn Grigg, North Carolina State Highway Commission, for his assistance in obtaining accident data.

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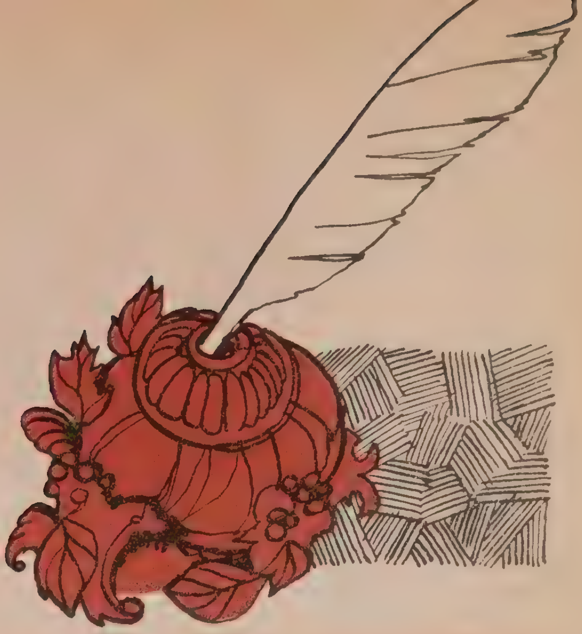

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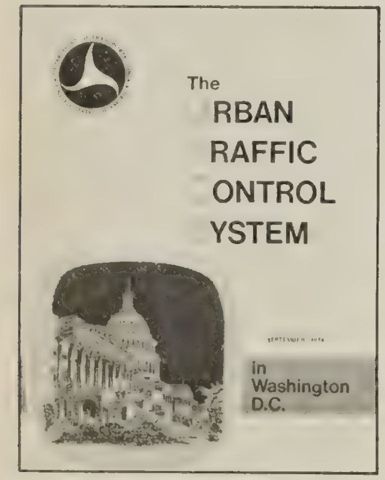
Implementation/User Items "how-to-do-it"

The following items are brief descriptions of selected reports which have been recently completed by State and Federal highway units in cooperation with the Implementation Division, Offices of Research and Development, Federal Highway Administration (FHWA). Some reports by others are included when they have a special interest to highway agencies. These reports will be available from the Implementation Division unless otherwise indicated. Those placed in the National Technical Information Service (NTIS) will be announced in this department after an NTIS accession number is assigned.

U.S. Department of Transportation
Federal Highway Administration
Office of Development
Implementation Division, HDV-20
Washington, D.C. 20590

The Urban Traffic Control System in Washington, D.C.

by FHWA Traffic Systems and Implementation Divisions



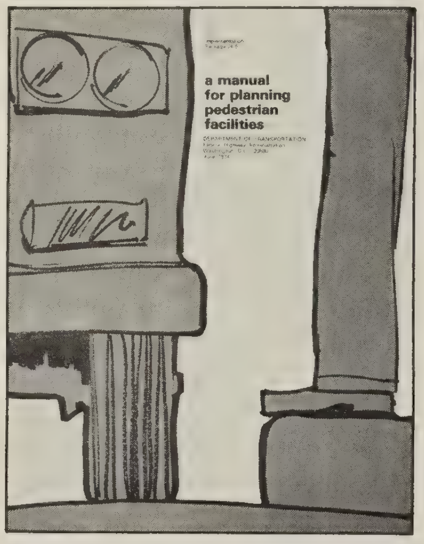
In many cities, highway agencies are currently planning for or installing digital computer controlled traffic signal systems. In order to familiarize these agencies with FHWA technology and research in this area, a brochure has been prepared which describes the FHWA's Washington, D.C. systems, research activities, and implementation aspects.

The brochure presents the objectives, design features, control strategy descriptions, experience, and applicability to other cities. It also includes a bibliography of significant documentation which is currently available.

The brochure is available from the Implementation Division.

A Manual for Planning Pedestrian Facilities

by FHWA Environmental Design and Control and Implementation Divisions



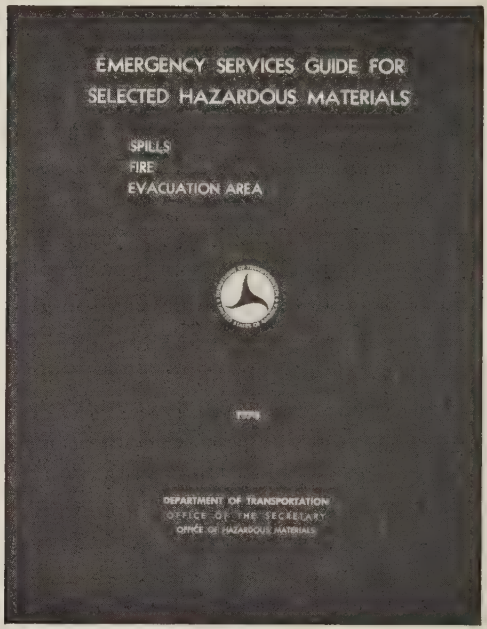
This manual provides the highway engineer and urban planner with guidelines for planning pedestrian facilities. It includes the basic concepts in pedestrian trip generation and movement, and the basic types of facilities available to the planner—categorized by horizontal, vertical, and time separations. It discusses each of the types of impacts to users and nonusers of pedestrian facilities and presents the interrelationships among facility characteristics and the various levels of impacts on pedestrians, motorists, abutting property occupants, and the community in general.

