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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

THE CRESCENT STUDY

by Jon P. Underwood,
Engineer of Research
and Development

Truck data are collected for a wide variety of purposes. The federal government, states and many local governments are often involved in separate programs to support highway planning and design, as well as size and weight enforcement and tax administration. For the trucking industry many of these data collections cause delays in the trucking operations and, therefore, increase transportation prices that are eventually paid by the goods user.

The need to economically acquire information on characteristics of heavy trucks brought about the Crescent or H.E.L.P. (Heavy Vehicle Electronic License Plate) Study. This project is an automatic truck traffic monitoring system. It combines automatic vehicle identification (AVI), weigh-in-motion (WIM) and automatic vehicle classification (AVC) technologies with a computerized data communications network.

This classification system will work in the manner indicated in Figure 1. The ELP or transponder shown on the front of the truck is a device coded with information to identify that particular truck as well as other classified information placed in the transponder by the truck owner. This transponder will be activated and read by the reader station. The truck owner information, along with the vehicle's weight and classification, will be forwarded to a central computer for use by various governmental entities for planning and design purposes.

The system will assist the trucking industry by giving each truck firm information on its individual fleet to aid firms in equipment manage-

INSIDE...

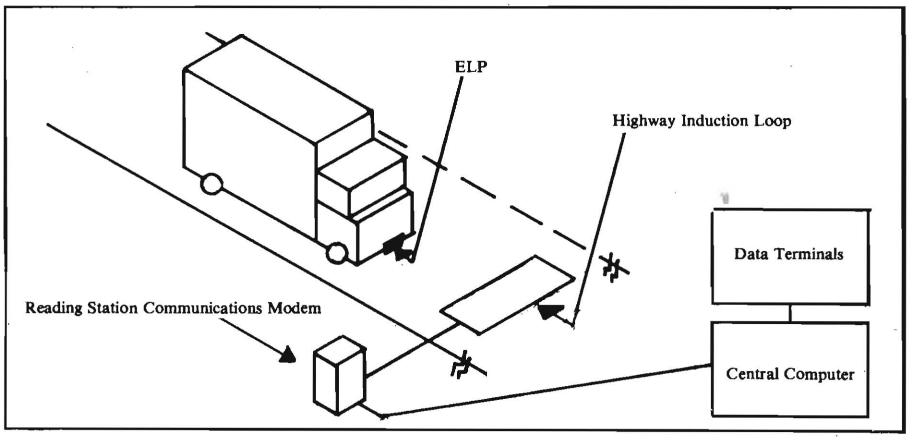

FIGURE 1 Electronic license plate.

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Transportation Planning Division, Research and Development Section,
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ment and business planning. Additionally, this system will assist the trucking industry by reducing delays at port-of-entry and various permitting locations, decreasing paperwork required to operate a truck over the road, reducing insurance premiums because of better crime detection and by allowing for better highways as a result of better data collected for design purposes.

The Crescent project will demonstrate the viability of the concept and provide a realistic evaluation of the system's benefit cost. It involves developing and/or testing the necessary hardware and software and installing and evaluating the system on a major truck route that runs from British Columbia, Canada, to southern California and from there eastward through Texas.

Even though this project is being conducted in the western part of the country, it is national and even international in scope. Additionally, it is the world's largest highway research project.

Since this is the largest highway research project in the world, it requires state participation and public-private cooperation. Figure 2 shows the monetary participation by various governments involved in the demonstration study. These are

FIGURE 2 Federal & state contributions in thousands.

	1986	1987	1988
Alaska	100	100	100
Arizona	250	150	100
Calif.	125	125	125
Nevada	25	25	25
N. Mex.	70	50	25
Oregon	204	160	30
Texas	150	200	50
Wash.	25	25	25
FHWA	250	-	-

cash contributions only and do not include the in-kind services and equipment provided by the participating states. The total money to be spent on this project, including in-kind services, is currently estimated to be in excess of $14 million. The cash budget this year is approximately $1.2 million and includes in excess of $813,000 in technical studies.

These studies include a system design study, automatic vehicle identification tests, development of performance specifications for weigh-in-motion, a small study to assist the states in site selection, and a small study to investigate the feasibility of using satellites for data collection and transmission. For the most part, these studies are being done by consultants...

The system design has provided detailed reports on 14 known AVI systems, outlined possible AVI specifications based on literature review, and developed tentative WIM and vehicle classification specifications. Additionally, the system will begin the satellite system evaluation and outline a possible vehicle management system for the trucking industry.

Yet to be determined is the type of automation system to be used. Questions we need to answer include the following: Is it going to be by state, by region or national? How do we control access to the data? Is the system going to be publicly or privately operated?

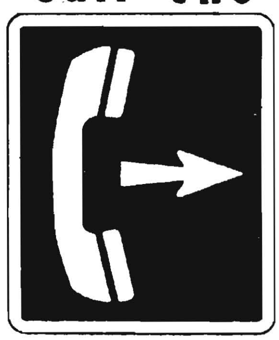
The various automatic vehicle identification systems (transponders and readers) will require a large amount of test coordination. This coordination will consist of reviews of past work, advice on laboratory and field tests, systems assessment, developing preferred system specifications, testing this system, and reporting to executive committee on the results.

The following are various AVI options to be considered: Should the system be optical (such as the railroads use with the various color markings on the railroad cars)? Should the system be inductive, i.e., activated on sensing presence of transponder? Should the information be transmitted via microwave, satellite, or how? The transponder has various options to be considered as well. Should it be active, i.e., powered when the vehicle is operating? Semi-active—powered only when in the presence of a reader? Those two types are powered by the truck's electrical system; the transponder could be passive, i.e., no vehicle power required to be read by the reader.

Additionally, the AVI chosen has to operate over multilanes of a highway, at 70+ mph, in all climates, be compact/portable, have low power requirements, and be secure with low error rate. The cost of this AVI system is estimated to be approximately $50 per transponder and $10,000 per roadway reader.

Weigh-in-motion performance specifications are required because of the many WIM options available. These systems perform at various levels of accuracy, maintenance requirements, and initial costs. Therefore, minimum performance specifications are necessary to determine which systems will give consistent data in this multistate study. A technical study is underway to estimate these benefits and costs.

Call the



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WEIGH-IN-MOTION IN THE TEXAS SDHPT

The recently developed 4-lane WIM equipment can automatically weigh, dimension and classify any selected types (or all types) of vehicles operating at normal road speeds. It's a far cry from the old photoelectric eyes used to determine average daily traffic on the lonely back roads of Texas or from static scales at busy interstate weigh stations with lines of trucks waiting along the main lanes. It gives the kind of detailed, large sample statistical data about traffic loading patterns needed for design and construction of durable multilane highways. The uses and usefulness of this equipment are just beginning to be tapped.

FIGURE 1 Multilane WIM installation.

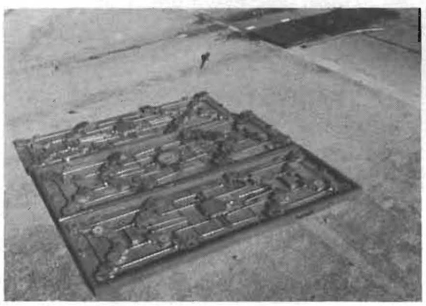

FIG.2 Three transducers awaiting installation.

