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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

LOW-MAINTENANCE ATTENUATOR PERFORMS WELL

FIG. 1: Low-maintenance crash attenuator.

FIG. 2: LMA after impact 4/89, IH-410.

BACKGROUND

Concrete safety-shaped barriers (CSSB) have gained wide spread use as an almost maintenance-free traffic barrier on high speed, heavily traveled roadways. However, the blunt end of such a safety shape, untreated and exposed, is as severe a hazard to motorists as an untreated structural column. Many different end treatments have been tried including sloped ends, flared ends, transitions to w-beam guardrail (with turned down ends or other suitable termination), and crash cushions. Any of these end treatments may present some safety and/or maintenance problem. Crash cushions are probably the safest CSSB end treatment, but their maintenance can be very costly. In Research Study 346, *Concrete Safety-Shaped Barrier for Roadside Application*, performed by Texas Transportation Institute (TTI), one of the major objectives was to design, construct, and crash test a prototype low-maintenance end treatment for concrete safety-shaped barriers and other narrow rigid objects (Fig. 1). The result was a crash cushion based on completely reusable rubber energy-absorbing cells and hinged thrie beam fenders (Fig. 2).

Other existing crash cushions use

INSIDE...

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expendable items (such as water, sand or hex-foam) to slow down a head-on impact safely. Every head-on impact into a conventional crash cushion destroys one or more of the energy-absorbing elements, spreading either water or debris onto the roadway. Labor and materials to replace the damaged elements are costly. Repair costs during the life of a frequently hit crash cushion can be much greater than the initial cost. Further more, maintenance activities on heavily traveled streets and freeways interrupts traffic, which increases accident risk, endangering both motorists and repair crews.

DESIGN CRITERIA

The design criteria were to: 1) have no sacrificial parts; 2) have sufficient strength to withstand most impacts without damage to any components; 3) be approximately the same width as a standard CSSB; 4) perform as a crash cushion when struck head-on and as a longitudinal barrier when hit from the side; and 5) meet nationally recognized safety standards set out in NCHRP 230, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances.* Preliminary analysis was based on the assumption that elastomeric cylinders in a row will collapse in a sequence such that one cylinder is almost completely collapsed before the next cylinder begins to collapse. This analysis showed that 28-inch outside diameter cylinders with two different wall thicknesses would meet safety criteria. The cylinders in the front of the treatment have a 1.75-inch wall and the back cylinders have a 4.5-inch wall. After lab testing numerous materials, a relatively hard natural rubber compound (durometer of 80) was chosen. The energy absorbing capacity of this material varied less than 35 percent for temperatures between -20°F and 120°F. This characteristic, primarily, made it possible to design an end treatment that would perform acceptably at the range of anticipated temperatures.

The design, as crash tested, consisted of six thin-walled (1.75-inch) cylinders in the front and seven thick-walled (4.5-inch) cylinders in the rear, separated and supported by steel diaphragms. Skid shoes were welded to the support legs to aid sliding. This placement allows unrestrained longitudinal collapse of the cylinders so they do not create excessive frictional forces by dragging on the ground. Rails with restraining chains prevent excess lateral movement (Fig. 3). A rubber cylinder, placed vertically in front of the unit, serves to minimize potential override or underride of an impacting vehicle. Thrie beam fender panels are attached to the steel diaphragms. The end treatment was designed to sustain most impacts without replacement of any parts and to be restored in less than an hour. However, the rubber cartridges do not have sufficient elastic stiffness to completely restore the system after a hit. Therefore, restraining cables were attached between the diaphragms allowing the cushion to be pulled back into place easily.

As well as satisfying NCHRP 230 guidelines, crash testing the cushion proved it was not damaged during head-on impacts with 1800 lb cars traveling at up to 60 mph and 4400 lb cars traveling at speeds of 50 mph (Fig. 4). These impact conditions include over 95 percent of expected head-on accidents. For these accidents, the end treatment can be repaired in less than an hour and the total repair costs are usually below $100. Furthermore, even relatively severe side impacts do not cause major damage to the system. In the final report of HPR 346, *Roadside Concrete Barrier: Warrants and End Treatment*, [Ref. 1], the researchers recommended that the low-maintenance rubber cylinder end treatment be installed on an experimental basis at several locations to examine its in-service performance. Subject to its acceptable field performance, they then recommended it could be installed as an operational system.

FIG. 3: Detail of hinge plate and restraining chain.

FIG. 4: No elements destroyed.

FIELD INSTALLATIONS

The field version of the low-maintenance attenuator (LMA), as it is being marketed by Energy Absorption Corporation, is approximately 34 feet long, which is 13 feet longer than a six bay GREAT system. The initial cost of an LMA is around $28,000, as opposed to around $13,000 for a GREAT (not including installation). This big a price difference means the LMA is only cost effective in a high hit area (5 or more hits a year). Probably, it is best used as a retrofit, rather than as an initial installation on a new facility, after accident data has been gathered proving a high frequency of impacts with narrow rigid structures and where no other way to eliminate the hazard exists.

San Antonio

San Antonio installed an LMA in

1987. It is on IH-410 eastbound where 410 passes under IH-10. The LMA replaced a HYDRO system. The annual average daily traffic (AADT) is 170,000. There is a left-hand exit in the vicinity and a complex interchange about a mile upstream from the LMA. Consequently, there is a lot of double movement and weaving in the area. Historically, most of the accidents are evening and late night.