The manual also describes an approach to general economic cost estimating in terms of both construction cost and continuing operating and maintenance costs. It gives several means of converting these costs to a figure useful in comparing facilities and evaluating benefits.

The manual is available from the Implementation Division.

Emergency Services Guide for Selected Hazardous Materials

by DOT Office of Hazardous Materials



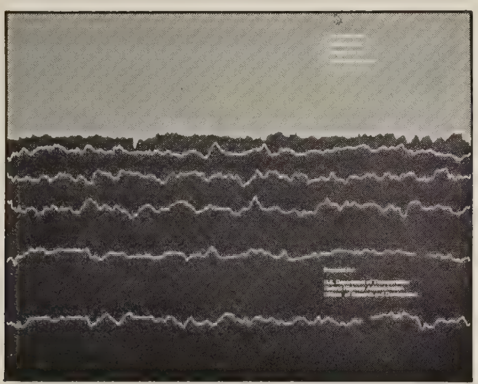
This manual provides a guide on actions to be taken to minimize the immediate hazard impact of spills encountered in the bulk transportation of certain selected hazardous materials. The major objective in developing the manual was to provide quantitative and more useful information than the general instruction found in most safety manuals.

The Spill Guides are divided into a left and right side. The left side is designed to assist emergency services such as fire-fighters and police to respond to a spill or fire during the first 30 minutes of an incident. The right side of each guide presents defined evacuation areas in a readily usable format in case of a bulk spill of certain hazardous materials.

The manual is available from the Implementation Division.

The Audible Landscape: A Manual for Highway Noise and Land Use

by FHWA Offices of Research and Development



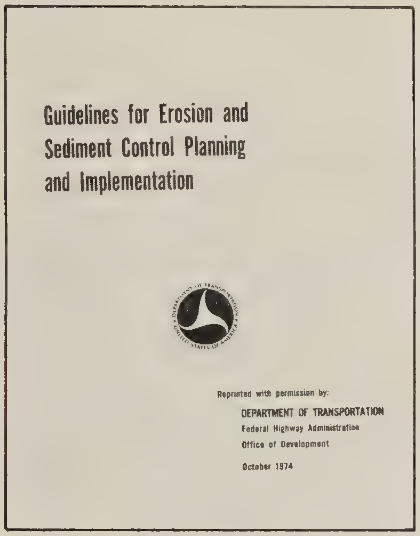
The manual discusses how to reduce undesirable effects of highway-generated noise through land use control. It suggests that zoning, legal restrictions, local government ownership, and tax incentives can all be used to reduce noise impacts near highways where sensitive urban land use has not yet been developed. Site planning—using building orientation, acoustical design, and construction—can also reduce noise impacts, especially where noise-sensitive receptors such as residences are to be placed next to the highway. Examples of land development based on many of the recommendations in the manual are given for three locations.

The manual is available for $1.55 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Guidelines for Erosion and Sediment Control Planning and Implementation

by U.S. Environmental Protection Agency

reprinted by FHWA Implementation Division


Guidelines for Erosion and Sediment Control Planning and Implementation

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DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Office of Development
October 1974

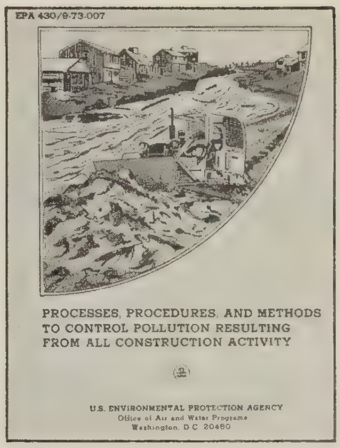
These guidelines are intended to help those responsible for, or engaged in, urban construction prevent the uncontrolled movement of soil and the subsequent damage it causes. The publication presents a comprehensive approach to the problem of erosion and sediment control from beginning of project planning to completion of construction. It provides (1) a description of how a preliminary site evaluation determines what potential sediment and erosion control problems exist at a site being considered for development; (2) guidance for the planning of an effective sediment and erosion control plan; and (3) procedures for the implementation of that plan during operations.

Technical information on 42 sediments and erosion control products, practices, and techniques is contained in four appendices. In addition, a cross-index and a glossary of technical terms used in the publication are provided.