Of the eight permanent WIM sites, six were upgraded in March 1984 to multiple lane weighing capabilities. The upgrading was accomplished by the addition of strain gauge transducers in each lane. These are part of the surface-mounted vehicle (loop) detector and axle detector technology developed at the Center for Transportation Research under Research Study No. 312. During routine weighing sessions, these transducers are wired into a van-mounted 10 megabyte, hard disk IBM PCXT with a 6800 front-end board and two automatic vehicle classifiers specially built by Radian. The system can estimate the weight of trucks traveling at any speed in any lane, 24-hours a day. The data are displayed on a video screen. An operator keys in the body type of the truck before storing the information on a magnetic disk. Two more sites, IH 45 north of Corsicana and IH 35 south of Austin, were installed as multilane sites after July 1984. In addition to the permanent WIM sites, portable "black mat" WIM systems are being used. In 1984 15,000 trucks were weighed by these WIM methods; in 1985 over 100,000 were weighed. Eventually, each district will have at least one WIM site to generate pertinent truck data samples.

The weigh-in-motion concept has been fostered by the Texas State Department of Highways and Public Transportation since 1963. For a decade or so, the figures Texas has reported to the FHWA on truck statistics have been generated by WIM systems of various sorts. These truck data are analyzed to form the "W" tables used to determine 18-kip equivalent single axle loadings (ESAL) for highway design. Realistic estimations of 18-kip ESAL's are critical factors in design life because the damage done by axles over 18,000 lbs (1 ESAL unit) rises exponentially rather than geometrically. For example, 20,000 lbs is only 11 percent heavier than 18,000 lbs, but

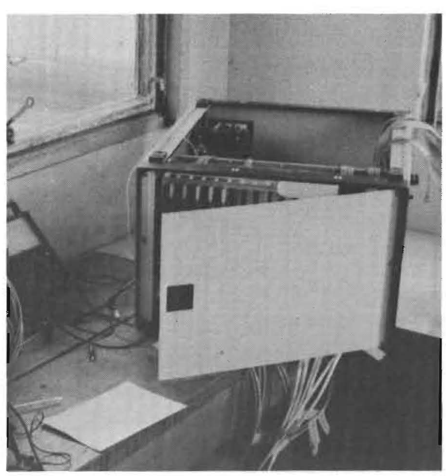

FIG.3 6800 front-end board.

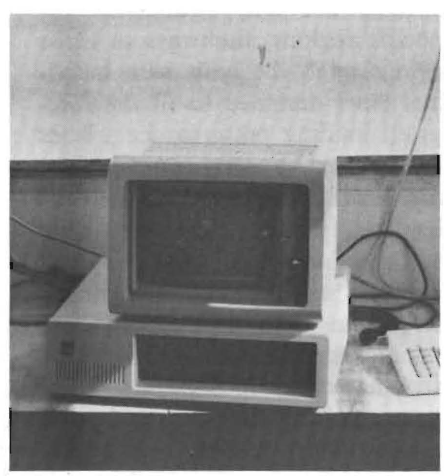

FIG.4 IBM PCXT.

a 20,000–lb axle does 57 percent more damage to the pavement (Table 1).

The "W" tables aren't the only use that can be made of WIM data, however. The multilane WIM statistics give a clear picture of the truck-traffic loading (frequency distributions of axle weights for each axle on

TABLE 1 Damage effect of 18-kip ESAL.

Single Axle Wt 1000 lbs	Relative Effect on Pavement
2	.0002
4	.002
6	.01
8	.03
10	.08
12	.18
14	.34
16	.60
18	1.00
20	1.57
22	2.34
24	3.36
26	4.67
28	6.29
30	8.28
32	10.70
34	13.62
36	17.12
38	21.31

Damage effect follows a 4th power curve.

each type of truck) for individual lanes. In the future, when loading patterns are well established for specific regions, highways in those regions might be built with individual lanes designed to fit the forecasted loading patterns; i.e., lanes which would be carrying most of the truck traffic would be designed for significantly more punishment than the other lanes. Lanewise designing could be used as a cost reducing method in both construction and maintenance. In construction, the extra materials which go into building a roadway that can withstand repeated heavy loading would only be needed for a portion of the roadway rather than the whole roadway. From a maintenance point of view, if a roadway is designed to bear an average truck traffic distribution equally on all lanes and the actual distribution of truck traffic tends to be significantly higher in one lane or lanes, then the lanes carrying the bigger portion of truck traffic will require maintenance more often than the rest of the roadway.

The WIM statistics also give a timewise distribution of the truck population on a given road and an estimate of individual truck speed. With this information correlations can be made concerning how many trucks that are violating the bridge-formula are also running over speed or at what hour the largest percentage of a certain type of truck is running over gross weight or what percentage of the over gross-weight trucks are running over speed, at what hour are the largest percentage of bridge-formula violators running, etc. (Table 2). The speed and weight correlations in particular can be used to get a better idea of the kind of stresses to which district bridges are being subjected. "Fishing charts," showing when the most violators are likely to be

FIGURE 5 WIM van on site during weighing.

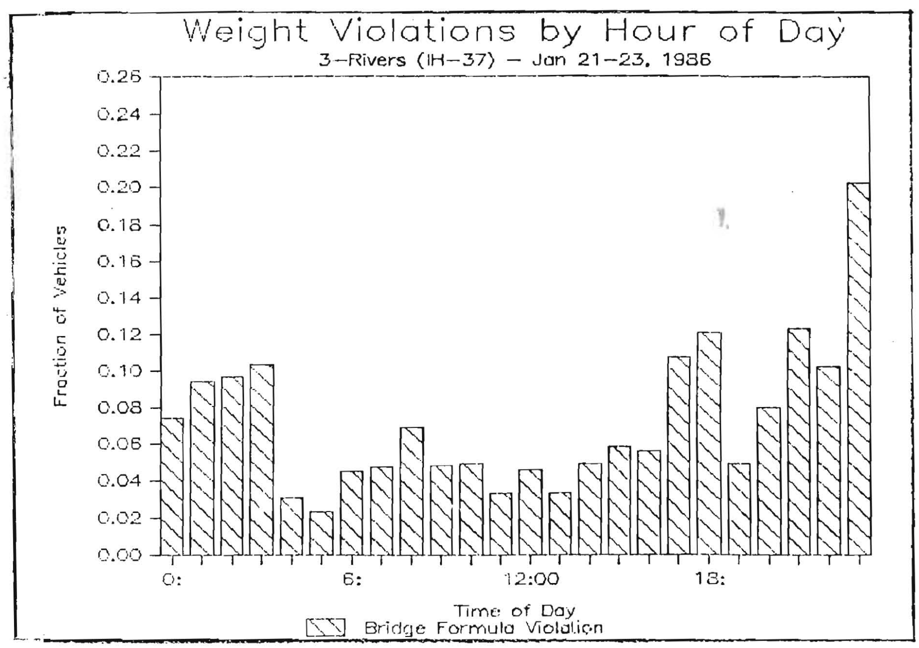

TABLE 2 Computer graphic of trucks violating the bridge formula

abroad, can be easily developed from this information.

Dr. Don Maxwell of Texas Transportation Institute, Texas A&M University and Mr. Scott Lambert, D-10R, have been developing graphics to put the data in the most useful forms for district personnel. Lotus 1-2-3 is the software being used to make correlations and generate the graphics. The field data is presently being analyzed on the mainframe, for speed's sake. Dr. Maxwell is working on a program in Turbo-Pascal that would analyze the field data nearly as quickly as the mainframe and, at the same time, create files that could be directly loaded to the Lotus 1-2-3 program. The Lotus software can be run on an IBM PCXT or any compatible computer with 512K of memory. It is fast, user friendly and effective in report generation. The graphics are done by sorting on a spreadsheet and can be expressed as bar, line, stack-bar, pie or symbol charts. Division-10R plans to furnish graphics and report summaries for each routine WIM session to the districts. Data is already available from selected weighing sessions 1984-1985. For more information, please contact Scott Lambert, (512) 465-7087, TEX-AN 886-7087 .

