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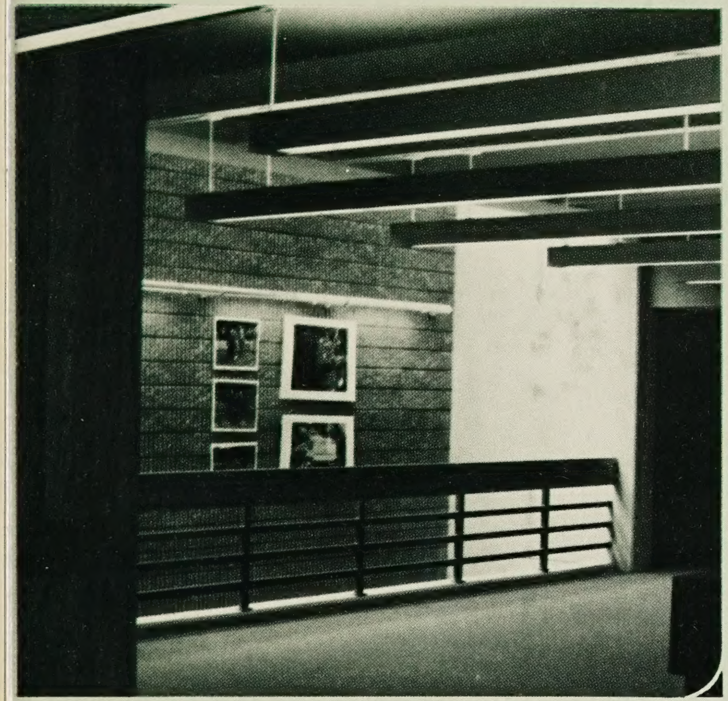

Public Roads

A Journal of Highway Research and Development

September 1983 Vol. 47, No. 2

COVER: Scenes in and around the new Turner-Fairbank Highway Research Center in McLean, Virginia.

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IN THIS ISSUE

Articles

Departments

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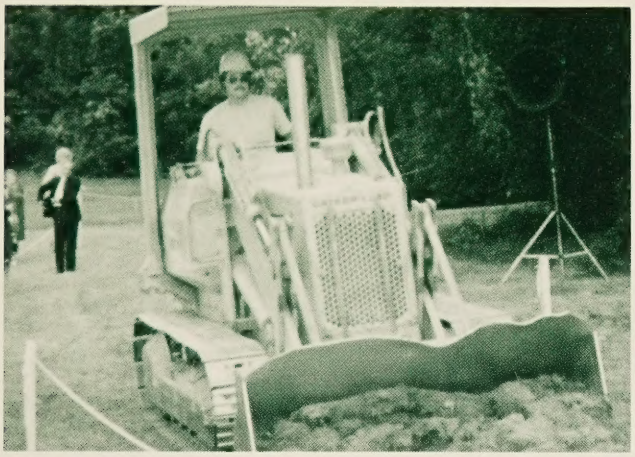
The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through March 31, 1985.

A Dream Becomes a Reality



Groundbreaking, September 17, 1980.

Front view of the Francis C. Turner Building.

May 5, 1983. Dedication Day. This day was the culmination of many years of work that resulted in the completion of an expanded Federal Highway Administration (FHWA) research facility in McLean, Virginia. On September 17, 1980, ground was broken for a new building at the Fairbank Highway Research Station[1] and on May 5, 1983, that building was dedicated. The new building was named in honor of Francis C. Turner, whose 43 years of service with the Bureau of Public Roads (BPR) and FHWA brought significant changes to highway transportation. The entire complex was renamed the Turner-Fairbank Highway Research Center.

Although the day of dedication began with a brief rain shower, the weather soon cleared and the ceremony took place under sunny skies. The ceremony began with a concert by the United States Coast Guard Band. Following the concert, Mr. Edwin M. Wood, Associate Administrator for Research, Development, and Technology, welcomed the several hundred employees and guests attending the dedication. The Coast Guard Band then played the National Anthem and Chaplain Eddy B. Moran of the United States Coast Guard gave the invocation.

Mr. Richard D. Morgan, Executive Director of FHWA, introduced several honored guests, including members of Congress, former Federal Highway Administrators, and members of transportation organizations. Following these introductions, Federal Highway Administrator R. A. Barnhart spoke briefly and then introduced Senator Jennings Randolph of West Virginia. Senator Randolph presented Mr. Turner with a flag that had been flown over the U.S. Capitol and a certificate of the flag's authenticity.

Mr. Barnhart then introduced the Secretary of Transportation, Elizabeth Hanford Dole, who was the key speaker for the dedication. She expressed her delight at participating in this event and talked about the future of research and the role it will play in the progress of our highway system. Secretary Dole also spoke of the importance of safety in highway transportation and stated, "This research center will enable us to learn more about highways, how to build them to greater life expectancies, how to make them more resistant to heavy loads, and above all, how to make them safer for all the people who use them." She praised Mr. Turner as exemplifying "the kind of person who always has the good of people first in mind."

Following Secretary Dole's speech, Mr. Lester P. Lamm, Deputy Federal Highway Administrator, dedicated the new building to Mr. Turner and presented him with a plaque similar to the one that is to be displayed permanently in the Francis C. Turner Building. In his acknowledgment of the dedication, Mr. Turner said he was very honored the building would bear his name, especially because this structure was one in which research would be conducted—it would be a "living" structure. He also said he was honored that his name would be linked with Herbert S. Fairbank's and spoke about Mr. Fairbank's accomplishments as a pioneer in research and Deputy Commissioner for Research of the Bureau of Public Roads. Mr. Turner ended his speech with the hope that future generations of his family and employees working in the new building would do nothing to tarnish the building's name.

Remarks then were made by Mr. Francis B. Francois, Executive Director of the American Association of State Highway and Transportation Officials, and by Mr. Richard M. Lauzier, Chairman of the Road Gang. The ceremony concluded with remarks and acknowledgments by Mr. Wood.

A Texas-style barbecue luncheon was served after the ceremony. Also, an open house was held in conjunction with the dedication. The guests enjoyed the many demonstrations and exhibits in the new facilities in the Turner Building and the existing laboratories in the Fairbank Building.

The following pages include pictures of the dedication ceremony and the new facility and additional information about Mr. Turner and the Turner-Fairbank Highway Research Center.

[1]See "A Dream Comes True," *Public Roads*, vol. 44, No. 3, December 1980, pp. 116–117, for an article on the groundbreaking.

Secretary of Transportation Elizabeth Hanford Dole and Federal Highway Administrator R. A. Barnhart (right) talk with Mr. Francis C. Turner before the ceremony.

Richard D. Morgan, Executive Director of FHWA, introduced honored guests.

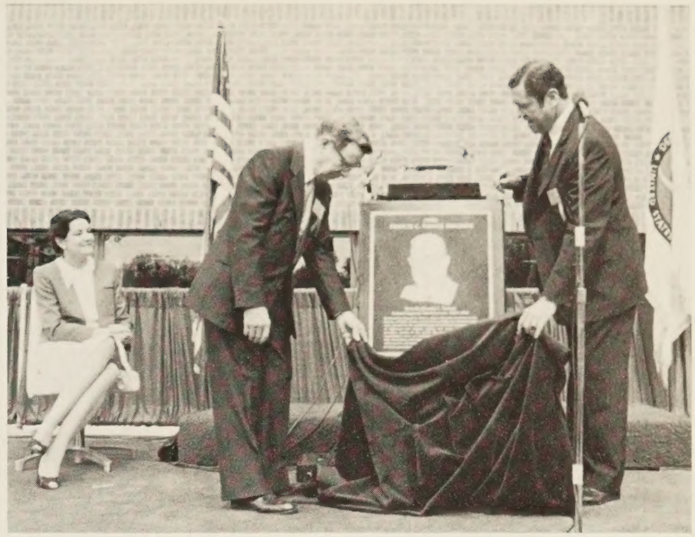
Secretary Dole was the key speaker.

Lester P. Lamm, Deputy Federal Highway Administrator, dedicated the new building in honor of Mr. Turner.

Mr. Turner acknowledged the dedication.

Several hundred employees and guests attended the dedication. The Fairbank Building is in the background.

Senator Jennings Randolph of West Virginia (right) presented Mr. Turner with a flag that had been flown over the U.S. Capitol and a certificate.



Mr. Lamm (right) presented Mr. Turner with a commemorative plaque.

Francis C. Turner

The new building dedicated on May 5, 1983, is named in honor of Francis C. Turner, who was the only chief executive of the Federal Highway Administration and its predecessor, Bureau of Public Roads (BPR), who spent his entire career within the organization. He began his career in 1929 when he joined the BPR as a junior highway engineer. His work in this position involved the study of construction methods (time and motion study work) with the objective of reducing highway construction costs while maintaining high quality. In his next position as an area engineer in Arkansas, his interests expanded to include maintenance. While working for the BPR, he completed graduate work on the effects of soil properties on maintenance operations. He came to Washington, D.C., in 1940 to work in the Office of Engineering and later Region 3, which at that time also was located in the District of Columbia.

In 1943, he was sent to Alaska to serve as adviser on maintenance of the Alaska Highway. While in Alaska, he pioneered the use of aerial photography in highway location. Because of the acclaim for his work in Alaska, Turner was selected to head a mission to develop a highway system in the Philippines and restore roads destroyed in World War II. During his 4 years in the Philippines (1946–1950), he coordinated all rehabilitation programs being conducted by nine U.S. Government agencies and, as a result, was awarded the Legion of Honor by the Government of the Philippines.

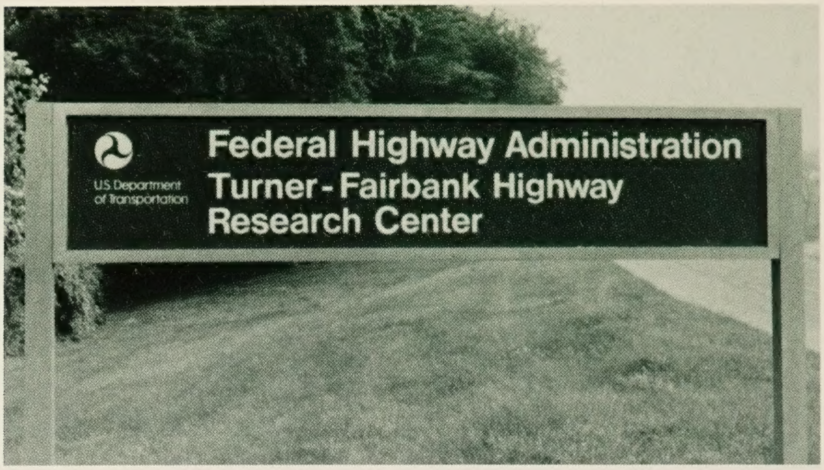
On his return to the United States in 1950, Turner became assistant to the Highway Commissioner, Thomas H. MacDonald. In this position, he coordinated the work on the Inter-American Highway and foreign activities in Ethiopia, Turkey, the Philippines, Liberia, and other countries.

Turner was appointed Executive Secretary for the Committee on the National Highway Program in 1954 and his influence on that committee is largely responsible for the mechanism established for financing construction of the Interstate system. Once the legislation establishing the Interstate Highway System was enacted, he served as Deputy Commissioner and Chief Engineer for Public Roads and worked to make the system successful.

On February 27, 1967, Turner became Director of Public Roads and on February 24, 1969, he was confirmed unanimously by the Senate as the Federal Highway Administrator.

Throughout his career, Frank Turner balanced his knowledge of the technical aspects of the highway industry with a broad perspective of highway systems as much more than concrete and pavement. He believed that transportation systems "had to move people, not just vehicles." He felt research was essential to meet the challenge of change in the highway environment and improve the construction, safety, and efficiency of our highway facilities. Turner was also a strong proponent of the development and implementation process and in 1969 outlined a plan for research implementation that set forth many of the principles that guided FHWA technology transfer through the 1970's and continue to guide us in the 1980's.

It is very fitting that this new facility was dedicated and named in honor of Frank Turner—a man who thrived on change, believed in innovation based on facts gathered through research, and played a significant role in implementing research results in the United States and throughout the world.



The Turner-Fairbank Highway Research Center

The Turner-Fairbank Highway Research Center will provide the Federal Highway Administration with additional laboratory facilities for staff research. The need for laboratory space was recognized in the 1920's, and during the 1920's and 1930's sites including Arlington Farms (now the Pentagon) and Gravelly Point (Washington National Airport) were used by the Bureau of Public Roads for research. In 1938, Congress authorized the purchase of nearly 600 acres in Langley (McLean), Virginia, and the construction of a research facility. Construction was almost finished on two buildings—the shop facility and heating plant—when the project was stopped in 1941 because of the war. After the war, the authorized funds were insufficient to construct the other buildings planned for the site (main laboratory and Bureau Headquarters building) so only the shop facility and heating plant were completed.

Since the 1940's, many changes have occurred at the site. The FHWA still occupies about 44 acres of the original land purchase. The remaining land has been transferred to several other government agencies, including the Central Intelligence Agency, the National Park Service, and the State of Virginia.

In the 1950's, the Bureau of Public Roads began limited research testing at the site. In 1963, the site was named the Fairbank Highway Research Station in honor of Herbert S. Fairbank, a pioneer in highway research and Deputy Commissioner for Research of the Bureau of Public Roads from 1944 to 1945. Since 1965 extensive modifications have been made to the two buildings in an effort to provide laboratory and administrative space. However, even with the remodeling, the original buildings could not meet the growing needs of a vigorous national research and development program. Planning for expansion began in 1967 and a master plan was completed in 1973. Following a lengthy process of review, approval, funds appropriation, architectural design, and contract negotiation, construction on the new building began in the fall of 1980.

The new facility provides 80,000 ft^2 (7 432 m^2) of laboratory, office, and support service space. It is designed as three separate sections. The first is a three-story office wing, which also houses conference areas and a human factors laboratory. The second is a light laboratory wing, which provides facilities for a highway driving simulator, a pavement components laboratory, an experimental vehicle preparation area, a highway communication and electronics laboratory, and a highway noise laboratory. The third wing of the building contains two major heavy laboratories—a structures laboratory and a highway hydraulics laboratory. The three sections of the building are joined at a central atrium, which provides a visual focal point for molding the sections into a single unit.