The guidelines are available for $1.75 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Processes, Procedures, and Methods to Control Pollution Resulting from all Construction Activity

by U.S. Environmental Protection Agency


EPA 430/9-73-007

PROCESSES, PROCEDURES, AND METHODS TO CONTROL POLLUTION RESULTING FROM ALL CONSTRUCTION ACTIVITY

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Washington, D.C. 20460

This publication presents information on processes, procedures, and methods for controlling sediment, stormwater, and pollutants other than sediment which result from construction activities. It examines processes such as site planning, preliminary site evaluation and design, use of planning tools, and structural and vegetative design considerations relative to development of a water pollution abatement plan suited to individual construction sites. It also examines procedures—at Federal, State, and local levels—relative to the control of land-disturbing activities and the interrelations between various procedures and processes. Methods examined include on-site erosion, sediment, and stormwater management control structures as well as soil stabilization practices useful for achieving control of sediment, stormwater runoff, and other pollutants resulting from construction activities. Stormwater management practices are discussed in detail.

The publication is available for $2.30 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

New Research in Progress

The following items identify new research studies that have been reported by FHWA's Offices of Research and Development.[1] These studies are sponsored in whole or in part with Federal highway funds. For further details, please contact the following: Staff and Contract Research—Editor; Highway Planning and Research (HP&R Research)—Performing State Highway Department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

FCP Category 1— Improved Highway Design and Operation for Safety

FCP Project 1A: Traffic Engineering Improvements for Safety

Title: Safety Aspects of Reduced Speed Limits and Reduction in Travel Caused by the Energy Crisis. (FCP No. 31A1604)
Objective: Evaluate the effects on traffic safety resulting from the change in motor vehicle use caused by the energy crisis. Travel, speed, and traffic accident data will be used to determine safety benefits from lower speed limits and from providing a uniform maximum speed in States which had differing limits for classes of vehicles. Analyze data in States which had day/night differential speed limits.
Performing Organization: Pennsylvania State University, University Park, Pa. 16802
Expected Completion Date: May 1976
Estimated Cost: $152,000 (FHWA Administrative Contract)

[1] Space limitation precludes publishing a complete list of new research studies in progress.

FCP Project 1H: Skid Accident Reduction

Title: Extension of Field Evaluations of Innovative Skid-Resistant Surfaces. (FCP No. 31H1234)
Objective: Field evaluate innovative materials and techniques for the construction and maintenance of pavement surfaces which are intended to provide and reasonably retain the levels of friction and texture for the traffic conditions for which these treatments are intended.
Performing Organization: Pennsylvania Department of Transportation, Harrisburg, Pa. 17120
Expected Completion Date: April 1978
Estimated Cost: $90,000 (FHWA Administrative Contract)

Title: Wet Weather Skidding Accident Reduction at Intersections. (FCP No. 51H4032)
Objective: Examine the methodology developed in NCHRP study 1–12 in order to improve and simplify the data collection and analysis techniques. Relate such methods to conflict analysis.
Performing Organization: Ohio Department of Transportation, Columbus, Ohio 43215
Expected Completion Date: October 1977
Estimated Cost: $200,000 (NCHRP)

FCP Project 1I: Traffic Lane Delineation Systems for Adequate Visibility and Durability

Title: Epoxy Striping for Improved Durability. (FCP No. 31I2112)

practical traffic lane marking system of improved durability based on generic, solvent-free, catalyzed epoxy or polyester materials. Evaluate such materials by laboratory and field tests.
Performing Organization: Amicon Corporation, Lexington, Mass. 02173
Expected Completion Date: November 1976
Estimated Cost: $149,000 (FHWA Administrative Contract)

FCP Project 1L: Improving Traffic Operations During Adverse Environmental Conditions

Title: Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments. (FCP No. 31L3042)
Objective: Establish the relationship

between the cost of various roadway delineation treatments and their effect on traffic safety and operations as a function of highway geometrics, traffic, and environmental conditions.
Performing Organization: Science Applications, Inc., La Jolla, Calif. 92037
Expected Completion Date: July 1977
Estimated Cost: $240,000 (FHWA Administrative Contract)

FCP Project 1O: Aids to Surveillance and Control

Title: Railroad-Highway Grade Crossing Safety. (FCP No. 31O1044)
Objective: Evaluate new candidate passive grade crossing warning systems at about 70 railroad-highway grade crossings in the 25 participating States. If a new signing and marking system is determined to be more effective than the existing cross-buck system, a change to the UMTCD will be recommended.
Performing Organization: Transportation Systems Center, Cambridge, Mass. 02142
Expected Completion Date: December 1976
Estimated Cost: $256,000 (FHWA Administrative Contract)