RTAP WEIGH-IN-MOTION DEMONSTRATION PROJECT

Texas was selected by the Federal Highway Administration as one of three states to participate in the first phase of a nationwide ***Demonstration of Coordinated Weight Monitoring and Enforcement Program Using Weigh-in-Motion (WIM) Equipment.*** This program was part of the Rural Technical Assistance Program (RTAP) authorized by Congress in 1982 to assist state and local authorities in solving rural transportation problems.

The Texas RTAP WIM Demonstration Project had the major objectives of demonstrating the use of state-of-the-art WIM equipment in rapid, safe collection of truck weight statistics and of determining the feasibility of using WIM equipment in the truck weight enforcement program. One of the unique features of the Texas RTAP WIM project is the development of a workable 4-lane WIM system. The 4-lane WIM system developed by the Radian Corporation in the first phase of the project was then used regularly during 1984 and 1985 for collecting truck weight statistical samples at selected locations on rural interstate highways.

Phase two, a series of data-taking sessions in the summer of 1984, produced statistics from 800 trucks upon which were based the comparisons and evaluations called for in the work plan. The 1984 data collection involved correlating high, intermediate and low speed WIM systems to legal, conventional, static scales. Each truck was weighed dynamically at speeds averaging 50, 30, and less than 10 mph, dimensioned, then weighed statically on several types of scales. Besides the basic objective of correlating WIM weight estimates to static weights, an evaluation of the overall performance capabilities of three types of static axle-load scales and three types of wheel-load weighers was done. The experiment was set up to determine (1) the accuracy with which truck weights can be measured with different weighing devices and techniques and (2) the amount of time required to weigh each truck. These are two important aspects in evaluating the feasibility of using WIM equipment for weight enforcement in Texas.

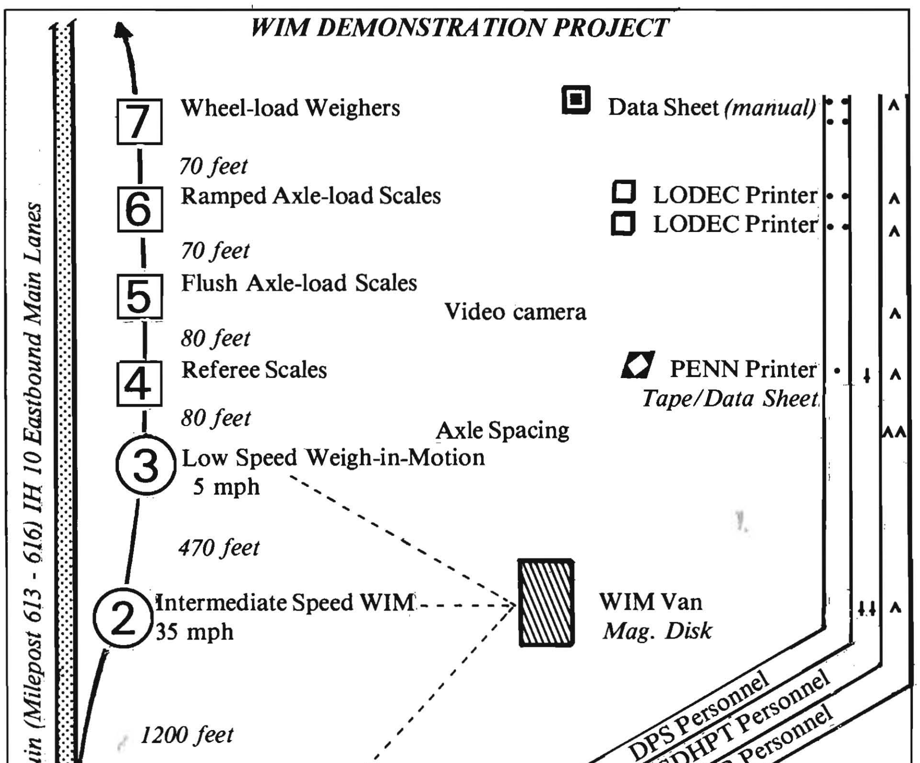

FIGURE 1

The data collection of the Texas RTAP project took place at the weigh station adjacent to the eastbound lanes of IH 10 at Milepost 616 east of Seguin. It required cooperation and coordination among the Federal Highway Administration (FHWA), the State Department of Highways and Public Transportation (SDHPT), the Department of Public Safety (DPS) and the Center for Transportation Research (CTR) with additional technical support from the Texas Department of Agriculture and the Radian Corporation.

Commercial trucks were pulled over to the shoulder by DPS troopers at a point about two miles upstream of the weigh station. The conditions of the experiment were explained by the officers to the drivers of selected trucks. A large card with a serialized number was handed to the driver to place in the windshield for identification. When the signal was given by radio that the weigh station was ready, the driver of the truck was told to proceed. Figure 1 shows the arrangement of the high-, medium- and low-speed WIM scales; three static scales, the axle and wheel scale, the flush--mounted axle-group scale and the ramped axle-group scale; and one of three types of portable wheel-load weighers.

In order to define accuracy, develop calibration factors and arrive at use tolerances for WIM systems, one of the static scales had to be chosen as a reference scale. In the field, the axle and wheel static scale (AX/WHL) proved to be accurate under dead weight loadings, reliable in repeated weighings of a test truck, and capable of weighing both wheel loads and axle loads without excessive deflection of the load receiving platform. Therefore, it was chosen. The low-speed WIM performed about as well as the ramped axle-group scale [AX/GRP (RAM)] and better than all the wheel-load weighers evaluated with respect to producing weights that agreed with those from the AX/WHL reference scale.

On-site calibration of the WIM

FIGURE 2 Aerial photo of RTAP WIM site near Sequin.

FIG.3 Installing the axle and wheel (AX/WHL) reference scale.

FIG.4 Truck approaching ISWIM.

FIGURE 5 The semi-portable ramped axle-group [AX/GRP (RAM)] scale.

systems proved to be very important. WIM weight estimates made after calibrating the system by various techniques were compared to weights measured on the accurate static reference scale. Mixed truck types were included in the analysis, and high, intermediate and low speeds were considered. A pronounced improvement in the weight estimate accuracy of the high- and intermediate-speed WIM systems occurred when loaded, 5-axle tractor-trailer trucks were used for calibration rather than a loaded, 2-axle, single-unit test truck. Both dead-load test blocks and low speed test vehicles proved to be adequate calibration for low-speed WIM systems.

Analysis of WIM systems performance at different speeds indicated that a properly calibrated system could produce the following results as compared to the respective weights from the AX/WHL reference scale.

These values imply that tolerances of about ± 4 percent, ± 6 percent and ± 9 percent would be appropriate when interpreting low-, intermediate- and high-speed WIM estimates of gross vehicle weight at a 95 percent confidence level. Likewise, tolerances of about ± 9 percent, ± 10 percent and ± 14 percent apply to WIM estimates of axle group weights for the same level of confidence. In general, the researchers felt that the observed differences in the WIM-estimated vehicle weights and comparable static weights should be attributed to the differences in weight distribution behavior on axles of a vehicle moving continuously over the road surface of a WIM system scale as opposed to stopping in successive axle positions on a static scale, rather than error in the WIM systems. It is interesting to note that the use tolerances for the properly calibrated low-speed and intermediate-speed WIM systems are lower than the corresponding use tolerances for all the static weighing devices utilized in the field study and that the high-speed WIM use tolerances are only slightly larger than those for the axle-group scale and the WL/100 wheel-load weigher, which were the best performers among the static weighing devices evaluated.

The Texas WIM Demonstration Project is felt to have successfully shown the effectiveness of state-of-the-art WIM equipment. Its potential usefulness for truck weight enforcement is seen not only in the high-speed WIM system, but also in the low-speed WIM. Full details of the data analysis will be available in the soon to be published Research Report 557-1F, ***Demonstration of Weigh-in-Motion Systems for Data Collection and Enforcement,*** by Clyde E. Lee, Bahman Izdmehr, and Randy Machemehl.