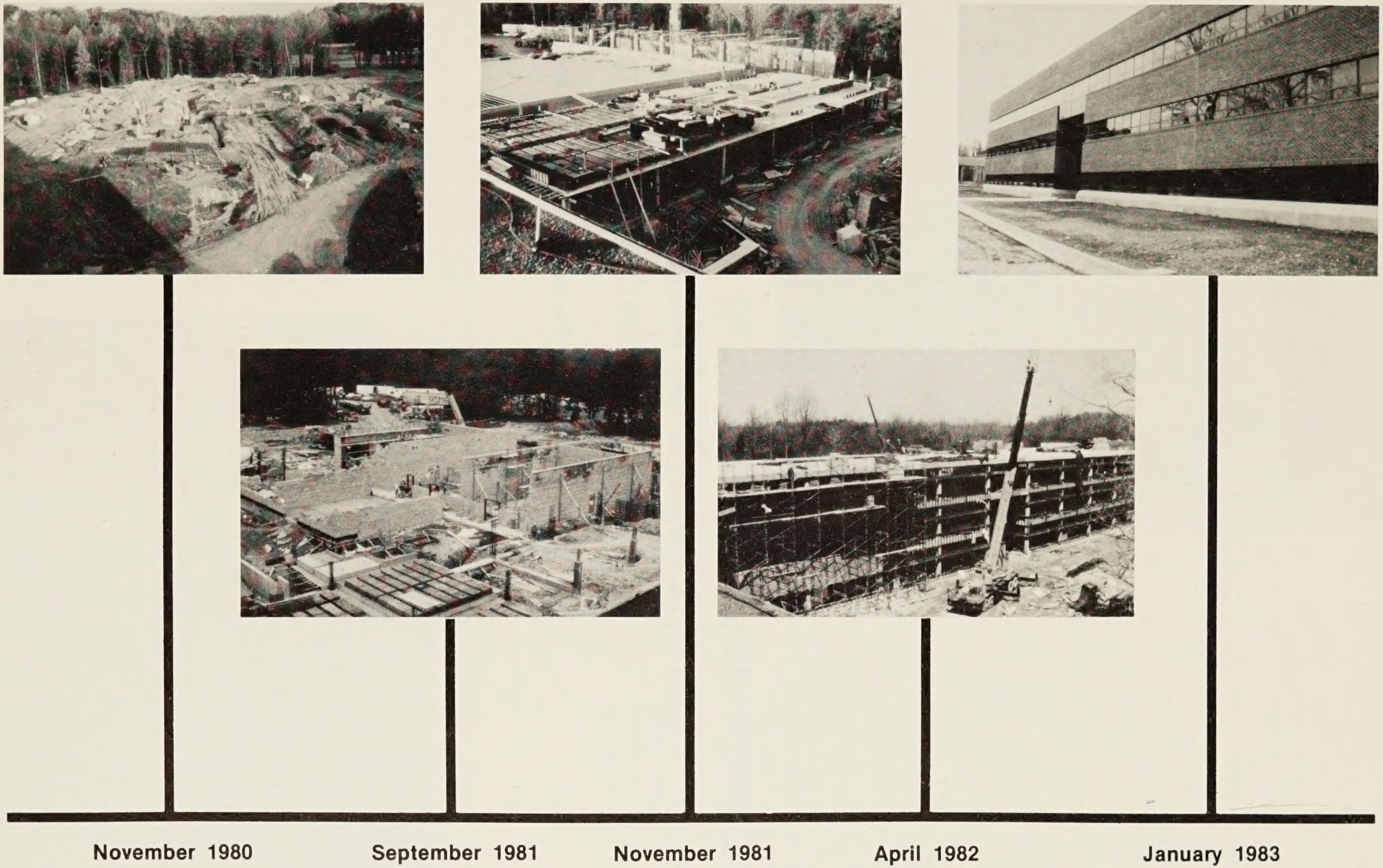
The thoroughness with which the facility is designed and constructed is demonstrated by the special characteristics of the structures laboratory, whose floor is composed of a four-celled structural box girder that has been fully instrumented as a research module itself. This feature will provide information about internal stresses created within the structural box girder when a test specimen is placed under load.

The size of the laboratories in the new facility will allow full-scale testing of the structural components of bridges and pavements. Construction techniques can be developed for cost-effective roadway systems that will absorb the loads and environmental stresses for longer periods of time than present designs.

Capabilities built into the facility make it possible to design, analyze, and evaluate major structural materials and highway components to determine their remaining life expectancy or, in some instances, the mode of failure.

The computer image-generated highway driving simulator and pupilometer allow laboratory observation of driver reactions to simulated highway conditions. In the safety of the laboratory, the researchers can identify dangerous situations and test available countermeasures.

The new facility has great potential for evaluating a wide variety of highway engineering problems. FHWA looks forward to full use of these unique laboratories and the development of new technology to provide a cost-efficient highway system with enhanced safety and operational capabilities.



Construction Progress—Beginning to End

Continuous Monitoring of Density and Temperature of Asphalt Concrete During Compaction

by

Patrick J. Campbell, Douglas H. Carter, and Terry M. Mitchell

Introduction

Nuclear gages have been used widely as quality control tools for the compaction of soils, base material, and asphalt pavements, as well as for the consolidation of portland cement concrete. The gages provide accurate, fast, and nondestructive density and moisture measurements. Until recently, these uses have been static, requiring the accumulation of random-sampled data and then statistical computation by a field technician before a decision can be reached on the acceptance, rejection, or price adjustment of a particular lot of material.

In 1979, the Federal Highway Administration (FHWA) Office of Research applied the same nuclear principles in a new gage—the Consolidation Monitoring Device (CMD). (*1*)[1] The CMD, a backscatter density gage, is mounted on a slipform paver and monitors continuously and automatically the degree of consolidation of newly placed portland cement concrete. Backscatter density measurement is illustrated schematically in figure 1. The amount of gamma radiation scattered back into the detector by the pavement or soil is proportional to the density of the reflecting material.

Many of the CMD concepts were used in developing a second new gage—the Density Monitoring Device (DMD). The DMD was developed to monitor continuously and automatically the density and temperature of asphalt concrete (AC) pavements while the pavements are being compacted by steel wheel rollers. A prototype DMD was constructed and evaluated in both the laboratory and the field. This article summarizes the DMD developmental study.[2]

An additional feature of the DMD is its ability to monitor the temperature of the AC pavement. Handheld infrared temperature sensors commonly are used at asphalt plants

[1]Italic number in parentheses identifies reference on page 55.

[2]D. Carter and P. Campbell, "Development of a Device for Continuous Monitoring of Asphalt Concrete Pavement Density and Temperature During Compaction," Federal Highway Administration, Washington, D.C. Report not yet published.

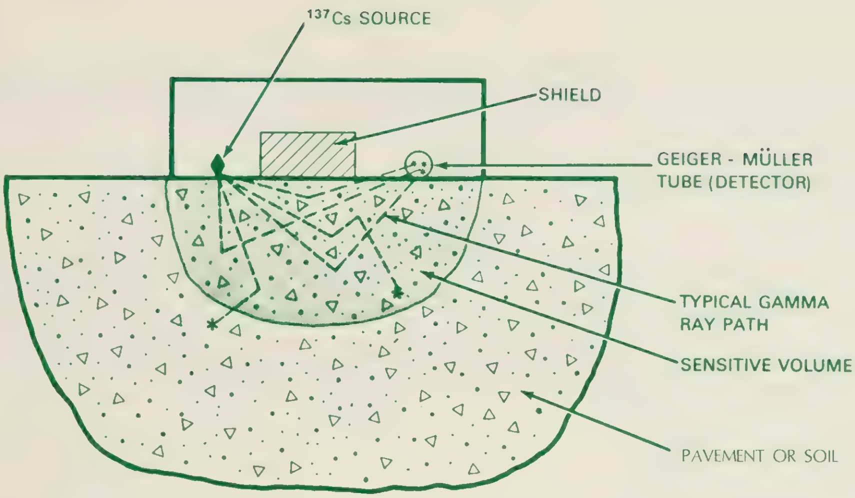


Figure 1.—Backscatter density measurement.

and at jobsites to accept or reject lots of asphalt mix and to monitor the cooling of pavements during compaction. Asphalt mix temperature is one of the most important factors affecting the ability to compact AC pavements. With most mixes, density can be increased by compaction only if the internal mat temperature remains above approximately 185° F (85° C). The time required for an asphalt mat to cool to this temperature varies because the rate of cooling is influenced by several ambient and mix design conditions. The DMD includes an infrared temperature sensor in the source/sensor unit and an analog meter display of the temperature for the roller operator. The infrared temperature sensor can be calibrated to display the internal temperature of an AC mat as determined by an asphalt thermometer.

The DMD is designed for mounting on either bumper of a steel wheel compactor. It can be used on either static weight or vibratory compactors and is most suitable for compactors used for intermediate or finish rolling of AC highway and airport pavements.

Instrument Design and Operation

The DMD consists of three major components—the source/sensor unit and carriage, the control/recorder box, and the meters. The source/sensor unit and the meters are connected to the control/recorder box by reinforced coaxial cables.

The source/sensor unit (fig. 2) includes a 10 mCi (370 MBq) Cesium–137 gamma ray source and a Geiger-Müller detector. The Geiger-Müller tube provides electrical pulses in a quantity proportional to the density of the pavement and transmits the pulses by coaxial cable to the control/recorder box.

The handle on the top of the source/sensor unit (fig. 3) is the source rod handle, which controls the location of the gamma ray source. The source can be located in the following positions:

- A safe position, with the source heavily shielded.
- A thin overlay position, for monitoring densities of overlays between 1.4 in (36 mm) and 2 in (51 mm) thick.
- A full depth position, for monitoring AC pavement layers thicker than 2 in (51 mm).

The tilted cylinder on top of the source/sensor unit contains the other major measuring system, the infrared temperature sensor. The sensor is a detector that absorbs infrared radiation emitted by the pavement surface and converts the radiation to an electrical signal. The signal then is amplified and transmitted through the coaxial cable to the control/recorder box.

Figure 2.—Source/sensor unit and carriage.

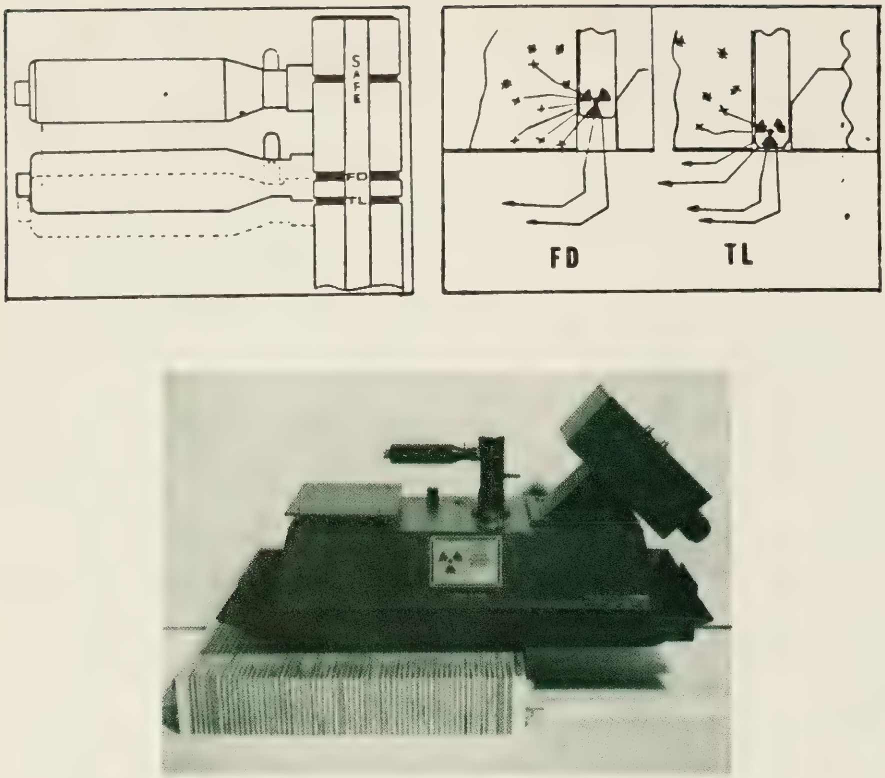


Figure 3.—Source/sensor unit (on calibration adjustment standard) and schematics of source rod handle locations.

As shown in figure 2, the source/sensor unit rides in a carriage attached to either bumper of a steel wheel compactor. When a compactor does not have an appropriate bumper, a special channel must be fabricated and welded on the compactor.

The source/sensor unit is suspended from the carriage by four stiff springs; the springs are installed and adjusted so that the carriage supports most of the weight of the source/sensor unit. The unit therefore exerts only a light pressure on the pavement surface, maintaining contact without marring the pavement surface as the unit slides along. Although the source/sensor unit will slide freely across most pavements, the DMD carriage includes piping to provide a water spray for additional lubrication.

The control/recorder box (fig. 4), typically positioned on the roller operator's deck, contains a 12 V d.c. power supply and the electronic circuitry necessary to convert the signals from both the density and temperature sensors into d.c. voltages. These voltages can drive both analog meter displays and strip chart recorders. The circuitry includes a first order time constant (resistance-capacitance) set at 20 seconds to average some of the randomness in the signals from both sensors. Because of the constant, the asphalt concrete currently being sensed is averaged into the readout along with a substantial amount of material sampled earlier.

The control/recorder box contains two strip chart recorders for permanent recording of the AC density and temperature. This is particularly useful because a record taken during the final compactor pass can be used as evidence of a pavement's density acceptability.

Controls also are included in the control/recorder box for setting target values at center scale of both the recorders and the meters. The target values are the pavement density in pounds per cubic foot (kilograms per cubic metre) required for acceptance and the minimum temperature of the AC mat on which rolling still will be effective.

The density and temperature meters (fig. 5) are installed close to the compactor operator's controls for easy viewing. Each meter has two color ranges under the meter needles. The red regions of the density and temperature meters indicate, respectively, incomplete compaction and lower than minimum mat temperature for effective rolling. The green regions indicate that the desired density has been achieved or that the mat temperature is still high enough for rolling to be effective.