FCP Category 4—Improved Materials Utilization and Durability

FCP Project 4B: Eliminate Premature Deterioration of Portland Cement Concrete

Title: Influence of Bridge Deck Repair on Corrosion of Reinforcing Steel. (FCP No. 54B2212)
Objective: Investigate the effect of repair techniques and materials on subsequent rebar corrosion in and around the patch.
Performing Organization: Battelle Columbus Laboratories, Columbus, Ohio 43201
Expected Completion Date: February 1977
Estimated Cost: $187,000 (NCHRP)

FCP Project 4C: Use of Waste as Material for Highways

Title: Power Plant Bottom Ash in Black Base and Bituminous Surfacing. (FCP No. 34C2084)
Objective: Investigate the feasibility of using power plant bottom ashes in bituminous mixtures. Develop the necessary technical information on the physical and engineering properties of bottom ashes and their mixtures to enable these materials to be used in highway construction.
Performing Organization: Ohio State University, Columbus, Ohio 43210
Expected Completion Date: June 1976
Estimated Cost: $81,000 (FHWA Administrative Contract)

FCP Project 4F: Develop More Significant and Rapid Test Procedures for Quality Assurance

Title: Development of a Device for Continuous Automatic Monitoring of Consolidation of Wet Concrete. (FCP No. 34F3222)
Objective: Develop a monitoring device to be used in conjunction with concrete construction that will permit continuous automatic monitoring of the degree of consolidation during the compaction phase of construction of a concrete structure.
Performing Organization: Rexnord, Inc., Milwaukee, Wis. 53201
Expected Completion Date: May 1976
Estimated Cost: $144,000 (FHWA Administrative Contract)

Title: Evaluation and Adaptation of Swiss Microscopic Methods of Examination of Hardened Portland Cement Concrete. (FCP No. 44F3262)
Objective: Investigate, evaluate, improve, and possibly adapt the microscopic methods of Wilk, Dobrolubov, and Romer to the study and quality control of concrete under the specification and with the engineering practices and types of concrete in use in this country.
Performing Organization: Virginia Highway Research Council, Charlottesville, Va. 22903
Expected Completion Date: October 1977
Estimated Cost: $72,000 (HP&R)

FCP Category 5—Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

FCP Project 5B: Tunneling Technology for Future Highways

Title: Prefabricated Structural Members for Cut-and-Cover Tunneling. (FCP No. 35B1032)
Objective: A comprehensive evaluation of the possibilities for improving cut-and-cover tunnel construction by use of prefabricated structural members.
Performing Organization: Consulting Engineers Group, Glenview, Ill. 60025
Expected Completion Date: March 1976
Estimated Cost: $92,000 (FHWA Administrative Contract)

FCP Project 5C: New Methodology for Flexible Pavement Design

Title: Subgrade Elastic Modulus Study. (FCP No. 45C3234)
Objective: Develop test methods for the approximation of subgrade dynamic elastic modulus for use in pavement design.
Performing Organization: Sergent-Hauskin-Beckwith, Phoenix, Ariz. 85007
Funding Agency: Arizona Department of Transportation
Expected Completion Date: December 1976
Estimated Cost: $125,000 (HP&R)

FCP Project 5D: Structural Rehabilitation of Pavement Systems

Title: Establish Criteria for Rehabilitation of California Pavements. (FCP No. 45D1083)
Objective: Develop reasonable and uniform standards upon which to establish priorities for pavement rehabilitation and to predict future pavement needs.
Performing Organization: California Department of Transportation, Sacramento, Calif. 95807
Expected Completion Date: June 1978
Estimated Cost: $142,000 (HP&R)

Title: Improved Drainage and Frost Design Criteria for New Jersey Pavement Design. (FCP No. 45D3022)
Objective: Improve pavement design methods to minimize frost and subsurface drainage problems.
Performing Organization: New Jersey Department of Transportation, Trenton, N.J. 08625
Expected Completion Date: January 1979
Estimated Cost: $350,000 (HP&R)

FCP Category 6—Prototype Development and Implementation of Research

FCP Project 6A: Construction and Maintenance Materials

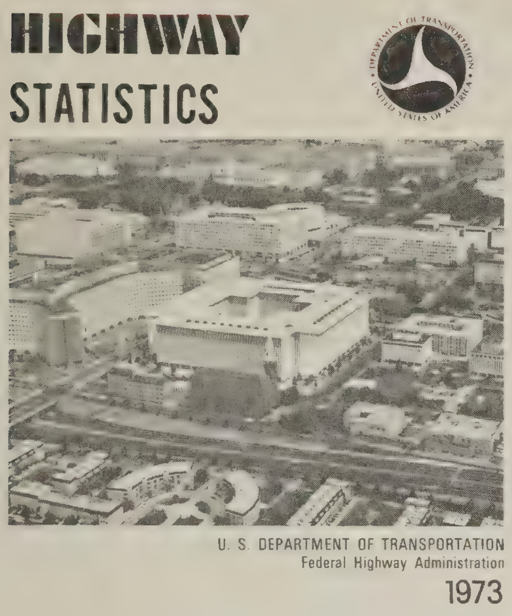
Title: Guidelines for Plastic Pipe Underdrains. (FCP No. 36A2214)
Objective: Test and evaluate the load-deformation characteristics of buried slotted plastic pipe underdrains, both statically and dynamically. Test under variable trench conditions, bedding shapes, pipe materials, backfill types and densities, and loading conditions. Develop a user manual in conjunction with the slotted underdrain concept.
Performing Organization: FHWA Region 8, Denver, Colo. 80225
Expected Completion Date: April 1976
Estimated Cost: $70,000 (FHWA Administrative Contract)