FIG.6 Wheel weighers in use.

SPEED AT WIM SCALE	STATISTICAL INFERENCE	GROSS-VEHICLE WEIGHT (Percent Difference)	AXLE-GROUP WEIGHT (Percent Difference)
LSWIM (10 mph)	Mean of Differences Range for 95%	- 0.2 + 3.8 to - 4.1	- 1.0 + 7.9 to -10.0
ISWIM (30 mph)	Mean of Differences Range for 95%	- 0.7 + 5.4 to - 6.8	- 0.7 + 9.2 to -10.6
HSWIM (55 mph)	Mean of Differences Range for 95%	- 1.3 + 7.6 to - 10.3	- 1.1 + 13.4 to - 15.7

TABLE 1 Analysis of WIM Systems.

DIALOG SLIDE SHOW

If you are still not certain what D-10R's link with the DIALOG system (see **TQ 1-4**) can do for you in the way of information retrieval, don't despair. Copies of ***DIALOG Database Descriptions*** are available on request through D-10R. Furthermore, a slide show, ***Introduction to DIALOG,*** has just been purchased explaining the capabilities of the DIALOG system. To request either ***DIALOG Database Descriptions*** or ***Introduction to DIALOG,*** please contact Debbie Jeffcoat [(512) 465-7984, TEX-AN 886-7684].

PUBLICATIONS OF INTEREST

The Impacts of Carpool Utilization on the Katy Freeway Authorized Vehicle Lane Initial Carpools Surveys, Dennis L. Christiansen, FHWA/TX-86/ +484-2, College Station: Texas A&M University Press, Dec. 1985.

Detecting Defects and Deterioration in Highway Structures, David G. Manning, NCHRP Synthesis of Highway Practice 118, Washington, D.C.: Transportation Research Board, July 1985.

FHWA Research, Development and Technology Implementation Catalog, Office of Implementation, McLean, VA: U.S. Department of Transportation, March 1985.

GEOMEMBRANES AS MOISTURE BARRIERS

by Malcolm L. Steinberg,
Supervising Planning Engineer,
District 15.

Studies to control destruction of pavement riding surfaces caused by expansive soil subgrades in District 15 with the use of geomembranes indicate that the relatively impermeable engineering fabrics may provide a solution to this expensive problem. These soils cause over $5 billion a year in damages to our nation's highways. Texas is not immune to the problem.

The idea of using the geomembranes is to minimize change in moisture content in the expansive soil which, in theory, will minimize pavement movement. In cooperation with D-10 Research, the Center for Transportation Research and Texas Transportation Institute—particularly with the guidance of Dr. Robert L. Lytton—various testing procedures were used. Procedures included profilometer readings, which were computer-reduced to serviceability indices; photologging, which documented cracks developing in the pavement; and recording a variety of sensors, which measured moisture content.

District 15's first use of a geomembrane test section was on an urban systems project, General McMullen Drive, in the late 1970's. The fabric was placed horizontally on the subgrade. In subsequent tests, the geomembranes were placed vertically to a depth of 8 feet on either side of a pavement section. This was done first on Loop 410 in the Valley Hi Drive area with subsequent sections being placed along Interstate 37 from Fair Avenue to Pecan Valley Drive, on U.S. 281 (the McAllister Freeway) southbound lane in the vicinity of the airport connection and on Interstate 10 on San Antonio's eastside.

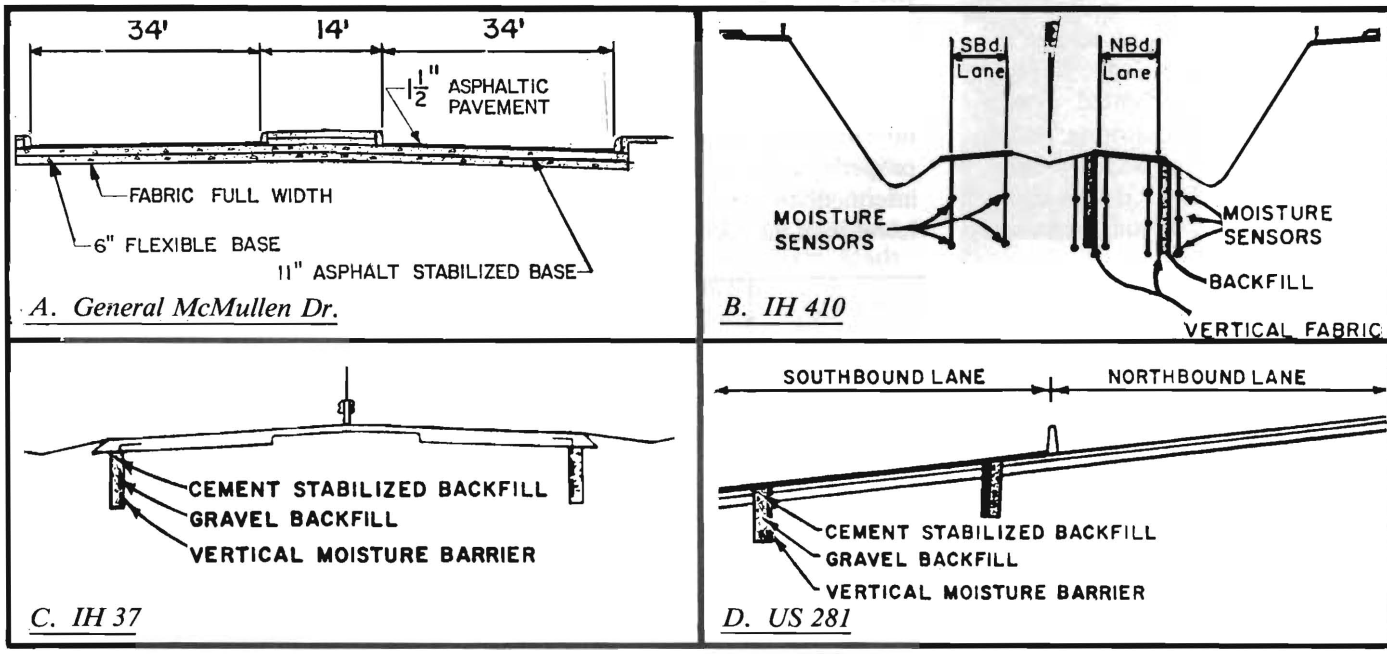

FIGURE 1 Typical sections.

In more than half of the comparisons, riding quality, as measured by the serviceability index, was significantly better in the fabric test sections than riding quality in the control sections for both vertical and horizontal fabric placement. More specifically, using pooled estimates of standard deviation (done at a 95 percent confidence level as a two-tailed test with Student's t-distribution) to compare means, 7 out of 12 comparisons for horizontal placement showed the fabric performed significantly better than the unprotected control; 4 showed no significant difference; and 1 showed the control performed better than the fabric. Based on this evidence, horizontal geomembranes can be expected to improve riding quality approximately 60 percent of the time.

For vertical placements, 9 comparisons were made; however, 3 had very small data samples (four points in each case) and should be considered inconclusive. Of the 6 conclusive comparisons, 5 showed the fabric performed significantly better than the control and 1 showed no significant difference. Based on this evidence, vertical geomembrane moisture barriers can be expected to significantly improve riding quality approximately 80 percent of the time.

An interesting point to note is that the geomembrane test section placed over the most active subgrade on General McMullen Drive exhibited a smoother ride and less cracking than any other section on that project. The detailed results of the monitoring of all the test sections are included in Research Report No. 187-12, which will soon be issued by D-10.