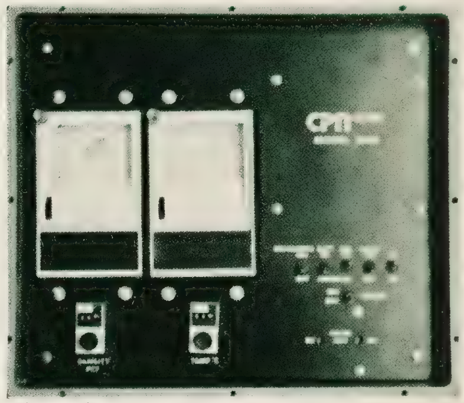


Figure 4.—Control/recorder box.

The foldable carriage, the base plates for the control/recorder and meter boxes, and the coaxial cables can remain with the host roller for the duration of the intended use of the DMD. The working components can be installed and checked for proper operation each morning that the DMD system is to be used; setup takes approximately 20 minutes.

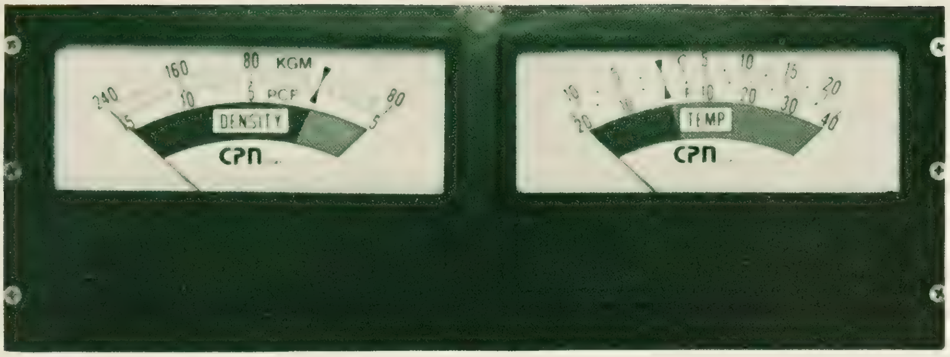


Figure 5.—Roller operator's display.

Laboratory Evaluation

The prototype DMD was completed early in 1982. Before it was evaluated in the field, a series of laboratory tests were conducted. Test objectives included establishing the following:

- The accuracy of the density and temperature monitoring system readouts.
- The effect of variations in surface roughness and aggregate chemical composition on the density readout.
- The depth sensitivity of the density reading; that is, the DMD's responsiveness to AC at various depths.
- The best means of calibrating the density and temperature monitoring systems in the field.

Results

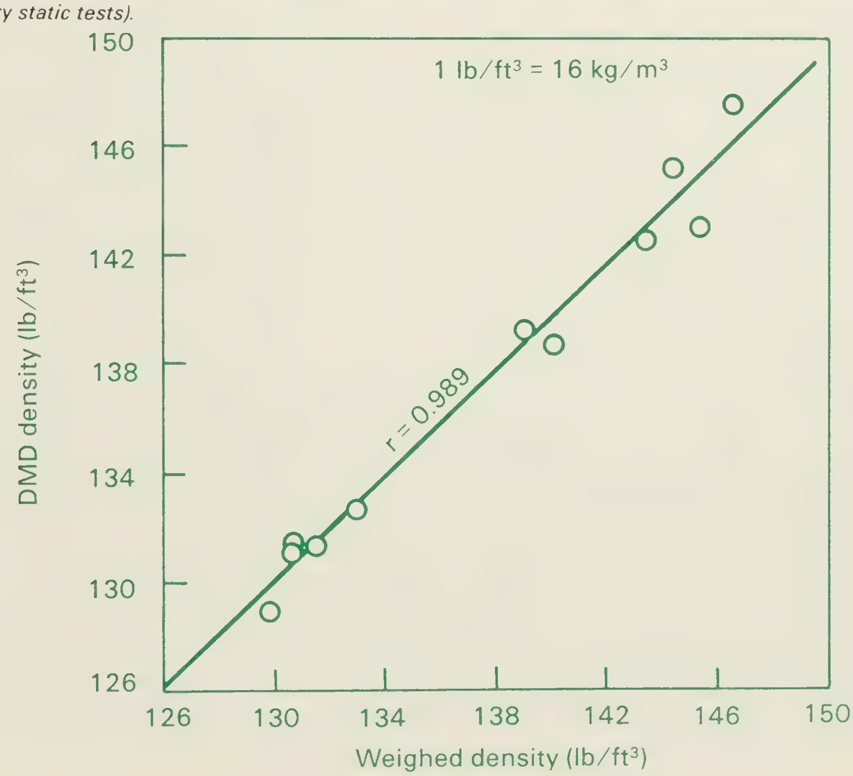
The density monitoring system was evaluated by measuring its performance over 11 AC standards 24 in x 24 in (610 mm x 610 mm) in area and 0.5, 1.0, or 2.0 in (13, 25, or 51 mm) thick. The AC was compacted carefully in steel-walled, wood-bottomed molds. The standards included weighed densities ranging from 125 lb/ft^3 (2 002 kg/m^3) to 145 lb/ft^3 (2 323 kg/m^3) and a range of surface roughnesses. All of the laboratory tests were static. Weighed density (the density established from gravimetric weighing of the known volume standards) was chosen as the standard of comparison for the accuracy determinations. Figure 6 plots the DMD density versus the weighed density for each sample. The correlation coefficient for 11 readings encompassing all of the listed variables was 0.989 and the standard error was $\pm$ 0.9 lb/ft^3 ($\pm$ 15 kg/m^3).

The DMD's responsiveness to AC at different depths depended on the position of the gamma ray source. In the full depth position, the data showed that 90 percent of the device's readout comes from the top 1.9 in (48 mm) of an AC sample and 99 percent comes from the top 2.75 in (70 mm). In the thin overlay position, 90 percent of the device's readout comes from the top 1.5 in (38 mm) and 99 percent from the top 2.25 in (57 mm).

The surface roughness effect is the error produced in the device's response when a uniform 0.050 in (1.3 mm) air gap is introduced beneath the source/sensor unit. The laboratory study showed this error to be 3.0 lb/ft^3 (48 kg/m^3) for the full depth mode of operation and 4.5 lb/ft^3 (72 kg/m^3) for the thin overlay mode. Such errors are sizable but are compensated for in the DMD by calibrating the device on "average" AC surface textures or by adjusting the calibration based on core density results.

The chemical composition effect was established by taking DMD readings on a series of nonasphaltic standards, three siliceous and three calcareous. When separate regression lines were fitted to each set of three points, the spread between

Figure 6.—Correlation between DMD density and weighed density measurements (laboratory static tests).



the two curves was less than 2.0 lb/ft^3 (32 kg/m^3) at all densities in the range from 100 to 160 lb/ft^3 (1 602 to 2 563 kg/m^3).

The temperature monitoring system was evaluated by comparing its responses with those obtained with a handheld infrared sensor. The data showed that the DMD and the handheld sensor differed by less than 4° F (2.2° C) over the critical temperature range of 160° to 210° F (70° to 100° C).

Calibration

The DMD initially was calibrated on the AC standards fabricated for the laboratory evaluation. Similar standards could be constructed by other gage users to represent their own typical AC mixes. However, to avoid the need to check or adjust the DMD calibration on the AC standards in the field, a magnesium/aluminum calibration adjustment block was constructed. Alternating sheets of the two materials were laminated to give a 14 in x 17 in x 3 in (360 mm x 430 mm x 75 mm) standard of known density. The metallic standard is not subject to moisture absorption, physical deterioration, or other long term conditions that may affect a natural standard. Referencing the magnesium/aluminum standard to the 11 AC standards is a relatively simple procedure. After the DMD is calibrated on the AC standards, the unit is positioned on the magnesium/aluminum standard with the aid of an aluminum guide plate (fig. 7). The obtained density value then is assigned to the metallic standard. Whenever calibration adjustment is necessary, the DMD is returned to the standard and adjusted until the standard's assigned density value is duplicated by the DMD density chart recorder and meter.

The temperature system is calibrated simply by adjusting the control in the control/recorder box to correspond to readings obtained with a handheld infrared sensor or a field thermometer inserted in the pavement.

Field Trials

The development of the DMD prototype included field trials during late 1982 and early 1983 on three paving projects in California and Arizona. The field trials compared density results obtained with the device with results obtained by current standard procedures—cores and static nuclear gages.

Initially, static DMD readings were compared with static standard nuclear density gage readings at the same field locations. Standard gage results at eight locations on a northern California paving project showed a mean density of 135.9 lb/ft^3 (2 177 kg/m^3), with a standard deviation of 2.0 lb/ft^3 (32 kg/m^3). At the same eight locations, the DMD showed a mean density of 137.9 lb/ft^3 (2 209 kg/m^3), with a standard deviation of 1.5 lb/ft^3 (24 kg/m^3). The DMD readings include a surface roughness correction of 3.0 lb/ft^3 (48 kg/m^3), so the uncorrected readings actually were slightly lower than the uncorrected static gage readings.

Dynamic DMD results (results obtained from a moving compactor) also were compared with static standard nuclear gage results and with core densities. Figure 8 shows typical data from one Arizona project. The figure shows the DMD density chart recording on the final roller pass on a 1,400 ft (430 m) length of pavement that includes a 200 ft (60 m) test strip, seven static backscatter density readings taken from randomly sampled locations on the short strip, and the densities of seven 6 in (150 mm) diameter cores taken at the static gage measurement locations. The integrated, continuous density measurement of the DMD correlates very well with both the static backscatter measurements and the core densities.

The field trials also showed the DMD to be easy to operate and fieldworthy. One person made routine calibration and operation checks of the DMD in about 20 minutes. Each day the DMD components were installed on and removed from the host roller in about 20 minutes, without the use of hand tools. With a 30-minute orientation, the roller operator, jobsite foreman, and project engineer were completely familiarized with all DMD controls and with the effectiveness of the compactive effort indicated by the readout instruments.

The field trials also showed that the DMD was mechanically and electronically stable under a variety of field conditions and that it could be operated throughout a typical paving day on its own fully charged 12 V power supply without disrupting any paving procedures or inconveniencing personnel.

Future Plans

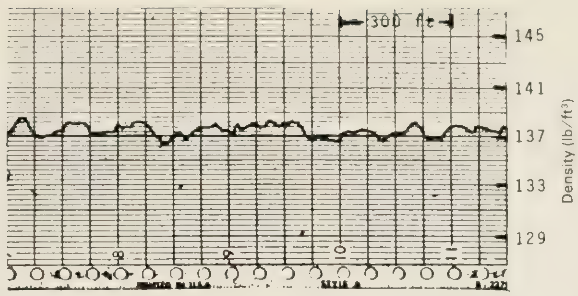
In early 1983 another nuclear gage manufacturer, Seaman Nuclear Corporation, began marketing a roller-mounted, continuous density monitoring device. This device, the Density-on-the-Run Meter (DOR), consists of a roller-shaped source/sensor unit, which mounts between the two rollers on a steel wheel compactor, and a regularly updated digital display of the density value (fig. 9). FHWA's Office of Engineer-

Figure 7.—Magnesium/aluminum calibration adjustment standard.

	Commercial Static Backscatter Gauge		6" Diameter Asphalt Core	
Site No.	Density in PCF	Relative* Compaction	Density in PCF	Relative* Compaction
1	138.3	96.9	137.6	96.5
2	138.2	96.9	137.5	96.4
3	137.6	96.5	136.9	96.0
4	139.4	97.8	138.7	97.3
5	137.9	96.7	137.2	96.2
6	137.7	96.6	137.0	96.1
7	137.9	96.7	137.2	96.2
Avg.	138.1	96.8	137.4	96.4

$$\text{Relative compaction} = \frac{\text{Field density}}{\text{Laboratory maximum density}} \times 100$$

Laboratory maximum density = 142.6 lb/ft³



1 in = 25.4 mm
1 ft = 0.305 m
1 lb/ft³ = 16 kg/m³

Figure 8.—Static backscatter density gage readings, core densities, and DMD strip chart record on Arizona project.

ing and Highway Operations Research and Development has established a series of contracts with State highway agencies for field trials of both the DMD and the DOR. Three State highway agencies are field testing both devices to further evaluate their utility, fieldworthiness, and accuracy. The field trials should be completed early in 1984.

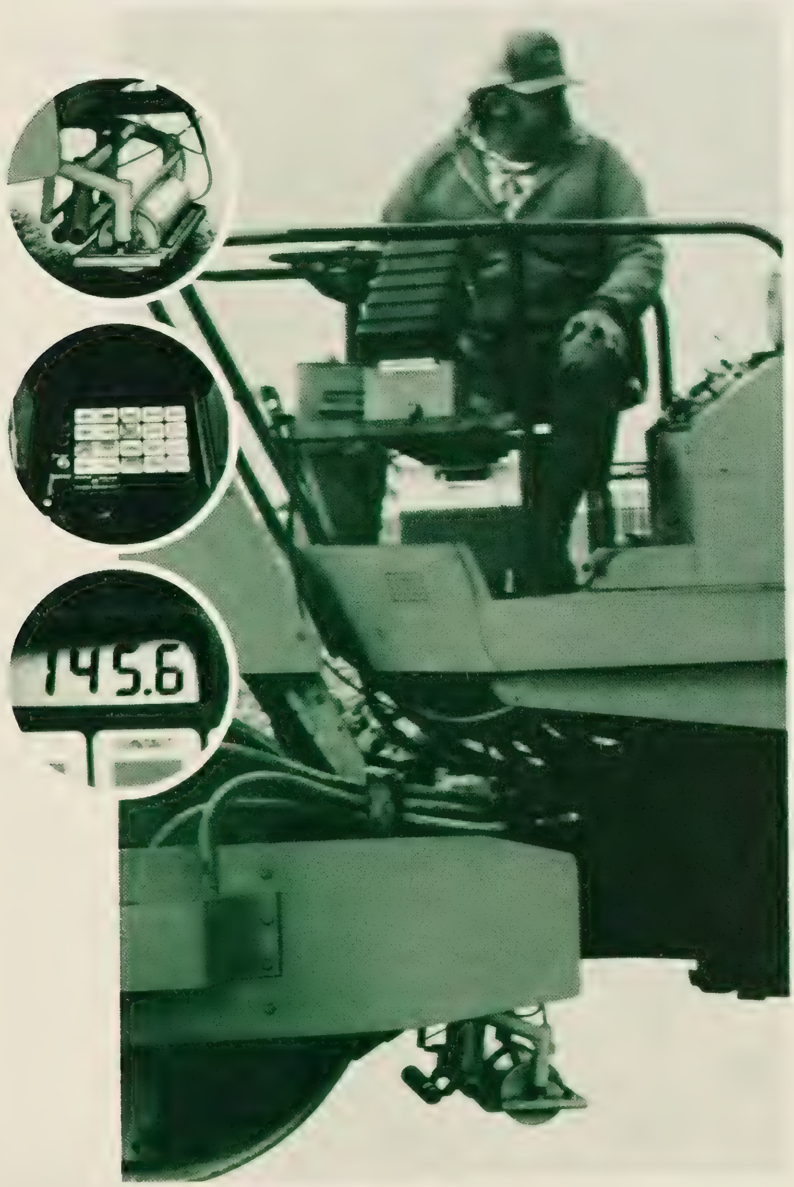


Figure 9.—Density-on-the-Run Meter.