Non-FCP Category 0—Other New Studies

Title: Annual End Movements of Prestressed Concrete Bridges. (FCP No. 40S1034)
Objective: Determine appropriate design values for longitudinal expansion of prestressed concrete due to temperature, creep, and shrinkage, thereby reducing over design of joint and bearing devices.
Performing Organization: New York Department of Transportation, Albany, N.Y. 12226
Expected Completion Date: December 1977
Estimated Cost: $88,000 (HP&R)

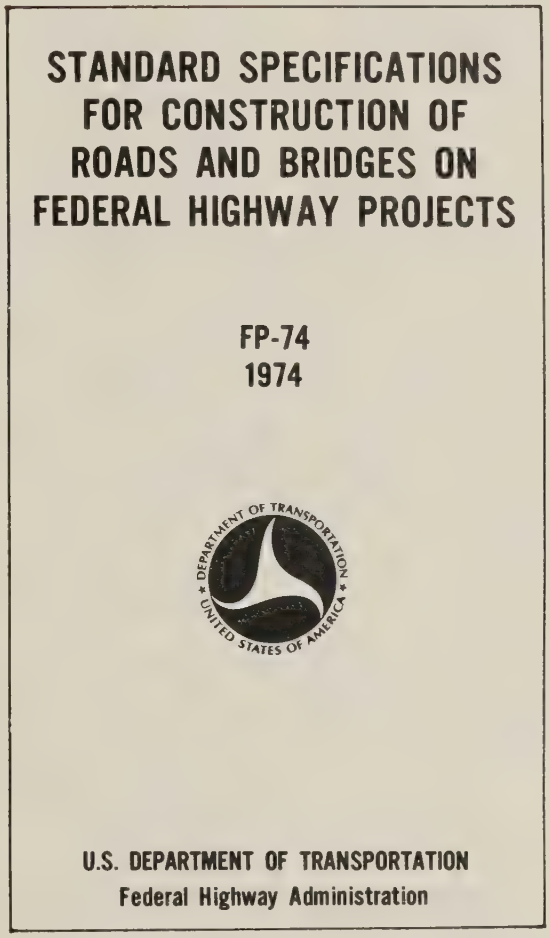
Title: Improving Embankment Design and Performance. (FCP No. 40S3562)
Objective: Determine the effects of variability of the compaction process on the quality of predictability of the engineering behavior of compacted Indiana soils.
Performing Organization: Purdue University, Lafayette, Ind. 47907
Funding Agency: Indiana State Highway Commission
Expected Completion Date: June 1977
Estimated Cost: $51,000 (HP&R)

New Publications



Highway Statistics, 1973 ($4.90 a copy), a 270-page bulletin, is the 29th in the annual series presenting statistical and analytical tables of general interest on motor fuel, motor vehicles, driver licensing, highway-user taxation, State and local highway financing, road and street mileage, and Federal aid for highways.

The **Highway Statistics** series has been published annually beginning in 1945 but most of the earlier editions, except 1969, 1970, 1971, and 1972, are now out of print. However, much of the information presented in the earlier editions is summarized in Highway Statistics, Summary to 1965 ($1.25 a copy). These documents may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.



Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-74, contains specifications for those items of work, materials, and construction methods that are generally applicable to direct Federal highway contracts, but it is adaptable for use by other highway agencies. It contains quality assurance provisions for several items and specifications covering other recently developed processes or methods.

This publication may be purchased for $4.55 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock No. 5001-00078).

FP-74 Construction Manual provides guidance to field personnel involved in construction contracts performed under the direct supervision of the Federal Highway Administration. Its purpose is to clarify the 1974 Standard Specifications, establish policies, and promote standardized procedures. The manual is designed to be compatible with the 1974 Standard Specifications.

This manual may be purchased for $5.75 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Stock No. 5001-00084).

Highway Research and Development Reports Available from the National Technical Information Service

The following highway research and development reports are for sale by the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

Other highway research and development reports available from the National Technical Information Service will be announced in future issues.