VIDEOS ON LOAN

The D-10 Research Library has the following video tapes available on a two-week loan basis:

☐ *Traffic Signal Systems, Parts 1 & 2*
½-inch format
FHWA-TS-86-204

☐ *Strategic Highway Research Program*
½-inch format
FHWA 4/85

☐ *Ralumac Use by Oklahoma*
¾-inch format
Ralumac Corp.

☐ *Diamond Grinding*
¾-inch format
Oklahoma DOT

Portland Cement Association
½-inch format
PCA 4R

☐ #1 *Minnesota I-90 Recycling*

☐ #2 *"Whitetopping" I-70 Sherman County, Kansas*

☐ #3 *Designing for Quality, 190-94 in Wisconsin*

☐ #4 *A Tied Concrete Shoulder, I-20 South Carolina*

☐ #5 *Recycled Concrete "D"—Cracked Pavement Trunk Hwy. 59 Minnesota*

☐ #6 *Iowa Bonded Overlay Project I-80*

☐ #7 *I-80 Reconstruction, Nebraska 1984*

☐ #8 *Recycling Continuously Reinforced Concrete Pavement on I-29 in North Dakota*

☐ #9 *Unbonded Overlay Interstate 70, Ohio—1984*

If you would like to view any of these tapes, either check the titles you want on this list and send it in or call Kevin Marsh [(512) 465-7644, TEX-AN 886-7644] or Debbie Jeffcoat [(512) 465-7684, TEX-AN 886-7684].

TEXAS RESEARCH SLIDE SHOW

The Technology Transfer subsection of D-10R has completed a 10.2 minute multimedia slide presentation that provides a promotional overview of the highway research program in Texas.

It's What You Don't See that Counts was chosen as the title to reflect the fact that the benefits and achievements of the research program are not as easily recognized as the finished product.

The concept of developing a presentation of this type originated from a recommendation by the Area III Advisory Committee. The idea was to create a general presentation that would be an informative piece for a broad audience including civic organizations, the legislature and highway department personnel.

The show has been transferred to video tape and is available for loan in either the video tape or multimedia form. Please contact Debbie Jeffcoat [(512) 465-7684, TEX-AN 886-7684] or Kevin Marsh [(512) 465-7644, TEX-AN 886-7644] for information.

AN EXCHANGE OF IDEAS

Articles, techniques or ideas about any facet of highways or public transportation are welcomed. If you have a new way to handle an old problem, a helpful hint for making better use of a standard procedure or product or new application of a common item, send it to us. It doesn't have to be an earthshaker to be useful and appreciated.

If you have an idea to share, a comment to make or materials to request, use the tear sheet in this issue or call Kathleen Jones at (512) 465-7947 or TEX-AN 886-7947.

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DISTRICT TWENTY-ONE'S SPECIALIZED SPREADER BOX

Ideas don't have to be brand new to be good. Often it's better to take a little time and let the glamour of newness wear off an invention before adopting it wholeheartedly. District 21 has an invention that's been proving its worth for more than fifteen years. It's a modified slide or spreader box designed to aid the repair of broken shoulder and pavement edges.

Before a cooperative effort between District 21's shop and the former maintenance foreman in Hebbronville resulted in the edge spreader box, broken pavement edge rehabilitation was a slow process. A truck with a minimum crew of five—one driver, four unloaders—took 30 minutes to unload and place cold mix or caliche flexible base. After unloading, two of the crew would hop into the empty truck and ride back to the maintenance yard to pick up the next load. This process was repeated through the day, the work going more slowly as the crew got tired. With the modified tailgate and spreader box (Fig. 1) on a dump truck, a minimum of two workers can unload and place the average 4 cu yd of material in five minutes.

The broken pavement edge is swept first. A tack coat of emulsified asphalt is shot along it. Following the asphalt distributor is a truck with cold mix. It runs with the spreader box centered on the tack-coated broken edge, discharging its load. When empty, the first truck drives off leaving the two crew members that unloaded it to wait for the next truck. The next truck, which should be waiting to discharge, drives up with a wheel against the edge of the newly placed cold mix to compact it. When the truck reaches the end of the last run, the crew unloads it. A truck-pulled static compactor follows the last discharging cold mix truck to complete compaction. Trucks carrying caliche flexible base (wetted to proper moisture content at the maintenance section) begin to lay

FIGURE 1 The modified box and tailgate arrangement.

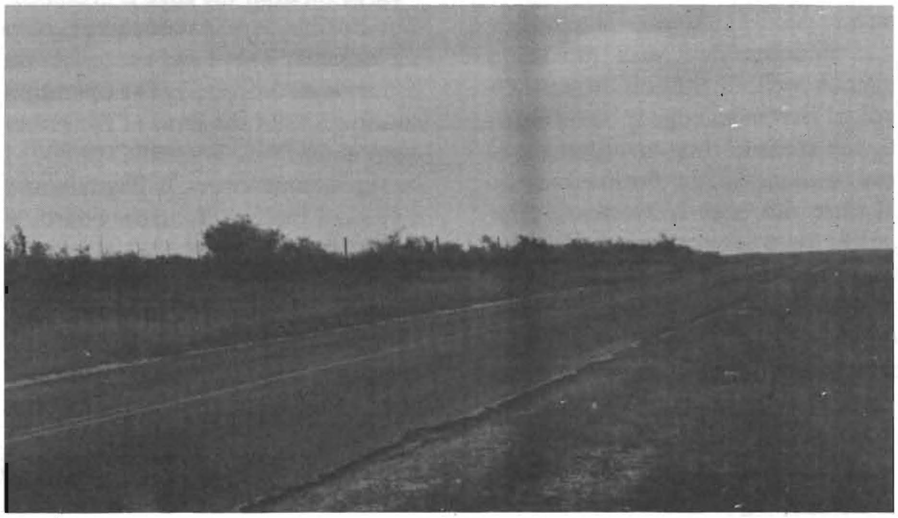

FIGURE 2 A broken pavement edge.

FIGURE 3 The slide or spreader box in position.

FIGURE 4 In action laying cold mix.

down the material against the edge of the compacted cold mix. The flexible base is compacted with the static roller as well. If the soil around the broken pavement edge is badly eroded, the spreader box arrangement is used to place caliche flexible base as fill after the edge is broomed. The flexible base is compacted with the static roller as well. If the soil around the broken pavement edge is badly eroded, the spreader box arrangement is used to place caliche flexible base as fill after the edge is broomed. The flexible base is compacted, then the tackcoat is shot and the operation proceeds as described. The operation continues until the limit of the safety zone is reached. The zone, provided by signs, cone tapers, a flagman and a shadow truck with arrow board, is moved forward as needed.

District 21 cycles six trucks continuously through an average job. Though this type of continuous operation requires more coordination, the sharp rise of 60 percent or more in rate of production is worth the effort. The increased ability to maintain pavement edges before they become seriously washed out means less money spent on major rehabilitation later. It also means less bumps and hazards to aggravate the motoring public.

The cost of repairing broken pavement edges with the modified spreader box is 85 to 90 cents per linear foot, depending on driving time to the job site. This cost includes striking off the flexible base, applying a tack coat, laying 1 to1½ inchs of cold mix, compacting the cold mix, placing caliche flexible base on the outside and striking it level with the original pavement.

Recently, District 21 made a video tape of their edge repair process to show to contractors. The District planned to place the flexible base and let a contract for the pavement. The contract was let for 25 cents a linear foot, excluding materials. The contractor to whom the job was awarded believes that he can streamline the process further. Mr. Sam Cox, Maintenance Engineer of District 21, says he's eager to see what the contractor can do with the process and the edge spreader box.