Summary

FHWA's Office of Engineering and Highway Operations Research and Development believes the DMD is a valuable new tool for controlling the quality of AC pavement as it is being placed. Continuous density and temperature monitoring allow compactors to be operated as efficiently as possible, by changing rolling patterns or by adjusting the amplitude and frequency of the vibrators on vibratory compactors. Immediate feedback also should allow plant or placement problems to be corrected if they produce detectable changes in compactibility. In addition, the DMD's strip chart recorder provides an extensive record of pavement density and can minimize the amount of additional core or static nuclear gage testing necessary for material acceptance.

REFERENCE

(*1*) T. M. Mitchell, P. L. Lee, and G. J. Eggert, "The CMD: A Device for Continuous Monitoring of the Consolidation of Plastic Concrete," *Public Roads*, vol. 42, No. 4, March 1979, pp. 148–155.

Patrick J. Campbell is the president of CPN Corporation in Pacheco, California. The company manufactures nuclear material testing gages used extensively in the construction, agricultural, and roofing industries. Mr. Campbell was the principal investigator on the DMD development study.

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The Use of Road Markings to Narrow Lanes for Controlling Speed in Residential Areas

by
Harry S. Lum

Introduction

This article describes a research study that addressed speeding on residential streets—one of the most common traffic complaints reported to law enforcement officers by residents. Speeding generally occurs on wide streets that have little or no horizontal or vertical curvature so drivers have a long sight distance. Deterring speeders in residential areas is vexing for traffic engineers because solutions are limited.

Thirty different countermeasures and strategies used in the United States and Great Britain to control speed were ineffective or minimally successful. (*1*)[1] It was concluded that enforcement coupled with a rational speed zoning policy was the most effective method of speed control in residential areas.

In a before-and-after study on the impact of street narrowing on speed, six locations on three different streets were narrowed as part of a street beautification program. (*2*) Street widths were reduced from 8 to 18 ft (2.4 to 5.5 m), leaving two traffic lanes at least 11 ft (3.4 m) wide each. These before-and-after studies showed that there was no consistent or material reduction in the average speeds after street narrowing. At two locations, the average speed increased 1 mph (1.6 km/h); at three locations, the average speed decreased between 1 and 3 mph (1.6 and 4.8 km/h); and at one location, the average speed decreased 5 mph (8 km/h) (table 1). Reducing lane width to 9 ft (2.7 m) might further reduce the speed.

[1]Italic numbers in parentheses identify references on page 60.

In a limited correlational analysis of 11 residential streets in San Francisco, California, it was concluded that street width, block length, and environmental (house) setback were positively correlated with drivers' speed. (*3*) However, there was no mention whether the correlations were statistically significant. The selected streets were level tangents carrying light traffic but were not arterial or commercial routes. Parallel parking was permitted and present on both sides of the street, and the longest block length considered was 614 ft (187 m).

In 1980 the Federal Highway Administration (FHWA) initiated a study to determine whether the speed distribution of motorists traveling on residential streets could be changed by reducing the number of fast drivers through psychoperception.[2] Lanes were striped 9 ft (2.7 m) wide to create the impression of a narrow street to determine if fast drivers would reduce their speeds.

Table 1.—Before-and-after speed studies at locations where streets were narrowed (*2*)

Location	95th Percentile speed Before	After	Net change
	mph	*mph*	*mph*
Bryant at 21st Street	34	33	-1
Bryant Street, 22d to 23d Street	28	25	-3
Bryant at 23d Street	26	27	+1
Harrison at 23d Street	35	30	-5
Harrison Street, 23d to 24th Street	32	30	-2
Sanchez, 14th to Duboce Street	27	28	+1

1 mph=1.6 km/h

Site and Land Use

Based on traffic studies, citizen complaints of excessive speed, and accident reports, four sites in Orlando, Florida, were considered for the experiment. Plaza Terrace and South Lake Orlando Parkway were chosen because observers could record radar speed readings without being noticed by motorists. Figures 1 and 2 show the two locations with the traffic control devices in place.

Plaza Terrace, located in the fully developed Audubon Park subdivision, is lined with single family homes and an apartment complex. Much of the through traffic uses Plaza Terrace to access an office complex adjacent to the subdivision.

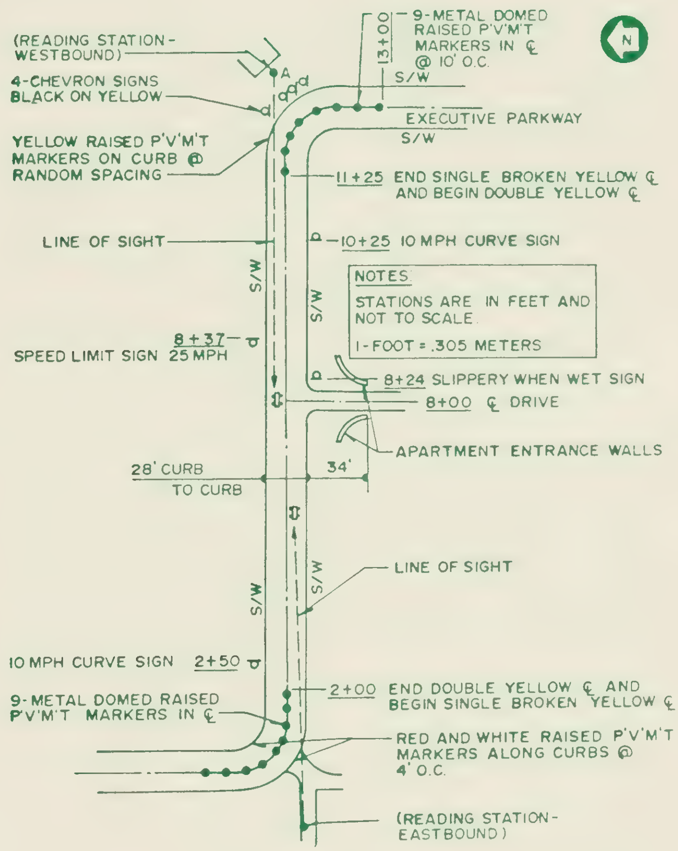

Figure 1.—Plaza Terrace test site.

[2]Kenneth Saunders et al., "Evaluation of Speed Control Measures on Residential Streets," *Federal Highway Administration*, May 1982. Unpublished report.

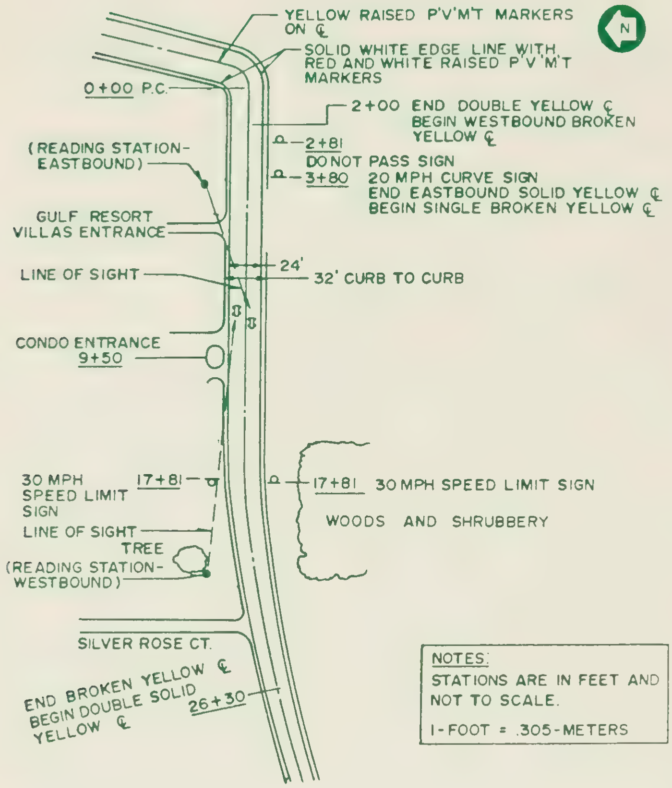

Figure 2.—South Lake Orlando Parkway test site.

South Lake Orlando Parkway, in the Rosemont subdivision, travels through a new and not yet fully developed residential area comprised mostly of single family homes and condominiums. A clubhouse with a restaurant and bar, tennis courts, and golf course is located on the north side of South Lake Orlando Parkway.

Experimental Treatments

Plaza Terrace is about 28 ft (8.5 m) wide; South Lake Orlando Parkway is about 36 ft (11 m) wide. Before the experiment the pavement markings at both sites consisted of a 6 in (152 mm) wide broken yellow centerline. The stripes were 10 ft (3 m) long with a 30 ft (9 m) gap between the stripes. Because of discoloration, the centerlines were restriped about 6 weeks before the experimental treatments were installed.

At the Plaza Terrace test site, 6 in (152 mm) wide solid white edgelines were added to the pavement to create two approximately 9 ft (2.7 m) lanes (fig. 3). Raised pavement markers also were installed at both ends of each segment of the broken centerline. Parking is not permitted on either side of the street.

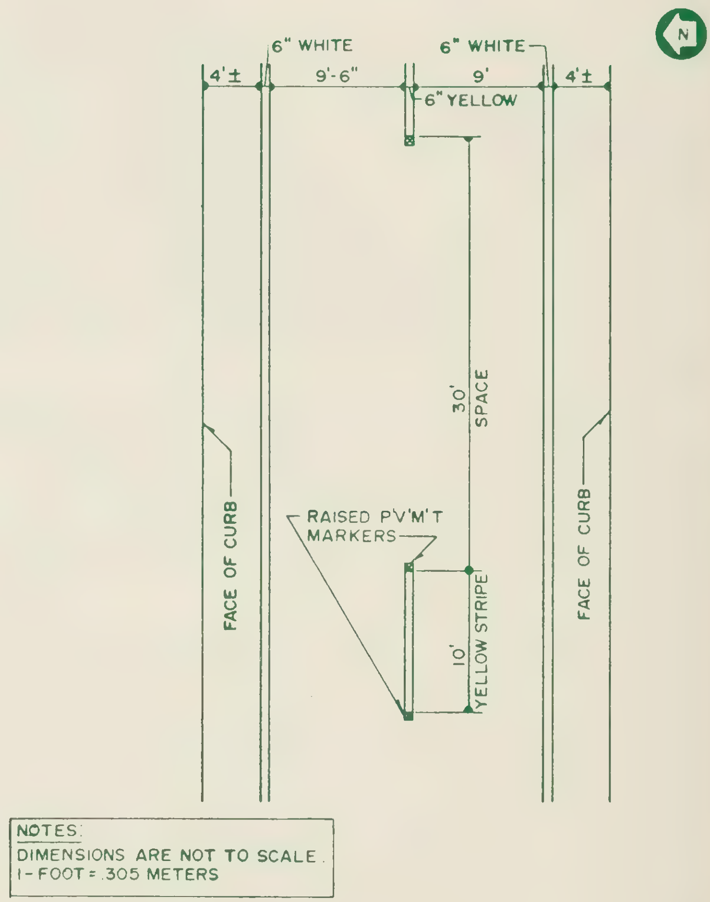

Figure 3.—Plaza Terrace test pavement treatment.

For the South Lake Orlando Parkway, the treatment consisted of two 9 ft (2.7 m) lanes with a standard broken yellow centerline and double solid white edgelines spaced 1.5 ft (0.5 m) apart (fig. 4). Red/white raised pavement markers were installed at both ends of each segment of the broken centerline. The same kind of markers also were installed along the edgelines nearest the centerline and alined with the centerline markers. Parking is permitted on both sides of the street.

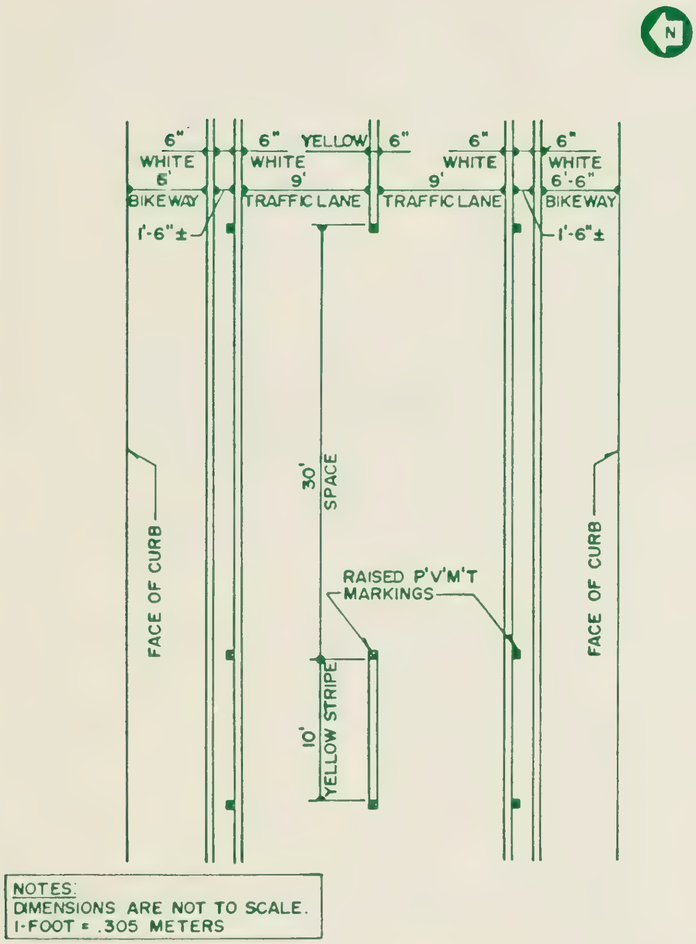

Figure 4.—South Lake Orlando Parkway test pavement treatment.