STRUCTURES

Stock No.	
PB 236787	Prediction and Field Evaluation of Downdrag Forces on a Single Pile.
PB 237959	User's Manual for Program Beam.
PB 237960	Strand Reinforcing for End Connections of Pretensioned I-Beam Bridges.
PB 237968	Climatic Influence on Drilled Shaft Piling.
PB 237971	Cyclic Load Tests of Composite Prestressed-Reinforced Concrete Panels.
PB 237978	Bridge Deck Rideability.
PB 238035	Temperature Detection Study.
PB 238040	Environmental Factors Relevant to Pavement Cracking in West Texas.
PB 238043	Proceedings of Workshop on Cut-and-Cover Tunneling: Precast and Cast-in-Place Diaphragm Walls Constructed Using Slurry Trench Techniques.
PB 238114	Landslides in the Pierre Shale in Central South Dakota.
PB 238156	Thermal Expansion and Contraction of Concrete Pavement in Utah.
PB 238159	Prediction of Long Term Deformation of a Compacted Cohesive Soil Embankment over a Soft Foundation.
PB 238164	Strength Coefficient of Materials.
PB 238166	Instrumentation for Long Term Field Structure and Model Structure Investigations.
PB 238167	Joint Road Friction Program (Research on Pavement Slipperiness).
PB 238273	Pavement Riding Quality.
PB 238367	Head-On Test of Cable Guardrail.
PB 238640	Performance of Two Layer Asphalt Stabilized Drainage Blankets for Highway Subdrainage.
PB 238690	Correlation of Mays Ride Meter to a CHLOE Profilometer.
PB 239045	Stochastic Study of Design Parameters and Lack-of-Fit of Performance Model in the Texas Flexible Pavement Design System.
PB 239053	Field Study of a Curved Box Beam Bridge.
PB 239078	Long-Term Deformation in Clay.
PB 239188	Fracture Toughness of Bridge Steels—Phase II Report.
PB 239244	Linear Elastic Layer Theory as a Model of Displacements Measured Within and Beneath Flexible Pavement Structures Loaded by the Dynaflect.
PB 239245	Use of Condition Surveys, Profile Studies, and Maintenance Studies in Relating Pavement Distress to Pavement Performance.
PB 239499	Investigation of Roadway Drainage as Related to the Performance of Flexible Pavements.

MATERIALS

Stock No.	
PB 238277	Protective Coatings for Highway Metals—Final Report.
PB 238327	Determination of Desirable Finish for Concrete Pavements.
PB 238638	D-Cracking of Concrete Pavements in Ohio.
PB 238675	Investigation of Multispectral Techniques for Remotely Identifying Terrain Features and Natural Materials.
PB 238885	Paint Systems for Highway Structural Steel—Final Report.
PB 238887	Alkali-Aggregate Reaction in Maine.
PB 238888	Accelerated Concrete Strength Study.
PB 238911	Determination of Feasible Testing Methods for Asphalt-Aggregate Cold Mix Bases.
PB 238955	The Influence of Retarding Admixtures on the Drying Shrinkage of Concrete.
PB 238956	Paving Asphalts: Chemical Compositon, Oxidative Weathering, and Asphalt-Aggregate Interactions—Part II.
PB 239043	D-Cracking in PCC Pavements—Cause and Prevention.

PB 239044 A Field Evaluation of the Void Spacing Indicator for Determining the Quality of Air Entrainment in Plastic Concrete.
PB 239046 Design and Economics of Bituminous Treated Bases in Texas.
PB 239076 A Laboratory Evaluation of Rubber-Asphalt Paving Mixtures.
PB 239077 Synthetic Aggregate Seal Coats.
PB 239080 Improvement in the Durability of Asphaltic Pavement.
PB 239106 Factors Influencing Deterioration and Spalling of Bridge and Pavement Concretes.
PB 239167 Variation in Temperature and Mechanical Properties of Asphalt Concrete due to "Storage in Surge Bins."

ENVIRONMENT

Stock No.
AD 000612 Practical Guidance for Design of Lined Channel Expansions at Culvert Outlets.
PB 238639 Evaluation of Illumination Designs for Accident Reduction at High Nighttime Accident Highway Sites.
PB 238685 Scour at Bridge Waterways—A Review.
PB 238689 Surface Icing of Insulated Pavements.
PB 238875 Louisiana Highway Research—Erosion Evaluation Study.
PB 239061 Friction Characteristics of Paving Materials in Connecticut.
PB 239111 Economic Evaluation of Mobile and Modular Housing Shipments by Highway (complete set).
PB 239112 Vol. I—Research Report.
PB 239113 Vol. II—Appendices.

IMPLEMENTATION

Stock No.
PB 238112 Nevada's Experience with Finishing of Concrete Structures—Final Report.
PB 238117 Study and Development of Advanced Survey Systems and Techniques.
PB 238461 Investigation of the Analytical Stereoplotter AP/C (OP/C Phase) in Application to Highway Engineering Projects.
PB 239051 Compaction of Asphalt Concrete Pavements—Final Report.
PB 239497 Implementation Package for Swelling Soils Treatment in Colorado.