DISTRICT TWO'S MOBILE CORING DRILL

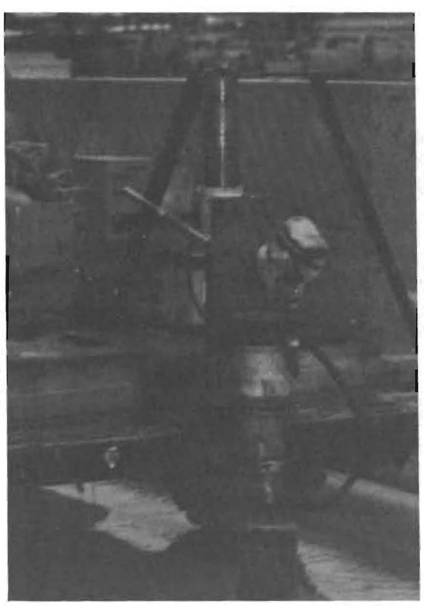

FIG.1 Drill system.

Ten years ago Mr. Red Owens of the City of Fort Worth had a good idea. His idea was to mount an electric coring drill rig in the bed of a pickup. The prototype was cobbled out of various salvaged and adapted parts. Once a large enough generator was hooked to it, it gave excellent service with very little trouble.

About a year ago, District 2 needed a portable coring drill, preferably electric, for in-place compaction control samples. District personnel had seen the City of Fort Worth's pickup-mounted coring drill and decided to copy it. Instead of using whatever parts were on hand, the decision was made to buy compatible column, carriage, electrical and

FIG.2 Layout of truck bed.

motor assemblies. A 5 kw, electrically started generator was purchased as well. District 2's shop manufactured the 50 gal water tank that sits horizontally against the cab in the bed of the pickup. Rate of flow from it is controlled by a valve set near the drilling unit. The mounting bracket and braces were also built in the District 2 shop. The present form of the bracket and braces "evolved" from earlier, less satisfactory attempts. The drill system can be switched out from truck to truck without a great deal of trouble. The cost breakdown of parts and labor for a drill system such as this is as follows:

The drill can cut a 2-inch thick core in about two minutes. As mentioned, it has been used for obtaining

COST OF DRILL SYSTEM
FOR
MOUNTING IN A PICKUP BED

HOLE HOG DRILL MACHINE			
Unit assembled w/small base			$ 1,139.75
Components:			
column assy. #B2140007593	$ 250.00		
carriage assy. #B2140006849	$ 88.00		
electrical box assy. #C2140007581	$ 93.75		
Motor assy., Black & Decker, 18 amp, 2 speed (350 & 900 rpm), #C21B0008811	$ 656.25		
DRILL BITS			
Thunderbolt, solid back, 4-1/4″	$ 152.00	ea	*not included in total.*
Thunderbolt, solid back, 6″	$ 194.00	ea	*not included in total.*
Purchased from: TECC Corp, 2625 Electronic Lane, Dallas, Texas 75220	214/357-6463, 1-800/527-0264		
GENERATOR			
Onan, model 5.0 CCK-3CR/1V, 5 kw 1800 rpm			$ 4,600.00
WATER TANK			
Shop made			$ 250.00
LABOR & MATERIALS			
Labor	$ 288.42		
Materials	$ 97.17		
Total			$ 385.59
TOTAL			$ 6,375.34

FIG.3 Detail of drill.

FIG.4 Detail of the water valve.

FIG.5 Detail of bracket & bracing.

FIGURE 6 Column assembly mounting.

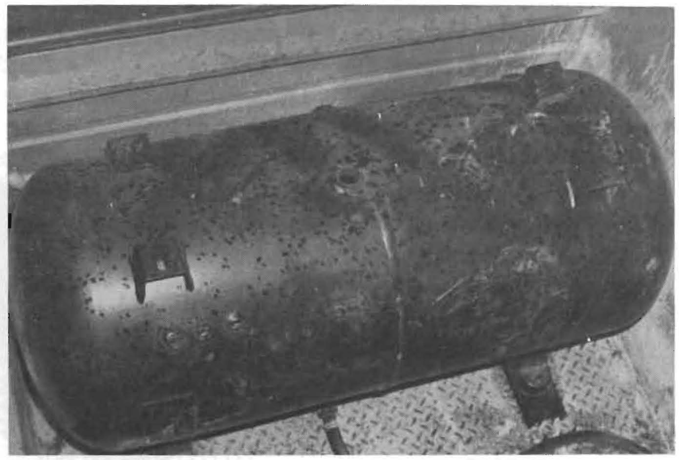

FIGURE 7 50 gallon water tank.

HMAC Item 340 in-place compaction control samples. District 2 also uses it to core bridge slabs for D-9 to test for salt and strength in concrete in accordance with D-5 requirements.

An added advantage to this drill system is that the drilling unit can be unbolted from the pickup bracket mounting, placed on a small, free-standing base, plugged into a convenient wall outlet and used as a portable electric coring drill. District 2 used it this way when they needed to punch 2-inch holes in the floor of the District Headquarters building to run wires for new data processing equipment. A gasoline powered drill had been tried first, but the fumes it produced were so bad that personnel had to leave the building.

THE ORIGINS OF ASTM

Up to 1903, there was little or no effort to develop standards for tests and specifications for asphalt, asphalt paving mixtures and construction practices. The large asphalt paving companies such as Barber and Warren-Scharf developed their own control standards and methods to determine the suitability of materials for use in pavements. A.W. Dow, Clifford Richardson, J.W. Howard, F.P. Smith, H.C. Bowen and numerous others had accomplished much in providing an understanding of asphalts and their function in paving mixtures. They were the pioneers in the development of test methods and schemes of analysis of asphaltic materials.

The advent of the automobile and the production of asphalt from petroleum prompted an urgent need for standardization of test methods and specifications for road building materials and construction. Up to 1901, the Federal Government had taken a minor role in road building. In that year Congress appropriated funds to establish a mechanical and chemical laboratory for testing road materials from all parts of the United States—FREE. Thus, the Office of Public Roads was established in the Department of Agriculture. Dr. Logan Walter Page of Harvard University was in charge of the laboratory (9). By 1911 the Office of Public Roads consisted of eleven employees. Prevost Hubbard, Charles S. Reeve, Albert T. Goldbeck and Edwin C. Lord made up a laboratory staff that undertook the investigation of materials for highway construction and the standardization of test methods and specifications. The American Society for Testing and Materials Committee D-4 on Road and Paving Materials was formed in 1903 and began the task of developing standard test methods and specifications for road and paving materials. Dr. L.W. Page of the Office of Public Roads was appointed acting chairman and later served as chairman of Committee D-4, until 1919.

The Office of Public Roads (later the Bureau of Public Roads—now the Federal Highway Administration) and ASTM have played an important role in the development and standardization of test methods and specifications since 1903. It appears appropriate to note that the ASTM developments at that time and as has continued through the years, resulted from the cooperative work of industry representatives, University personnel, State and Federal employees. The same people responsible for Federal developments often provided leadership in ASTM serving as task committee chairmen or subcommittee and task force chairmen.

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Woodrow J. Halstead and J. York Welborn, *"History of the Development of Asphalt Testing Apparatus and Asphalt Specifications," Proceedings of the Association of Asphalt Paving Technologists Technical Sessions,* 43A (1974): 96.