Data Collection

The data collection crew consisted of three people. One member stationed at the east end of the street recorded the speed of the eastbound vehicles using a handheld battery-operated radar gun; the second member stationed at the opposite end of the street recorded the speed of westbound vehicles with another radar gun. The third member of the crew recorded traffic volume and any "unusual" events. Only the speeds of free flowing vehicles were recorded; speeds of vehicles influenced by a lead vehicle or vehicles turning into a driveway or apartment entrance were not recorded.

Three sets of data were collected—one set for the before period and two sets for the after period. The first set of after data was collected immediately after the treatments were installed. The second set of after data, collected approximately 2 weeks later, was used to test for possible delayed or lasting effects of the treatments. Each set of data consisted of 2 days' readings for 1-hour intervals in the morning, afternoon, and evening. With one exception, between 60 to 100 speed readings were recorded for each morning, afternoon, and evening data period. Overall, approximately 3,300 readings were recorded.

Analysis

Table 2 outlines 36 comparisons of which 23 show an increase in average speed, 2 show no change, and 11 show a decrease. In general, the median speeds (not presented) differed no more than 1 mph (1.6 km/h) from the mean speeds. The 85th percentile speed for South Lake Orlando Parkway ranged between 37 and 44 mph (60 and 71 km/h) and for Plaza Terrace between 35 and 42 mph (56 and 68 km/h).

Statistical analyses also were performed. Bonferroni's t-statistic was used for simultaneous significance tests for pairwise comparisons of the means of the three sets of data for each site and each time period. (*4*) No statistical difference in the mean speeds between any two sets of speed readings was found at the 5 percent significance level. The Kolmogorov-Smirnov test also revealed no statistical change in the speed distribution among the three sets of data for the two sites. (*5*)

There were some instances of excessive speed. In this article, excessive speed is defined as 15 mph (24 km/h) over the legal speed limit based on the premise that the less law-abiding drivers will travel in excess of three standard deviations (one standard deviation is approximately 5 mph [8 km/h]) above the legal speed limit. For South Lake Orlando Parkway, the legal speed limit is 30 mph (48 km/h). Approximately 3 percent of the drivers in the before period and 2.8 percent in the after period were traveling over 45 mph (72 km/h), or three standard deviations above the legal speed limit. For Plaza Terrace, 6.9 percent of the drivers in the before period and 5.2 percent in the after period were traveling over 40 mph (64 km/h), or three standard deviations over the legal speed limit of 25 mph (40 km/h). The difference in the before-and-after percentages at either site is not statistically significant. The top speed recorded in this study was 64 mph (103 km/h).

Table 2.—Mean speeds before and after experimental treatments at Plaza Terrace and South Lake Orlando Parkway

Site	Before treatment	Immediately after treatment	Approximately 2 weeks after treatment	Difference in mean speeds: Before and immediately after treatment	Before and approximately 2 weeks after treatment	Immediately after and approximately 2 weeks after treatment
	mph	mph	mph	mph	mph	mph
Plaza Terrace						
9 a.m. (westbound)	32.1	33.0	33.0	+0.9	+0.9	0.0
9 a.m. (eastbound)	32.2	32.9	33.6	+0.7	-1.4	+0.7
1 p.m. (westbound)	32.6	32.4	32.6	-0.2	0.0	+0.2
1 p.m. (eastbound)	33.0	31.0	34.2	-2.0	+1.2	+3.2
8 p.m. (westbound)	31.2	31.4	31.5	+0.2	+0.3	+0.1
8 p.m. (eastbound)	33.5	31.6	33.1	-1.9	-0.4	+1.5
South Lake Orlando Parkway						
7 a.m. (westbound)	32.5	35.2	33.8	+2.7	+1.3	-1.4
7 a.m. (eastbound)	35.1	35.4	35.6	+0.3	+0.5	+0.2
3 p.m. (westbound)	35.9	36.9	36.1	+1.0	+0.2	-0.8
3 p.m. (eastbound)	33.6	35.1	34.0	+1.5	+0.4	-1.1
6 p.m. (westbound)	37.7	36.8	35.6	-0.9	-2.1	-1.2
6 p.m. (eastbound)	33.9	33.4	34.4	-0.5	+0.5	+1.0

1 mph=1.6 km/h

Summary and Conclusions

The study shows that longitudinal pavement markings combined with raised pavement markers to create an impression of a narrower street have no effect on the mean speeds or the speed distributions of drivers on residential streets. It is conjectured that the delineated lanes made the driver's task of tracking the roadway easier. It was observed that few drivers straddled or crossed the edgelines, and when they did they quickly corrected their course to stay within their lane of travel. With long sight distances and street widths wide enough for emergency maneuvers, drivers do not perceive the 9 ft (2.7 m) delineated lanes as narrow. The passive traffic control devices tested did not eliminate speeding. In summary, this study generally supports findings of previous studies on speed control on residential streets.

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(5) S. Siegel, "Nonparametric Statistics: For the Behavioral Sciences," *McGraw-Hill Book Company*, 1956.

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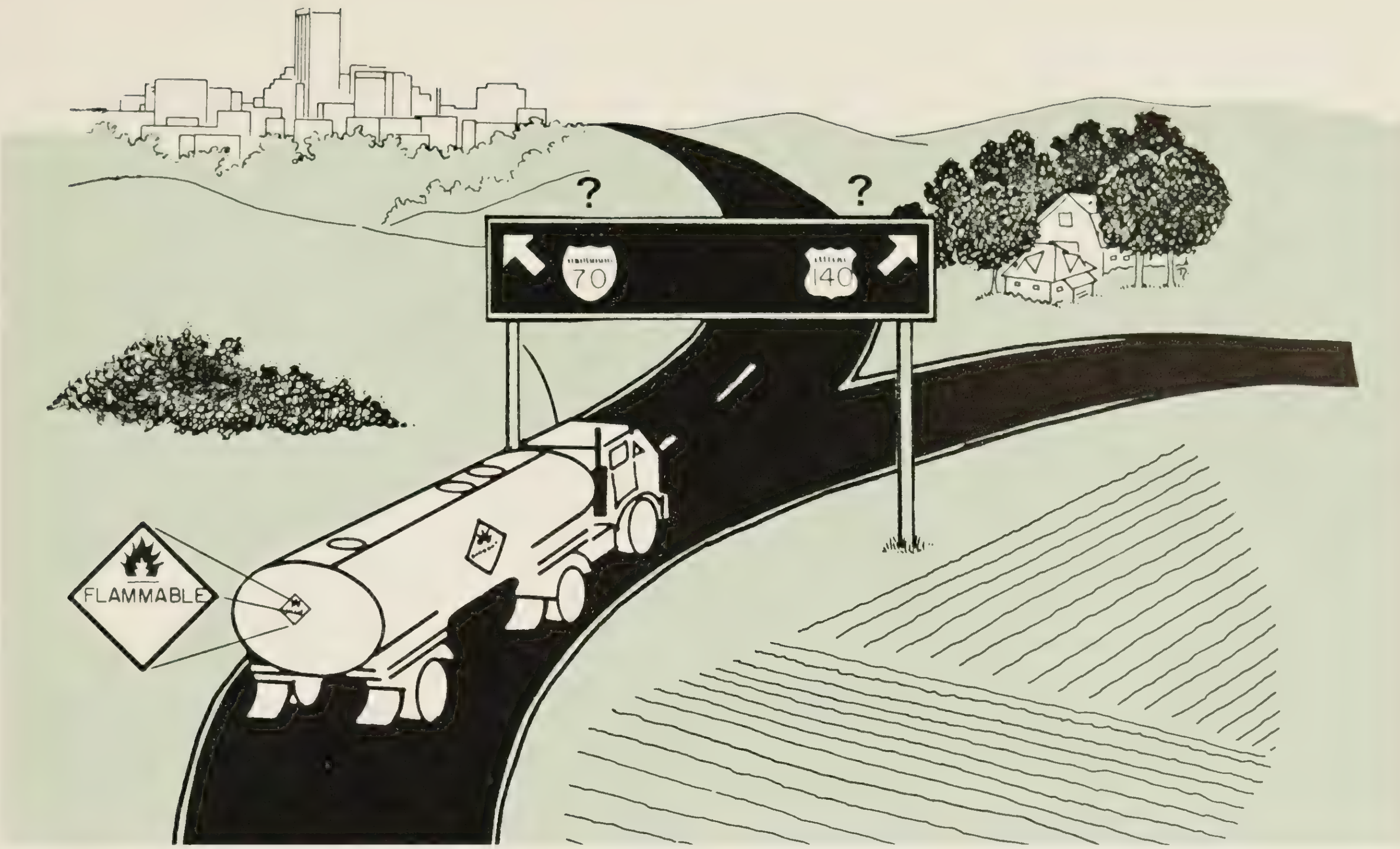
[3]Report with stock number is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.



Guidelines for Designating Routes for Transporting Hazardous Materials

by
Charles J. Nemmers and William L. Williams

This article summarizes the results of a Federal Highway Administration (FHWA) study to develop guidelines for designating highway routes for transporting hazardous materials. (*1, 2*)[1] A hazardous material is a "substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce . . .". (*3*) The guidelines presented can be used by State officials, planners, and engineers to evaluate hazardous materials movements over interstate highways, urban arterials, and rural highways according to the risks posed to nearby populations and property.

[1]Italic numbers in parentheses identify references on page 65.

Introduction

Several factors have contributed to growing governmental, industrial, and private concerns about hazardous shipments over highways including the increased number of serious accidents involving hazardous materials in recent years, questions regarding technical abilities to control these problems (particularly oil spills and poisonous gas releases), and increased awareness of the magnitude of the potential problem.

The U.S. Department of Transportation has responded to many of these concerns under authority granted by the 1974 Hazardous Materials Transportation Act. (*3*) Virtually all aspects of packaging, handling, and labeling of hazardous materials are regulated. Truck carrier route selection, the subject of this article, also is regulated. Many of the risks associated with transporting hazardous materials can be reduced substantially by thoughtful routing. For example, highly vulnerable population centers or environmentally sensitive areas can be avoided, minimizing their potential exposure.

It is important to recognize the extent of the hazardous materials transport problem. Highway accident records of the U.S. Department of Transportation's Materials Transportation Board spanning the 5½-year period between July 1973 and December 1978 indicate 77 deaths, 596 injuries, and 2,131 accidents associated with transporting hazardous materials. (*1*) Gasoline, fuel oil, and acid are involved in nearly 92 percent of all hazardous materials accidents (table 1). Although eliminating hazardous materials accidents is a worthwhile goal, it should be pointed out that industry has been doing a good job in transporting these hazardous commodities. Fatalities associated with hazardous materials transport comprise approximately 0.03 percent of all highway fatalities.

Routing Method

The routing method developed in the FHWA study is designed to identify and evaluate roadway and community characteristics that make one route safer than another when transporting hazardous materials. The method involves identifying highways where accidents are less likely to occur and areas where the consequences will be less severe if accidents do occur. The method allows persons with little or no knowledge of hazardous materials shipments or transportation planning to conduct their own analysis. Experiences indicate that approximately 40 to 80 person-hours are necessary for analyzing 50 to 100 route miles (80 to 161 route kilometres). The depth of the analysis, the familiarity with local data, and the characteristics of the routes evaluated can alter this estimate.

The analysis may be conducted by an individual or by a group of people representing various agencies and interests. Perhaps the most cost effective approach is to assemble a project team to scope the problem and structure the analysis. The technical work then may be performed by one or two individuals and the project team reconvened to discuss findings.

Table 1.—Distribution of highway accidents involving hazardous materials by commodity (*1*)

Commodity	Accidents
	percent
Flammable liquids (gasoline, paint, alcohol)	60.5
Combustible liquids (fuel oil, kerosene)	16.3
Corrosives (sultric acid)	11.6
Flammable compressed gas (liquid petroleum gas)	3.2
All others combined	8.4

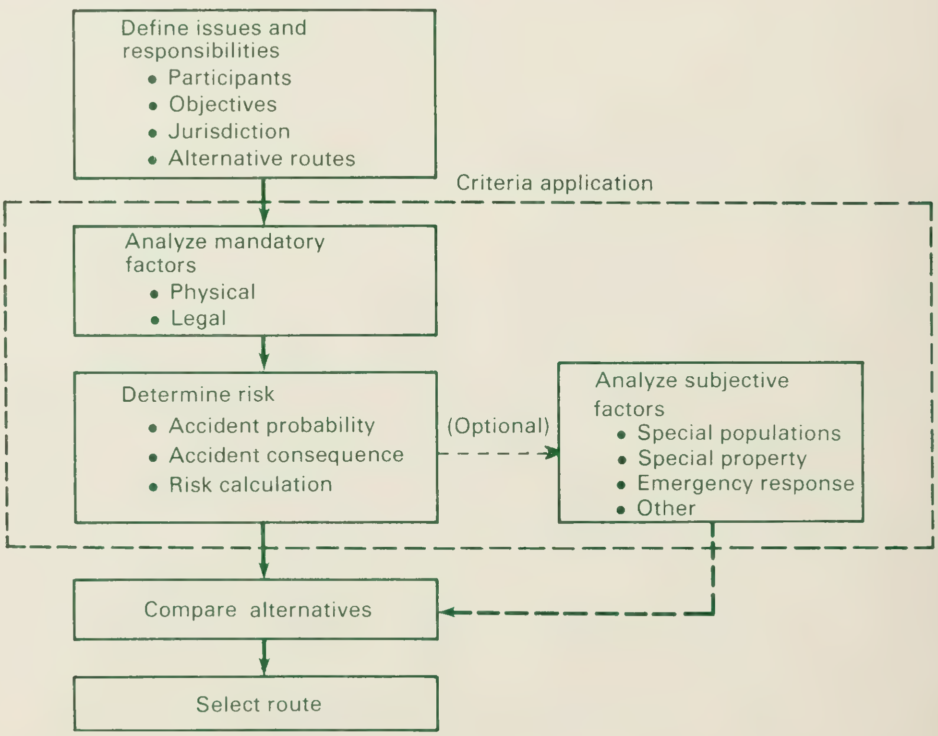
The sequence of tasks and decision points in the method allows the analyst early in the process to eliminate alternative routes that clearly are unacceptable. The first step in the analysis is to identify the roles of the performing agency, identify the affected parties, and identify the community's objectives for managing hazardous materials. Alternative routes that are consistent with community objectives are selected, factors that affect hazardous materials routing decisions are investigated, and then criteria are applied to determine which routes are most or least preferred.