PLANNING

Stock No.
PB 238116 Feasibility of Toll Removal from the Interstate Highway System.

GENERAL

Stock No.
PB 238917 1974 World Survey of Current Research and Development on Roads and Road Transport.

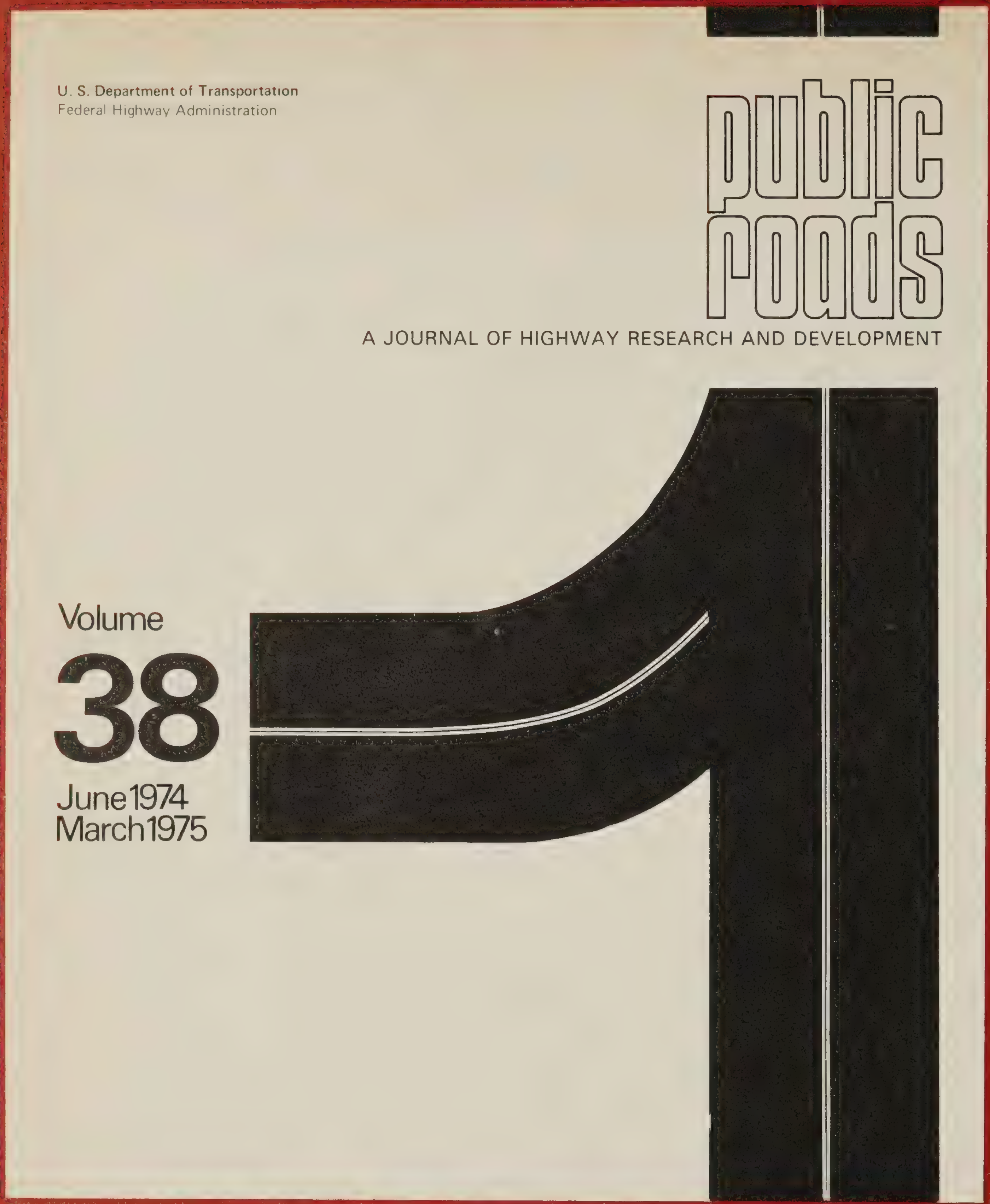
ERRATA

In the article "Reducing Uncertainty in Interchange Design Evaluations" in the March 1975 issue of ***Public Roads,*** vol. 38, No. 4, page 146, col. 3, lines 19–23, should read:

In this process, the end points–worth values of 0 and ***10****—are first identified, its being quite obvious which end of the scale is preferable over all other points.*

In figure 6 on page 148, ***the green and gray bands representing Alternatives 1 and 2 should be reversed.***

The study "Microwave Heating for Road Construction and Maintenance" on page 162 of *New Research in Progress* is funded by five ***State Departments of Transportation: Connecticut, Illinois, Maryland, Ohio,*** and ***Pennsylvania.***



TITLE SHEET, VOLUME 38

The title sheet for volume 38, June 1974–March 1975, of *Public Roads,* A Journal of Highway Research and Development, is now available. This sheet contains a chronological list of article titles and an alphabetical list of authors' names. Copies of this title sheet can be obtained by sending a request to the managing editor of the magazine, U.S. Department of Transportation, Federal Highway Administration (HDV-10), Washington, D.C. 20590.