NONDESTRUCTIVE TESTING: RADIOGRAPHY

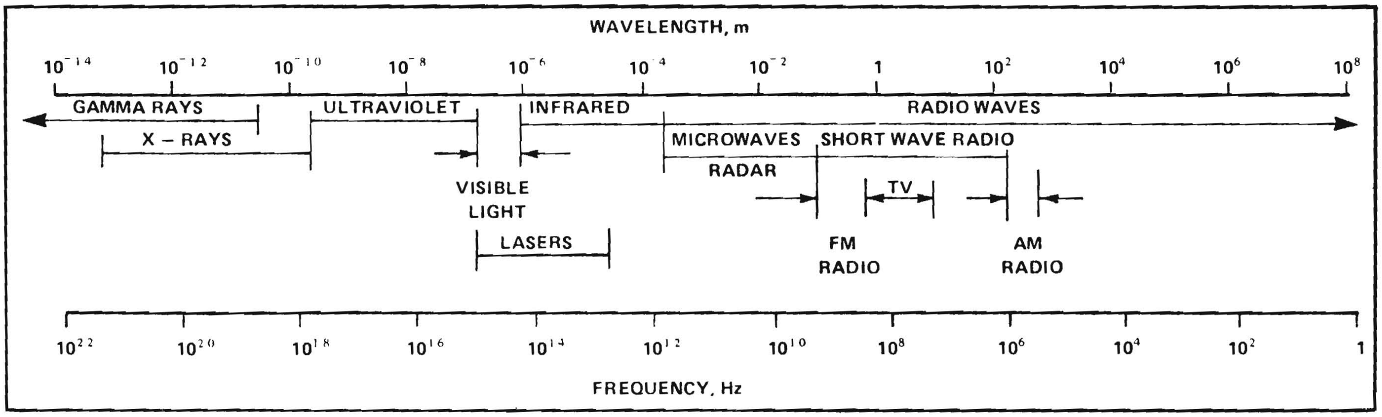

FIGURE 1 The electromagnetic spectrum.

The following article is an excerpt from the July 1985 NCHRP Synthesis of Highway Practice Report 118, ***DETECTING DEFECTS AND DETERIORATION IN HIGHWAY STRUCTURES,*** by David G. Manning. It does not constitute a standard, specification or regulation.

The electromagnetic spectrum is shown in Figure 1 and comprises wave lengths ranging from approximately 10^{-13} m to several thousands of meters. The common property of the waves comprising the electromagnetic spectrum is that they are not affected by electric or magnetic fields. The velocity of the waves is 3×10^8 m/sec in vacuum. In other media, the velocity is a function of the density and atomic number of the media. The frequency and wavelength are related by the simple expression:

$$f = \frac{v}{\lambda} \qquad (1)$$

where

f = frequency,
v = velocity, and
λ = wavelength.

Although the entire electromagnetic spectrum has a profound effect on everyday life, it is the shorter wavelengths that have application in nondestructive testing because of the greater energy levels associated with them. The ability of radiation to penetrate matter is a function of the kind of matter and the wavelength (or energy) of the radiation. The loss of energy as the radiation penetrates the material is known as attenuation and depends on both the nature of the material (different materials absorb radiation at different rates) and its thickness. Long-wavelength waves, such as broadcast waves, not only require large antenna arrays but attenuate rapidly in solid material.

Microwaves are the longest-wavelength wave in general use for testing and inspection purposes. Microwaves range in wavelength from 300 to 0.3 mm, corresponding to a frequency range of 10^9 to 10^{12} Hz *(8)*. Their most common use in materials testing is to determine the moisture content of porous materials. Microwaves are strongly absorbed by water and consequently moisture content can be measured from the attenuation characteristics of the microwaves.

A laser is a pure concentration of coherent light of almost a single wavelength. Most lasers have wavelengths in the visible and infrared ranges but work is underway to produce "free-electron" lasers ranging in wavelength from microwaves to X rays. Lasers are produced when a medium, such as a crystal, gas, or liquid, is energized by high-intensity light, an electric discharge, or nuclear radiation. Energy levels range from very low energy continuous discharges to very high energy pulses. Although lasers have numerous industrial and medical uses, the main application for highway structures is in precision measuring devices and, possibly in the future, holography.

The only difference between X rays and gamma rays is one of origin, although the properties of each are dependent on the particular wavelength and energy *(9)*. X rays result from an atomic process outside the atomic nucleus; gamma rays usually from a nuclear process. Together they make up the short wavelength, high-frequency end of the electromagnetic spectrum and have the greatest penetrating power. The frequency is directly proportional to the wave energy so that gamma rays have higher energy levels than X rays. X-ray energies are typically in the kilo electron volt (10^3 eV) range; gamma rays have energies in the mega electron volt (10^6eV) range. The individual rays are often referred to as photons. Each photon, having a specific energy, can be thought of as having an equivalent mass, the value of which is given by Einstein's equation, $E = mc^2$. The photons behave as, and can be treated as, particles with mass and momentum. It is often more convenient to think of X rays and gamma rays as particles rather than as waves, especially when considering particle attenuation...

Two experimental techniques,

radiography and radiometry, are employed (*11*). In radiography, the emerging radiation is detected by a photographic emulsion and variations in the density of the exposed film reflect the internal structure of the material under examination. In radiometry, variations in the gamma intensity are detected by radiation detectors, such as Geiger or scintillation counters, and measured by associated electronic apparatus.

Radiography with gamma rays has been investigated for detecting variations in consolidation in members up to about 18-in. (450 mm) thick, locating reinforcement, measuring the extent of corrosion, and assessing the quality of grouting in prestressing ducts (*11, 82-84*). It is also used in Eastern Europe and the Soviet Union for quality-control testing (*11, 27*). At thicknesses greater than about 18-in. (450 mm), the long exposure needed makes the process uneconomical (*86*). It should be noted that concrete is often used as a shielding material against high-energy X rays and gamma rays because it is an effective absorber. This characteristic clearly limits the application of radiography to relatively thin members.

Many of the methods of measuring in-situ density involve drilling holes in the concrete and placing the radioactive source or the detector in the hole (*23, 88*). This technique can be used to detect honeycombing or voids but cores are also necessary for calibration purposes if density is to be measured in absolute terms. Although it may be justifiable in determining if a defective component in a structure should be replaced at the time of construction, or for checking remedial measures, there are few occasions when such testing is warranted on highway structures already in service.

The main application for gamma radiography is for detecting defects in prestressed concrete structures. Laboratory work in England (*84*) showed that radiography could detect voids in grout as small as 3/16 in. (5 mm) in concrete beams 5-in. (125-mm) thick. It has also been used in the field on sections up to 16-in. (400-mm) thick (*21*). Most of the experience with radiography in the field has been in France where it has been used since 1968 to locate the position of prestressing cables, detect defects in cables, and examine the quality of grout (*89*). More recently, the equipment has been developed into a system that makes possible the detailed inspection of cables in box, I-section, and slab bridges (*90*). The system is known as SCORPION (from radioSCOpie par Rayonnement Pour l'Inspection des Ouvrages en betoN, which can be translated as radiation radiography for the inspection of concrete structures). It consists of a radioactive source, a detector, and a remote command module as illustrated in Figure 2. The detector includes a filter, a converter (which forms an optical replica of the incident radiation), a mirror, and a low-light-level television camera. The source and detector are mounted on movable platforms, which can be operated by remote control from the command module. The command module also includes a television monitor, storage unit, and video-tape recorder. A prototype unit was constructed in 1979 and has been found capable of examining concrete thickness up to 18 in. (450 mm) in field trials. In September 1984, construction began on another unit, SCORPION 2, that will utilize a linear accelerator as the source of radiation, giving the unit the capability to examine concrete up to 4-ft (1.2-m) thick.