Factors that influence routing decisions and the criteria for applying the factors are grouped into three categories that correspond to three levels of decisionmaking. Each decision level identifies characteristics that would preclude the use of a particular route. This progression of decision points is used to successively reduce the number of alternatives and ultimately select a preferred routing.

Define Issues and Responsibilities

Initial project activities involve structuring the routing analysis and establishing community consensus. Thoughtful problem identification and project planning in the early stages will make it easier to select the routes to be analyzed and the procedures to be used. Figure 1 shows the steps in the hazardous materials routing method.

Figure 1.—Hazardous materials routing method.



Participants

Decisions about routing requirements for hazardous materials affect many community members including motor carriers, public safety officials (for example, fire, police, civil defense), State and local government officials, the general public, and industries serving motor carriers. The first step in the routing analysis is to identify all potentially affected parties and contact representatives of these groups.

Objectives

Another responsibility of the project team is to establish and document the community's objectives in conducting a routing analysis. Whether the routings will apply to through or local deliveries also should be established. The logical progression is to designate through hazardous materials routes first and then use these routes as the primary access points for local routes into the community centers.

Another issue that must be resolved is whether the routing analysis will be for all hazardous materials, commonly transported hazardous materials (for example, gasoline), or only unusually dangerous materials (for example, poisonous gas). Other problems to be addressed are the quantity of hazardous materials carried on individual vehicles and routing requirements for small hazardous materials shipments.

Jurisdiction

One method for resolving jurisdictional conflicts between States and municipalities is to delineate responsibilities for local versus through routing of hazardous materials. Through routing, for example, might be the responsibility of the State so that requirements are consistent throughout the State and local conflicts that might impede the free flow of commerce are minimized. Local communities should provide input to these decisions and might assume responsibility for designating local routes that would connect the through routes with the major delivery, pickup, and storage sites within the community.

Alternative routes

By this point in the project, the performing agency should be well acquainted with the agencies and individuals involved with hazardous materials movements and the overall purpose of the routing analysis. With the aid of regional road maps, routes that satisfy community objectives, are reasonably compatible with existing hazardous materials trucking practices, and do not have obvious physical and/or legal constraints that seriously impede or prohibit their use should be identified.

Limited staff time will preclude analyzing all alternatives, and the initial subjective selection of routes to be analyzed should reflect a knowledge of local demography, roadways, and traffic conditions. At this stage in the analysis, to select routes for the through transport of hazardous materials, populated areas should be avoided and interstates should be used as much as possible because their safety records are better.

Analyze Physical and Legal Mandatory Routing Factors

Mandatory routing factors (physical or legal constraints that prevent or prohibit hazardous materials shipments) are investigated at the first decision level in eliminating alternatives. These constraints may apply to all motor carriers or only carriers of specific hazardous commodities.

Weight limitations on bridges and height restrictions on overpasses are the most common physical impediments that will preclude the use of a route. Other constraints might include inadequate shoulder construction activities or inadequate turning spaces.

Laws and regulations that prohibit hazardous materials on specific roadways or structures (for example, bridges and tunnels) are investigated for each alternative. Local and State traffic engineers are the most direct source for this information; however, bridge, tunnel, and turnpike authorities also should be contacted to identify any hazardous materials restrictions on these facilities.

Determine Risk

For the routing analysis, risk is the probability of a hazardous materials accident times the consequences of a hazardous materials accident. The major criterion for route selection is that route which has the lowest risk value. Roadways with the smallest adjacent population and number of properties, as well as accident rates, will have the lowest risk values. If sufficient differences (25 percent or more) exist between the risks on alternative routes, it may be possible to designate the preferred hazardous materials route on the basis of the mandatory factors and the risk calculations.

Accident probability

To determine the probability of a hazardous materials accident, accident rate data are estimated for all vehicles and then factored to represent the much smaller incidence of hazardous materials vehicles in the traffic stream. The typical method for assembling accident rates is to contact State or local traffic engineers and use their existing data. If neither accident rates nor frequencies are available, the analyst must estimate accident rates using mathematical models. (*2*)

Accident consequences

Consequences may be measured for population, property, or both. The potential impact area for a hazardous materials release will depend on the class of hazardous material being considered. The choice of which class to analyze may be based on local knowledge or determined by inspecting the hazardous materials incident data base maintained by the U.S. Department of Transportation Materials Transportation Board. To measure population within the potential impact zone, the zone is scaled off on census tract maps. The routing method is flexible enough to permit modifications in the consequence measurement techniques without distorting the fundamental risk equation. Property consequences are measured by determining the value of roadway structures and buildings on or adjacent to the right-of-way.

Risk calculation

The potential consequences (population and/or property) and accident probabilities for a segment of a route are multiplied to calculate the segment risk. Adding all segment risk values produces the total risk for the route. The population risk value and property risk value are calculated and presented separately.

Subjective Routing Factors

Subjective factors are useful for tie-breaking decisions where no one alternative is clearly superior to the others. Subjective factors should reflect community priorities and values. Typical subjective factors might include the locations of emergency response teams and their ability to respond to hazardous material releases, the locations of semiambulatory or preschool populations that may be unable to evacuate themselves, and sensitive ecological areas with critical importance such as watersheds and reservoirs (fig. 2).

Final Route Selection

The final step in the analysis is to compare the alternatives according to their lengths, travel times, potential risks, and any additional subjective factors that were introduced. Selection of the preferred route should reflect the community's consensus on which criteria are most important. The route selection decision should be thoroughly documented for the public record.

The Routing Analysis Worksheet (RAW) presented in figure 3 summarizes each component of the alternatives analysis in the order corresponding to the sequence of activities described in this article. The worksheet insures consistent application and documentation of the criteria used to evaluate alternative hazardous materials routes.

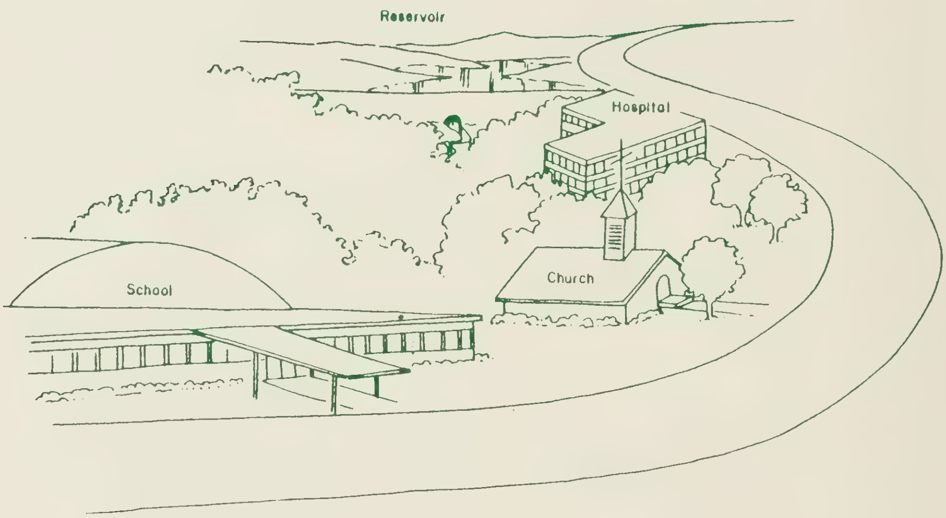


Figure 2.—Possible subjective factors.

1 ROUTE CHARACTERISTICS

Alternative No. ______ Length ______ Miles Travel Time ____ Minutes Circuity ______

Origin ______ Destination ______ Via ______

Description ______

Is the route currently used by hazardous materials carriers? Yes No

Explain ______

Select hazardous materials class for study:

Impact Radius ______

2. MANDATORY FACTORS

Are there any physical constraints? Yes No Explain ______

Are there any legal constraints? Yes No Explain ______

3. RISK DETERMINATION

Segment No.	Probability of a Hazardous Materials Accident		Potential Population Exposed to Hazardous Materials		Population Risk
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
				Total	

Segment No.	Probability of a Hazardous Materials Accident		Potential Property Exposed to Hazardous Materials		Property Risk
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
______	______	×	______	=	______
				Total	

4. SUBJECTIVE FACTORS (OPTIONAL)

Which of the following are subjective factors in the routing decision?

Explain the choice of all subjective factors and how they are to be applied in the routing decision.

Special Populations Yes No

Special Properties Yes No

Emergency Response Capability Yes No

Other Yes No

Figure 3.—Hazardous materials Routing Analysis Worksheet.

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William L. Williams is a highway engineer in the Safety and Traffic Implementation Division, Office of Implementation, Federal Highway Administration. He manages technology transfer in the area of traffic engineering. Before joining the Office of Implementation, Mr. Williams was with the National Cooperative Highway Research Program of the Transportation Research Board and prior to that he was head of traffic operations for the State of West Virginia.

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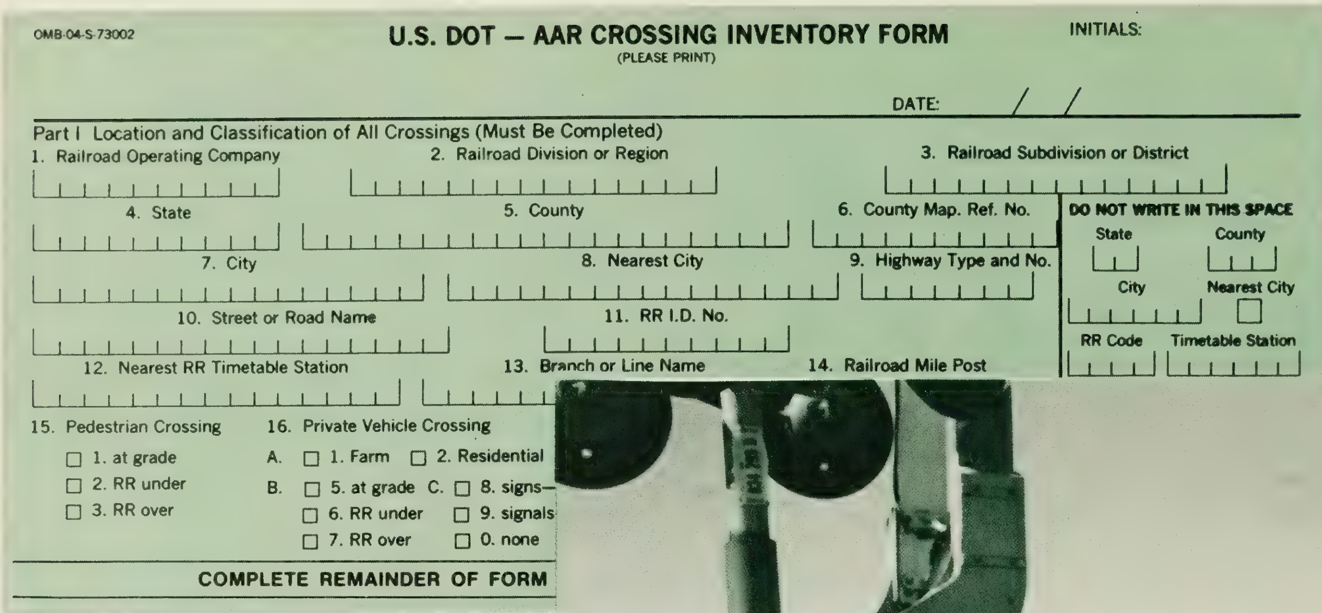
(*2*) E. J. Barber and L. K. Hildebrand, "Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials," Report No. FHWA-IP-80-15, *Federal Highway Administration*, Washington, D.C., November 1980. (Report is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Stock No. 050-001-00198-5.)

(*3*) Title 49 of the Code of Federal Regulations, ch. 1, subch. C: Hazardous Materials Regulations, sec. 171.8, Oct. 3, 1979.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U.S. DOT — AAR CROSSING INVENTORY FORM
(PLEASE PRINT)

INITIALS:

DATE: / /

Part I Location and Classification of All Crossings (Must Be Completed)

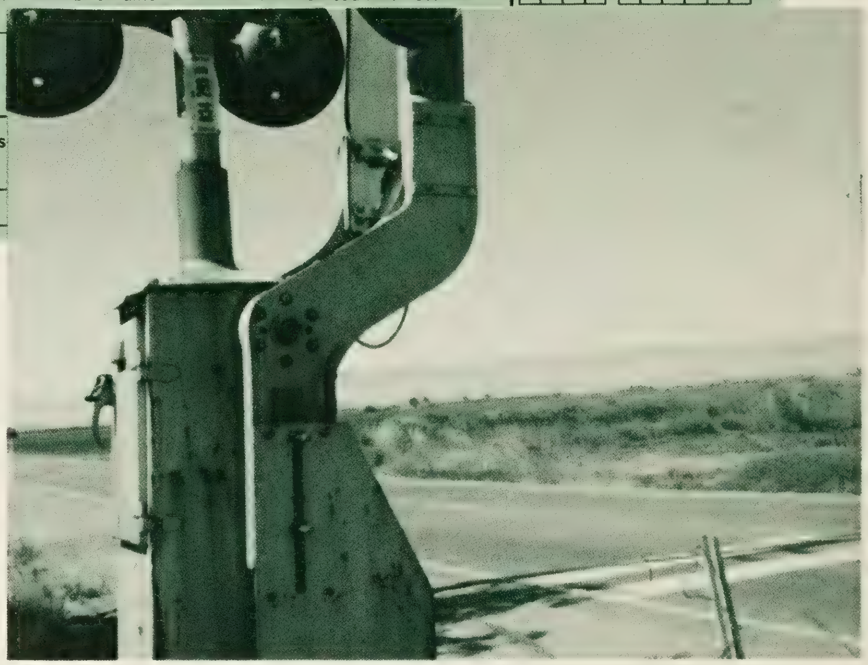
1. Railroad Operating Company
2. Railroad Division or Region
3. Railroad Subdivision or District
4. State
5. County
6. County Map. Ref. No.
7. City
8. Nearest City
9. Highway Type and No.
10. Street or Road Name
11. RR I.D. No.
12. Nearest RR Timetable Station
13. Branch or Line Name
14. Railroad Mile Post

DO NOT WRITE IN THIS SPACE
State County
City Nearest City
RR Code Timetable Station

15. Pedestrian Crossing
☐ 1. at grade
☐ 2. RR under
☐ 3. RR over

16. Private Vehicle Crossing
A. ☐ 1. Farm ☐ 2. Residential
B. ☐ 5. at grade C. ☐ 8. signs—
☐ 6. RR under ☐ 9. signals
☐ 7. RR over ☐ 0. none

COMPLETE REMAINDER OF FORM



National Railroad-Highway Crossing Inventory

by
Janet A. Coleman and Bruce F. George

This article provides some background and current status information on the national railroad-highway crossing inventory in an attempt to encourage States and railroad companies to continue their participation in the program.