U.S. Government Printing Office: 1975—620-833/4

Publications of the Federal Highway Administration

The following publications are sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Orders should be sent direct to the Superintendent of Documents. Prepayment is required.

The Audible Landscape: Manual for Highway Noise (1974), $1.55.

Bridge Inspector's Training Manual (1970), $2.50; (1971), $2.50.

Construction Manual FP-74 (1974), $5.75.

Coordination of Urban Development and the Planning and Development of Transportation Facilities (March 1974), $2.50.

Corrugated Metal Pipe (1970), 65 cents.

Economics and Social Effects of Highways (1972), $1.45.

Evaluation of Potential Effects of U.S. Freight Transportation Advances on Highway Requirements (Research Phases 1 and 2), $2.75.

Fatal and Injury Accident Rates on Federal-Aid and Other Highway Systems (1971), $1.

Federal Assistance Available (1971), 25 cents.

Federal Laws, Regulations, and Other Material Relating to Highways (1974), $2.95.

A Guide to Parking Systems Analysis, $2.85.

Handbook of Highway Safety Design and Operating Practices (1973), $2.

Highway and Urban Mass Transportation (Spring 1972), 90 cents; (Fall 1972), 90 cents; (Winter 1972), 90 cents.

Highway Joint Development and Multiple Use (1970), $1.50.

Highway Statistics (published annually since 1945): (1968), $3.15; (1970), $3.30; (1971), $3.30; (1972), $3.20. (Other years out of print.)

Hydraulic Design Series:
No. 1—Hydraulics of Bridge Waterways, $1.60.
No. 3—Design Charts for Open-Channel Flow (1961), $2.10.
No. 4—Design of Roadside Drainage Channels, $1.

Hydraulic Engineering Circulars:
No. 5—Hydraulic Charts for the Selection of Highway Culverts (1965), 95 cents.
No. 11—Use of Riprap for Bank Protection (1967), 85 cents.
No. 12—Drainage of Highway Pavements (1969), $1.55.
No. 13—Hydraulic Design of Improved Inlets for Culverts (1974), $2.20.

Interstate System Accident Research Study (1970), $1.90.

Interstate System Route and Log Finder List (1971), 35 cents.

Manual on Uniform Traffic Control Devices for Streets and Highways (1971), $4.90.
Part VI, Traffic Controls for Street and Highway Construction and Maintenance Operations (1973), $1.25.
Part VII, Traffic Controls for School Areas (1971), 75 cents.

Maximum Safe Speed for Motor Vehicles (1969), $1.50.

Motor Carrier Safety Regulations (1973), $1.20.

National Highway Needs Report, H. Comm. Print 91st Cong., $1.35.

The National System of Interstate and Defense Highways (1972), 25 cents.

The New Look in Traffic Signs and Markings (1972), 50 cents.

Park & Recreational Facilities (1971), 90 cents.

Quality Assurance in Highway Construction (1970), $1.05.

R&D Highway and Safety Transportation System Studies (1971), $3.70; (1973), $4.50.

Reinforced Concrete Bridge Members—Ultimate Design (1969), $1.10.

Reinforced Concrete Pipe Culverts—Criteria for Structural Design and Installation (1963), 95 cents.

Road User and Personal Property Taxes on Selected Motor Vehicles (1973), $1.50.

Socio and Economic Effects of Highways (1974), $2.15.

Specifications for Aerial Surveys and Mapping by Photogrammetrical Methods for Highways (1968), $2.

Standard Plans for Highway Bridges:
Vol. II—Structural Steel Superstructures (1968), $2.60.
Vol. III—Timber Bridges (1969), $2.
Vol. IVA—Typical Continuous Bridges Load Factor Design (1973), $2.90.
Vol. V—Typical Pedestrian Bridges (1962), $3.40.

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (1969), $6.35.

Status of the Urban Corridor Demonstration Program (1974), $1.80.

Traffic Assignment—Methods, Applications, Products (1973), $2.90.

Transportation Planning Data for Urbanized Areas based on 1960 census (1970), $13.

Urban Mass Transportation Travel Surveys (1972), $2.10.

Urban Origin-Destination Surveys/Sampling Urban Travel Behavior, $3.20.

Urban Planning General Information (March 1972), $3.65.

Ultrasonic Testing Inspection for Butt Welds in Highway and Railway Bridges (1973), 80 cents.

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A JOURNAL OF HIGHWAY RESEARCH AND DEVELOPMENT