There have been numerous attempts dating back to 1949 to apply

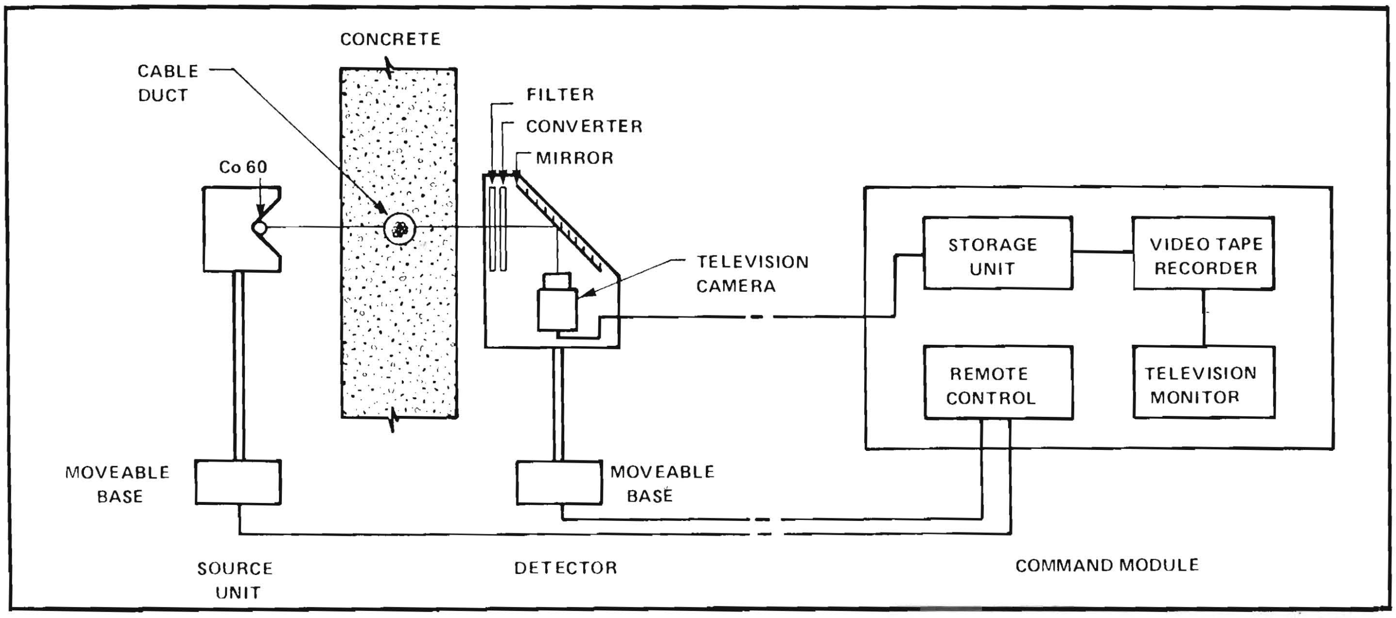

FIGURE 2 Elements of a SCORPION system.

X rays and gamma radiography for the nondestructive examination of concrete, especially in Europe (*82-86*). As discussed... (above), X rays and gamma rays differ only in their origin. This difference has considerable practical significance because X-ray equipment has a high initial cost, produces very high voltages, and is not portable with the result that X rays offer little scope for use in the field (*23, 87*).

A recent development in the field of radiography has been the technique of computed tomography. The process is used to produce an image from thousands of low-voltage X-ray radiographs taken from all sides of an object. It has proven to be a very valuable tool in the medical profession for the examination of tissues not visible on conventional X-ray plates. The same techniques are now beginning to be applied to the study of engineering materials (*1*).

The principle involved in radiographic methods is that as the radiation passes through a material of variable density, more radiation is absorbed by the denser parts of the material than the less dense parts. Most applications of radiographic techniques involve the transmission of wave energy rather than the reflection and refraction methods common with lower frequency methods. However, back-scatter techniques can be used where only one face of a member is accessible; although, as with the indirect method of ultrasonic testing, this is much less satisfactory then direct transmission.

The developments in France in inspecting prestressed concrete have not been publicized in North America. Although the system appears viable, independent confirmation of its capabilities is needed. Radiographic techniques are well suited to detecting voids in grout and cables that are broken or out of position. However, it should be recognized that small amounts of corrosion will not be detected.

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REQUESTS FOR INFORMATION

Texas Transportation Institute is conducting Study No. 419 titled ***Characterization of Asphalts Using Gel Permeation Chromatography and Other Methods*** for the Texas SDHPT. The study objectives include development of gel permeation chromatography (GPC) as an asphalt quality inspection tool, development of chemical methods for analysis of asphalts, and evaluation of these tests regarding their potential to predict pavement performance. They are searching for asphalt pavements exhibiting poor performance for which the asphalt cement received the blame and for exceptionally good asphalt pavements. The researchers may wish to observe the pavement in question and/or obtain samples for testing and analysis. *If you would like to participate in the study, please contact Joe Button at 409/845-9965 (TEX-AN 857-9965).*

CARPOOLS AND THE KATY FREEWAY AVL

In April 1985, carpools began using the Katy Freeway authorized vehicle lane (AVL) in Houston. A major reason for allowing carpools to use this AVL was to counter the perception that the AVL was not being utilized fully enough. A survey of transit, vanpool and non-AVL motorists was conducted in March 1985. AVL carpool motorists were surveyed in October 1985. These surveys confirm that a perception of underutilization does exist (Table 1).

TABLE 1 Perceptions of the Level of Utilization of the Katy Authorized Vehicle Lane.

Measure of Effectiveness of Success	Authorized Vehicle Lane Users			Non AVL Users Motorists
	Transit	Vanpool	Carpool	
Is the AVL sufficiently utilized				
Yes	49%	30%	34%	3%
No	33%	51%	43%	90%
Not sure	18%	19%	23%	7%
Is the AVL a good improvement				
Yes	----	----	----	41%
No	----	----	----	35%
Not sure	----	----	----	24%

The perceived impacts of the AVL on ridesharing and congestion are not clear (Table 2). There is general agreement that travel times for users of the AVL have been reduced. Opinions as to whether freeway congestion had been reduced differed. As to whether the AVL had increased vanpooling or transit ridership, the greatest percentage response tended to be "not sure."

TABLE 2 Impact of the Katy AVL on Mode Choice.

Impact on Mode Choice	Authorized Vehicle Lane Users			Non AVL Users Motorists
	Transit	Vanpool	Carpool	
How important is the AVL in your decision to bus, van or carpool				
Very important	39%	25%	47%	----
Somewhat important	26%	16%	10%	----
Not important	35%	59%	43%	----
Would you bus/van/carpool if there were no AVL				
Yes	69%	87%	70%	----
No	15%	6%	16%	----
Not sure	16%	7%	14%	----
Has the AVL increased transit ridership				
Yes	69%	35%	43%	28%
No	7%	14%	6%	26%
Not sure	24%	51%	51%	46%
Increased vanpool ridership				
Yes	18%	32%	43%	20%
No	11%	26%	8%	39%
Not sure	71%	42%	49%	41%
Reduced freeway congestion				
Yes	40%	29%	33%	14%
No	25%	36%	29%	70%
Not sure	35%	35%	38%	16%
Reduced AVL travel times				
Yes	79%	80%	99%	61%
No	11%	11%	0%	12%
Not Sure	10%	9%	1%	27%

The AVL appears to have had some impact on mode choice (Table 2). While 69% of the AVL transit patrons, 87% of the AVL vanpool patrons, and 70% of the AVL carpool patrons indicated they would be using that mode even if there were no AVL, 15% of transit patrons, 6% of vanpoolers, and 16% of carpoolers said they would not. Furthermore, 39% of transit patrons, 25% of vanpoolers, and 47% of carpoolers felt the AVL was very important in the mode selection decision.

It should be realized that these surveys were conducted shortly after the various modes were allowed onto the AVL. The bus and van surveys were conducted 5 months after the AVL opened; the carpool survey was conducted 6 months after the first carpoolers were allowed onto the AVL. The impact of the AVL will be better identified when subsequent "after" evaluations are performed.

More detailed information can be obtained from Research Report 484-2, ***The Impacts of Carpool Utilization on the Katy Freeway Authorized Vehicle Lane Initial Carpools Surveys.***