Introduction

In 1972 the U.S. Department of Transportation submitted to Congress a two-part railroad-highway safety report that recommended alternative ways to reduce railroad-highway crossing accidents, injuries, and fatalities. (*1*)[1] Part II of the report included a recommendation to develop an information system on railroad-highway crossings. At that time, crossing information was maintained by railroad companies, States, Federal agencies, and some local agencies, and the information often was incomplete, fragmented, and not uniform.

If railroad-highway crossing safety improvement programs were to be systematically planned and evaluated, Federal agencies, States, and railroad companies needed certain site-specific crossing information for all public and private crossings in the United States. The major emphasis was on public crossings. The Federal Railroad Administration (FRA) assumed principal responsibility for developing the national crossing inventory system and allocated funds for the project. Additional funding later was provided by the Federal Highway Administration (FHWA) to complete the project, which was a cooperative effort between the U.S. Department of Transportation and the railroad companies with the costs equally shared.

The railroad companies, under the direction of the Association of American Railroads and the American Short Line Railroad Association, were responsible for obtaining site-specific inventory information on each crossing, installing and maintaining a unique identification number plate at each crossing, and updating railroad information.

[1]Italic numbers in parentheses identify references on page 68.

With the assistance of the FHWA, State highway agencies provided site-specific highway information for each public crossing and also were responsible for updating the highway inventory information. Other State and local agencies were encouraged to participate in the project.

The computer-based file was conceived and completed in an unprecedented tripartite (industry-State-Federal) effort between 1972 and 1975. The three-phase inventory project began in mid-1972. Phase I, completed in November 1972, consisted of designing the inventory numbering system, number plates, inventory forms and procedures, and test phase. Phase II, completed in June 1973, consisted of testing the number plates and the inventory forms and procedures, developing the cost estimates for field implementation, and designing and testing the computer files and data handling procedures. Phase III was the national implementation of the project.

The initial inventory file was completed in 1975. Over 400,000 public and private at-grade and grade-separated railroad-highway crossing sites were visited, numbered, and inventoried. Data collected included the kind of crossing, the crossing location, and the crossing's immediate surroundings. For public at-grade crossings (over 200,000) data on railroad and highway traffic, operating and physical characteristics, warning devices, and administrative responsibilities also were reported.

Status

Initially, inventory updates initiated by one party (either a State or a railroad company) had to be reviewed by the other party, which often delayed updating the inventory files. Currently, single party updates are processed, which has greatly increased the number of updated records. (*2*)

Other changes to facilitate the updating procedures and encourage participation by States and railroad companies include the following:

- Mass updating—When a large number of crossings have had changes affecting the same few data items for each crossing, mass updating is suggested using a fill-in-the-blank computer printout or a magnetic tape in the prescribed format. An example of a mass update would be to change a railroad name or increase highway traffic volumes by a certain percent. Specific questions regarding the mass updates can be referred to the FRA's Office of Safety.
- Updated records from the national file—States or railroad companies may request copies of updated records in a computer-generated form, a one-page-per-crossing printout, or a magnetic tape.

The FRA's Office of Safety currently maintains the crossing inventory, but States and railroad companies are responsible for keeping the inventory current. Last year, States and railroad companies voluntarily reported to the FRA nearly 100,000 changes. Although this number is a new annual high, the accuracy of inventory data is an increasing concern. Some States and railroad companies are making a concerted effort to maintain their portions of the inventory file; however, currently, about 40 percent of the States and railroad companies are not participating in the inventory program. A State or railroad company is considered to be participating if at least 1 percent of its crossing data is updated during a 12-month period.

Table 1 shows the number of inventory updates between April 1, 1982, and March 31, 1983. Quarterly inventory information is summarized by FRA. Also, tables summarizing State and railroad company participation in the inventory program and an annual bulletin summarizing crossing accident/incident and inventory data are available from the FRA's Office of Safety.

Table 1.—Inventory updates processed between April 1982 and March 1983

Inventory updates	Railroad-highway crossings: Public	Private	Total
State initiated	40,832	2,188	43,020
Railroad company initiated	17,376	4,113	21,489
Data base corrections	—	—	27,033[1]
			91,542
Total crossings (1981)	252,097	139,182	391,279

[1]Includes changes to administrative data such as railroad name.

Use of the Inventory

The inventory file continues to be used extensively by Federal, State, and railroad company program managers, public and private researchers, and consulting engineers, and often by industry and private litigants. The file is a key input to the U.S. Department of Transportation's railroad-highway crossing resource allocation procedures and accident prediction formulas. The unique inventory identification number plate at each crossing is the reporting and communications link used by railroad companies and local, State, and Federal agencies because it insures positive identification of a particular crossing. The inventory file has been used in many Federally funded research studies to help identify field test sites. Two specific studies involve the testing of new at-crossing warning devices and the testing of activated crossing advance warning signals. The apportionment of crossing safety funds is based, in part, on the number of railroad-highway crossings in each State as determined by the inventory file.

In October 1978 the National Highway Traffic Safety Administration added the railroad-highway crossing identification number to its Fatal Accident Reporting System (FARS). For the first time vehicle and driver characteristics from fatal railroad-highway crossing accidents can be analyzed. FARS data records for fatal crossing accidents now can be linked to crossing inventory data records and the crossing accident data records maintained by FRA.

Future of the Inventory

A task force composed of Federal, State, and industry representatives has been meeting to identify simpler, more flexible updating procedures for railroad companies and States. Proposed changes, circulated to States, railroad companies, and Federal agencies for comment, are designed to simplify updating procedures, eliminate data items that are not used, and add new data items requested by States and railroad companies. The FRA and FHWA also are funding a study to investigate why some States and railroad companies have not participated in the voluntary update program. Uses of the inventory will be analyzed and the costs of the proposed changes will be determined. The study is expected to begin in September 1983.

It is crucial to the continuance of railroad-highway crossing safety programs that the credibility of the inventory file be maintained. The inventory files are a valuable tool in safety research and Federal, State, and railroad planning efforts.

REFERENCES

(*1*) Report to Congress, "Railroad-Highway Safety: Part I—A Comprehensive Statement of the Problem and Part II—Recommendations for Resolving the Problem," *Federal Railroad Administration and Federal Highway Administration*, Washington, D.C., November 1971 and August 1972.

(*2*) "A Supplement to the National Railroad-Highway Crossing Inventory Update Manual," *U.S. Department of Transportation*, Washington, D.C., 1980.

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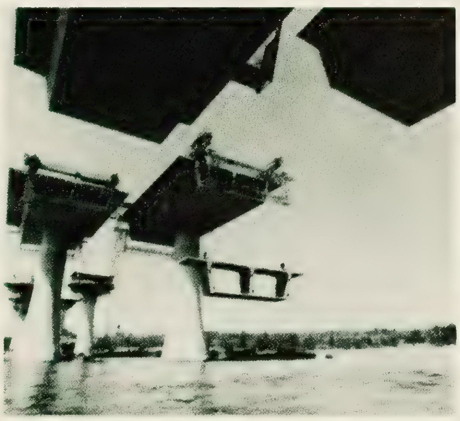
Bruce F. George is a rail-highway crossing program specialist in the Federal Railroad Administration's Office of Safety where he is involved in railroad-highway crossing safety and related programs. Before joining FRA in 1974, Mr. George was with the U.S. Department of Army.

Recent Research Reports You Should Know About

The following are brief descriptions of selected reports recently published by the Federal Highway Administration, Offices of Research, Development, and Technology. The Office of Engineering and Highway Operations Research and Development (R&D) includes the Structures Division; Pavement Division; Construction, Maintenance, and Environmental Design Division; and the Materials Technology and Chemistry Division. The Office of Safety and Traffic Operations R&D includes the Systems Technology Division, Safety and Design Division, Traffic Control and Operations Division, and Urban Traffic Management Division. The reports are available from the source noted at the end of each description.

When ordering from the National Technical Information Service (NTIS), use PB number and/or the report number with the report title.

Feasibility of Standard Sections for Segmental Prestressed Concrete Box Girder Bridges, Report No. FHWA/RD-82/024



by Structures Division

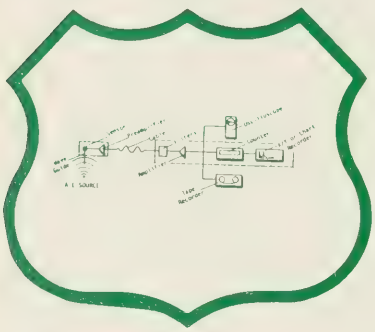
A segmental prestressed concrete box girder bridge incorporates a series of transversely oriented, precast or cast-in-place modules that have single or multiple hollow cells and rectangular or trapezoidal cross sections. Longitudinal continuity of the modules is provided by post-tensioned steel prestressing strand that passes through ducts in the concrete shell or through the open hollows of the box section cells. This structural concept, a European development of the post-World War II era, can safely and economically be used for spans up to 800 ft (244 m). The resistance of a box girder section to torsion makes it particularly suitable for balanced cantilever erection from piers—a technique that permits rapid construction of long spans without using supporting falsework or shoring. The first segmental box girder bridge in the United States was built in Texas in 1973, and more than 45 such bridges have been completed in the U.S. and Canada since then.

The growing use of this construction technique suggested standardizing at least some aspects of the bridge design and detailing to gain cost savings through mass production, reduce construction time, and improve the quality of the finished product. Furthermore, the availability of standard sections may lead to even greater use of this new structural concept as additional savings are realized.

This report includes statistical analyses of detailed data on existing bridges of this kind in the United States and Canada to determine design correlations and uniformity of significant structural parameters, particularly the geometrics used. Design studies were made to determine the most economical use of materials.

The report concludes that some standardization of prestressed concrete segmental box girder bridge design and construction is feasible and cost effective at this time and that its implementation could lead to wider use of this concept for highway bridge construction. The specific aspects of segmental prestressed concrete box girder bridges that should and should not be standardized are described and discussed in the report.

The report may be purchased from NTIS (Stock No. PB 83 169458).



Use of Acoustic Emissions to Predict Ground Stability, Report No. FHWA/RD-82/052

by Structures Division

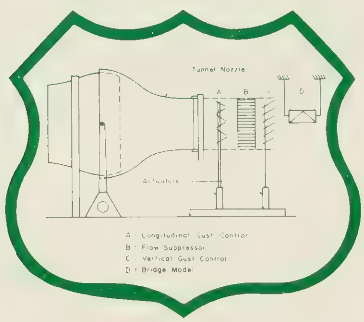
This report summarizes the findings of a 2-year effort to assess the feasibility of using the acoustic emission (AE) method for predicting ground stability in underground excavations. All types of ground (soil, rock, and mixed conditions) were evaluated, as were different construction practices (cut and cover and tunneling).

The laboratory phase of the project emphasized rock specimen testing where four fundamental AE signature types were discovered and appear to be valid for a range of rock types, tested in both compression and tension. The signatures also have been related to basic rock deformation characteristics.

Field testing of the AE method was performed at five field sites, all involving mass transit systems, where both single and multiple channel AE detection systems were used. In one of these cases, the instability of a tunnel roof was observed 1½ days before an actual failure. Other measurements indicated some instabilities, but were not verified by failures. Thus, the AE technique has not been proven for rating "standup time" on a continuous basis during and immediately following excavation. A significantly larger data base using the method in similar environments is needed.

The report may be purchased from NTIS (Stock No. PB 83 178764).

Active Modeling of Turbulence for Wind Tunnel Studies of Bridge Models, Report No. FHWA/RD-82/148



by Structures Division

This report describes a new method of turbulence generation for wind tunnel studies of bridge models. In this method additional energy is supplied to the mean flow by actively stirring air. Two arrays of symmetric airfoils, driven by an appropriate servosystem and input driving signals, are placed in the smooth, uniform flow and oscillate pseudorandomly.

Various configurations of the generator were considered, and velocity measurements were taken in the near wake downstream of the generator. Turbulence intensities, scales, and spectra were evaluated at different locations.

Turbulence of given characteristics for vertical and horizontal velocity components could be generated if the experimental configuration of the generator was selected correctly. Measured velocity spectra agreed well with the target spectra, especially in the low frequency range. The integral scales of turbulence were approximately one order of magnitude larger than the scales of a typical grid turbulence generated in the same wind tunnel conditions.

The report may be purchased from NTIS (Stock No. PB 83 201947).

Pasco-Kennewick Cable-Stayed Bridge Wind and Motion Data, Report No. FHWA/RD-82/067

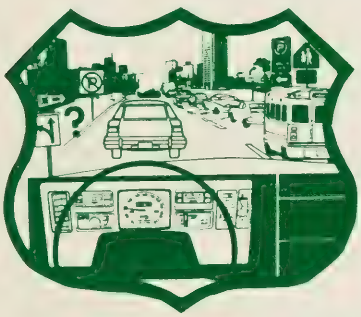
by Structures Division

This report presents approximately 2 years of wind and motion data for the Pasco-Kennewick cable-stayed bridge in the State of Washington. Objectives, in addition to the data collection, included processing to show wind turbulence characteristics, bridge vibratory characteristics, and possible relations between wind and deck motions. The data reduction process also is described in the report.

Wind data are formulated as spectra and coherence functions for three directions relative to the bridge. Acceleration spectra for the same winds are presented, and it is observed that acceleration responses are low and sensitive to wind direction. The bridge fundamental mode shapes and frequencies are derived and shown to be consistent with calculations. Cable frequencies are also determined. Damping estimates are made for the deck and cables by the half bandwidth method.

The report may be purchased from NTIS (Stock No. PB 83 201996).

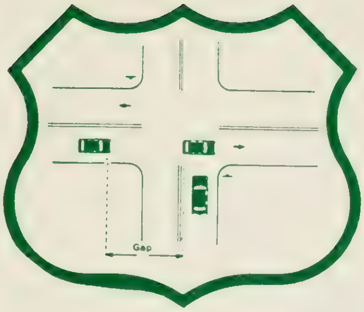
Traffic Signs in Complex Visual Environments, Report No. FHWA/RD-82/102



by Systems Technology Division

Effectively detecting and recognizing traffic control devices is related to sign luminance and contrast with the immediate surroundings. Additionally, complex visual scenes are known to degrade visual performance. A laboratory study was conducted to determine ways of measuring visual complexity and to assess how changes in sign luminance can offset decrements in performance that result from added complexity.

The report may be purchased from NTIS.



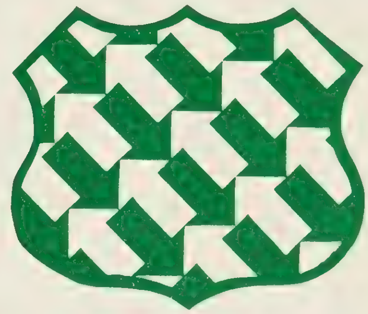
Candidate Signal Warrants From Gap Data, Report No. FHWA/RD-82/152

by Traffic Control and Operations Division

This report describes a method for determining the need for a traffic signal using site-specific information on gaps in the major road traffic. Formulas relating delay to the ratio of side street volume and gaps on the major road (analagous to the volume/capacity ratio) were derived from data collected at 43 intersections using automatic gap counters. The formulas were further validated at 18 intersections. The results show that the volume-to-gap ratio is an accurate estimator of side street delay and that the gap-based warrant is an accurate estimator of signal need when compared with engineering judgment. The gap-based warrant generally is more restrictive than existing signal warrants.

The method consists of collecting the number and size of gaps during a 4-hour period using a modified volume counter or commercially available gap counter. Using known information about driver gap acceptance, the gap data are converted to an equivalent number of adequate gaps (the gap availability parameter). The side street volume and gap availability parameter are plotted on an analysis diagram that shows average side street delay. If the average side street delay exceeds the threshold value of tolerable delay for the community (for example, 25 seconds per vehicle), then a signal may be warranted. Gap-based signal warrants for peak hour conditions and pedestrian considerations also are included in the report.

The report may be purchased from NTIS.



Computerized Signal Systems: Overview and Product Summaries, Report No. FHWA-TS-82-218

by Urban Traffic Management Division

This report provides an overview of the use of computers for traffic control of street networks. It is intended as a quick reference for the computer-based systems currently available in the United States for the control of traffic in large street networks, as well as arterials and small networks. The report includes a functional description of a computer-based traffic control system and discussions of specific systems available in the United States. Charts comparing salient features of alternative systems are provided.

The report may be purchased from NTIS.

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

The following are brief descriptions of selected items that have been completed recently by State and Federal highway units in cooperation with the Office of Implementation, Offices of Research, Development, and Technology, Federal Highway Administration. Some items by others are included when they have a special interest to highway agencies. Requests for items available from the Office of Implementation should be addressed to:

Federal Highway Administration
Office of Implementation, HRT-1
6300 Georgetown Pike
McLean, Virginia 22101

A Method for Wetland Functional Assessment, Vol. I, Critical Review and Evaluation Concepts, and Vol. II, FHWA Assessment Method, Report Nos. FHWA-IP-82-23 and -24

by Office of Implementation

These reports present a state-of-the-art review of wetland functions including groundwater recharge and discharge, flood storage and desynchronization, shoreline anchoring and dissipation of erosive forces, sediment trapping, nutrient retention and removal, food chain support (detrital export), habitat for fish and wildlife, and active and passive recreation. The reports cover all wetland types in the continental United States and use the U.S. Fish and Wildlife Service wetland classification system.

Volume I examines the validity, interactions, and possible significance thresholds for the functions, as well as documents their underlying processes. With appropriate qualifying information, wetland types are ranked for each function. Wetland types ideal for each function are identified and illustrated. Potential impacts of highways upon each function are described and, where available, thresholds are given.

Volume II provides a rapid assessment procedure for screening functional values of wetlands. The assessment method is qualitative and not based on a series of weights and scores. It can be used to evaluate the importance of a single wetland or to compare several wetlands. Contributions of wetlands versus their basins are differentiated, and seasonal variability is taken into account. Net primary productivity data for wetland plants are cataloged by region.

Limited copies of the report are available from the Office of Implementation.

Evaluation of Snowplowable Markers, Report No. FHWA-TS-82-222

by Office of Implementation

Five different snowplowable markers—Stimsonite 96, Dura-Brite, recessed, Kingray, and Prismo Roadstud—were evaluated under similar traffic and snowplowing operations. The Stimsonite 96, Dura-Brite, and recessed markers were found to be acceptable snowplowable markers and have adequate reflectivity during both dry and wet nighttime conditions. This reflectivity was maintained over the test period, and the markers proved to be durable when subjected to snowplow operations. However, considering all available input, the recessed marker is the most functional and cost effective.

Limited copies of the report are available from the Office of Implementation.

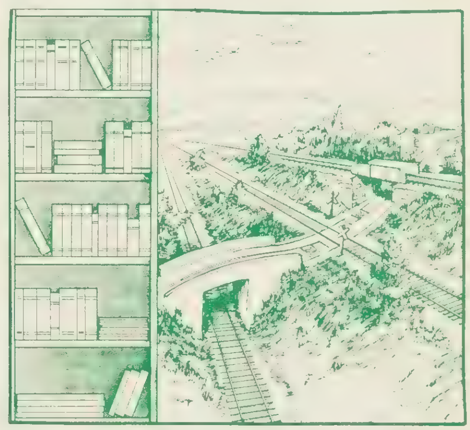
Value Engineering Study of Drainage Maintenance, Report No. FHWA-TS-82-223

by Office of Implementation

This report is the 12th in a series on optimizing maintenance activities. These studies using value engineering techniques are conducted by teams of maintenance and operations engineers from several highway agencies. This study was conducted by Iowa, Mississippi, Pennsylvania, and the National Park Service. The report includes recommendations in the areas of equipment selection, size of work crews, and the disposal of excavated material. The use of the proper combination of equipment can result in a substantial reduction in the cost of drainage maintenance.

Limited copies of the report are available from the Office of Implementation.

Compilation of State Laws and Regulations on Matters Affecting Rail-Highway Crossings, Report No. FHWA-TS-83-203



by Office of Implementation

This report is a compilation of State laws, ordinances, and regulations pertaining to rail-highway crossings organized by State, key word, and subject. It is intended as a reference tool for those working in the rail-highway crossing safety field and is not a legal document.

Limited copies of the report are available from the Office of Implementation.

Temporary Asphalt Islands

by Office of Implementation

This brochure describes the main features and advantages of the temporary asphalt island—a low cost alternative to the portable concrete median barrier for maintaining two-way traffic through construction zones where positive separation of traffic is not required. The brochure also contains a sample plan detail

of the island. The island is narrower than portable barriers and therefore sacrifices less lane width and can be installed and removed more quickly. Also, the island leaves no misleading scars on the pavement and costs about 1/10 as much as the portable barrier. The island is being evaluated in North Carolina.

The brochure is available from the Office of Implementation.

New Research in Progress

The following new research studies reported by FHWA's Offices of Research, Development, and Technology are sponsored in whole or in part with Federal highway funds. For further details on a particular study, please note the kind of study at the end of each description and contact the following: Staff and administrative contract research—*Public Roads* magazine; Highway Planning and Research (HP&R)—performing State highway or transportation department; National Cooperative Highway Research Program (NCHRP)—Program Director, National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, NW., Washington, D.C. 20418

FCP Category 1—Improved Highway Design and Operation for Safety

FCP Project 1A: Traffic Engineering Improvements for Safety

Title: Intersection Channelization. (FCP No. 51A3063)
Objective: Survey current practices. Visit sites to obtain photographs and insights on channelization design, performance, and experiences. Provide a detailed description of various channelization techniques including physical design, performance, safety impact, costs, maintenance problems, and examples of best current practices.
Performing Organization: Jack E. Leish & Associates, Evanston, Ill. 60201
Expected Completion Date: June 1984
Estimated Cost: $130,000 (NCHRP)

FCP Category 2—Reduction of Traffic Congestion and Improved Operational Efficiency

FCP Project 2N: Improved Traffic Signing and Motorist Information

Title: Highway Simulator Maintenance and Support. (FCP No. 32N3112)
Objective: Provide staffing to operate the highway simulator and maintain system hardware and software.
Performing Organization: ENSCO, Inc., Springfield, Va. 22151
Expected Completion Date: May 1985
Estimated Cost: $75,000 (FHWA Administrative Contract)

Title: Validation of Highway Driving Simulator. (FCP No. 22N3132)
Objective: Assess the performance of the highway driving simulator and perform experiments to validate the accuracy of subject responses compared with actual driving situations.
Performing Organization: Federal Highway Administration, Washington, D.C. 20590
Expected Completion Date: September 1984
Estimated Cost: $11,000 (FHWA Staff Research)

FCP Category 3—Environmental Considerations in Highway Design, Location, Construction, and Operation

FCP Category 3F: Pollution Reduction and Environmental Enhancement

Title: Absorptive Barriers for Noise Reduction. (FCP No. 33F4713)
Objective: Assess the technical and economic potential of adopting Japanese technology in absorptive noise barrier design for use in the United States. Develop a technical report and slide-tape presentation on absorptive noise barrier design and construction techniques.
Performing Organization: Vanderbilt University, Nashville, Tenn. 37238
Expected Completion Date: January 1984
Estimated Cost: $23,800 (FHWA Administrative Contract)

FCP Category 4—Improved Materials Utilization and Durability

FCP Category 4K: Cost-Effective Rigid Concrete Construction and Rehabilitation in Adverse Environments

Title: In Situ Determination of Moisture Level in Structural Concrete by the Modified Nuclear Magnetic Resonance (NMR) Method. (FCP No. 34K1011)
Objective: Modify the available NMR instrument and microprocessor for nondestructively measuring the moisture levels in structural concrete in the field. Improve the accuracy and reduce the work necessary to obtain reliable information from the collected field data.
Performing Organization: Southwest Research Institute, San Antonio, Tex. 78284
Expected Completion Date: November 1984
Estimated Cost: $49,700 (FHWA Administrative Contract)

Title: In Situ Measurement of Rate of Corrosion of Reinforcing Steel in Concrete. (FCP No. 34K1012)
Objective: Evaluate and determine the suitability of the existing instrument for measuring the rate of corrosion of steel in concrete. Measure the rate of corrosion of reinforcing steel on selected bridge decks. Incorporate all the modifications in the final version of the developed equipment.
Performing Organization: National Bureau of Standards, Washington, D.C. 20234
Expected Completion Date: March 1985
Estimated Cost: $75,000 (FHWA Administrative Contract)

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

FCP Project 5I: Improved Structural Design and Construction Techniques for Culverts

Title: Durability of Bituminous-Lined Corrugated Steel Pipe Storm Sewers. (FCP No. 4513354)
Objective: Investigate corrugated metal pipe storm sewers having 10 years service to relate performance to condition of bituminous coating, pH of storm water, abrasiveness of flow, and depth of burial. Evaluate study data and develop procedures for determining the kind of protection required for specific sites. Recommend needed changes in design and maintenance standards.
Performing Organization: Environmental Engineers, Scientists, & Planners, Columbus, Ohio 43229
Funding Agency: Ohio Department of Transportation
Expected Completion Date: October 1984
Estimated Cost: $97,000 (HP&R)

*U.S. Government Printing Office: 1983—381-783/205

FCP Project 5L: Safe Life Design for Bridges

Title: Residual Stress Measurements in Steel Components for Highway Bridges. (FCP No. 35L2062)
Objective: Develop, fabricate, and assemble a nondestructive evaluation instrumentation system for detection, evaluation, and channelization of residual stress gradients and stress patterns in welded connections.
Performing Organization: Southwest Research Institute, San Antonio, Tex. 78284
Expected Completion Date: May 1985
Estimated Cost: $221,700 (FHWA Administrative Contract)

FCP Project 5N: Pavement Management Strategies

Title: Analytical Methods for Decisionmaking. (FCP No. 45N2542)
Objective: Develop a physical model to describe the condition and needed repairs of a pavement as functions of time and traffic. Determine condition and rate of change of condition by comparing any two successive inspections of the pavements. Develop an economic model to relate pavement condition to the cost of repair. Determine the economic impact of maintenance and contract repair tactics applied at various stages of the pavement's life for various deterioration rates.
Performing Organization: New York State Department of Transportation, Albany, N.Y. 12232
Expected Completion Date: March 1986
Estimated Cost: $250,000 (HP&R)

FCP Category 6—Improved Technology for Highway Construction

FCP Project 6J: Construction Management

Title: Development of a Computer Program to Detect Bidding Collusion. (FCP No. 36J2113)
Objective: Determine what information, programs, and systems are currently in use to detect bidding collusion. Develop a computer program for use by all State highway agencies that will detect possible bidding collusion.
Performing Organization: ABT Associates, Inc., Cambridge, Mass. 02138
Expected Completion Date: October 1984
Estimated Cost: $173,280 (FHWA Administrative Contract)

FCP Category 0—Other New Studies

Title: Aerial Photogrammetric Research Using the Aerial Camera Certification Range. (FCP No. 40M4163)
Objective: Conduct comparative resolution measurement tests over known precision of range control points. Determine the accuracy of horizontal control transfer using dual altitude coverage and determine the economy of these operations by conducting flights over the precision range using a gyro-stabilized camera.
Performing Organization: Georgia Department of Transportation, Atlanta, Ga. 30334
Expected Completion Date: March 1985
Estimated Cost: $22,800 (HP&R)

Title: Bridge Deck Restoration Methods and Procedures—Phase II, Experimental Construction. (FCP No. 40M5804)
Objective: Determine the durability of about 50 installations on California bridges. Installations include deck membranes, cathodic protection, latex modified overlays, headers, sealants, and epoxy injection. Evaluate the effects of traffic, tire chains, weather, and snow removal.
Performing Organization: California Department of Transportation, Sacramento, Calif. 95814
Expected Completion Date: December 1992
Estimated Cost: $33,000 (HP&R)

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Federal Highway Administration
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