The only variation from the original design is the addition of a GREAT nose guard to the vertical front cylinder. District personnel thought the delineation of the face of the nose guard improved the system's overall visibility, as well as improving the system's appearance.

The IH-410 LMA has been hit at least 8 times in the last two years. The hits have ranged in severity from collapsing the unit approximately 14 feet to just knocking the nose guard askew slightly (Figs. 5 & 6). In no case have there been fatalities or major injuries resulting from vehicles hitting this LMA. In fact, district personnel have yet to see an automobile which has hit the LMA because no driver has had to be towed from the site. The only part that has had to be replaced is the GREAT nose guard. The system has taken, on the average, 45 minutes to restore, as opposed to the 2 to 3 hours it took to repair the HYDRO that used to be there.

District 15 is pleased with the field performance of the LMA and feels it may be the best of all the different types of units they've worked with so far. They consider it well worth the $25,000 initial fee and, in 1989, installed another unit at a different location on IH-10. At the time of writing, it had not been hit.

Fort Worth

At about the same time San Antonio installed their first LMA, Fort Worth District also installed one at the IH-20 north/IH-820 east interchange. This LMA replaced a sandbarrel crash cushion that was constantly being hit and needing maintenance. The AADT through this area is 90,000. The LMA was installed without major modification to the Special Specification Item, "Low Maintenance Crash Cushions," and the LMCC-87 drawings. However, to make the black rubber front cylinder more visible to motorists, a nine square reflector panel has been placed on it.

Since 1987, the LMA has been hit about five times hard enough to require a crew to come and pull it back out. Scrapes, bumps and dings suggest that the LMA has had a number of minor impacts as well that haven't required any maintenance. None of the impacts severely compressed the LMA, although one fender panel has had to be replaced. All vehicles impacting the LMA have been driven away before Department personnel got word of the accidents.

Fifteen or twenty minutes is all it has taken a crew to pull the LMA back out after it has been hit. The hit that required a fender to be replaced took a little over an hour to repair. The cost was under $100.

The LMA seems to have solved the crash cushion maintenance problem at this site. The only minor objection to it is, with the exposed matte black rubber cylinder hanging out in front and the rather lumpy appearance of the cylinders in the bays, that it's not very aesthetically appealing. However, district maintenance personnel love it for its performance, even if it's not very pretty.

Austin

District 14 has the most recent LMA installation, placed 31 October 1989. The LMA was placed on IH-35 on the elevated express lanes southbound near where the elevated entrance ramp from Airport Blvd. joins. The AADT is 182,000. The LMA replaces a narrow HYDRO which was protecting a concrete safety-shaped barrier. This HYDRO had experienced an average of six to seven hits a year. The HYDRO had performed well, protecting errant motorists from serious injury. However, every time it was hit, it sprayed antifreeze all over the lanes, and often the district had to close the entrance ramp and two southbound express lanes for several hours in order to repair the unit.

Two unique features of the IH-35 installation are the design of the front anchor plate and the fact the unit was preassembled before being brought to the site. The LMA sits halfway on one bridge deck and halfway on another, so there is lateral and vertical motion to be dealt with. The standard anchor design would not adequately handle the

FIG. 5: Mild hit 9/9/88, IH-410.

FIG. 6: Severe hit 8/89, IH-410.

stresses, so TTI designed a special one (Fig. 7). It consists of two plates bolt-anchored to the deck on either side of the longitudinal split with a top plate that bridges the split. The top plate has two oval holes that fit over the cylinders that are part of the bottom plates. Rods, secured by cotter pins, near the top of each cylinder keep the top plate from coming off. The assembly allows approximately 2 inches of play horizontally and vertically around each cylinder. The restraining cable runs into the top plate and is tensioned in the same manner that the cable is tensioned on a standard front anchor plate.

The crew preassembled most of the unit in the maintenance yard to save installation time. The rubber cylinder for the bay nearest the backstop was the only piece unattached before the unit went to the job. Preassembly not only saved installation time, it also allowed the crew, who had not assembled an LMA before, to learn how to assemble the unit correctly without having to be exposed to the dangers of traffic. The unit was brought in by flatbed truck and positioned between the lateral motion restraint rails by a hydraulic crane (Fig. 8). The lifting bar, also shown in Figure 8, was fabricated at District 14 for this job.

After the unit was lifted onto the rails, the crew attached it to the backstop. The LMA was then stretched, using the crane, to its full length. The lateral motion restraining chains were then hooked over their respective studs. Again using the crane, the last cylinder was positioned in the end bay. The crew bolted the cylinder to its diaphragm, tensioned the sliding hinge plates on the fender panels, and attached the restraining cable. The entire job from the removal of the HYDRO to the final tightening of the cable on the new LMA took about six hours. The estimated time savings of preassembling the unit was six hours.

The Austin unit had not been hit yet at the time of this writing.

CONCLUSIONS

So far, the low-maintenance crash attenuator is behaving in the field exactly as predicted in the research. The performance of the 1987 LMA installations in San Antonio and Fort Worth bears out the reusable nature of the system. Both districts have minimized out-of-service time and produced maintenance savings when the LMAs are compared to the systems they replaced. Rather than initial installations on new facilities, LMAs are probably best used as a retrofit shielding narrow objects at sites where accident data has proven a high frequency of impacts and where no way of eliminating the hazard exists. For information on how, when and where to install LMAs, districts should contact their Highway Design Division (D-8) Field Area Engineers.

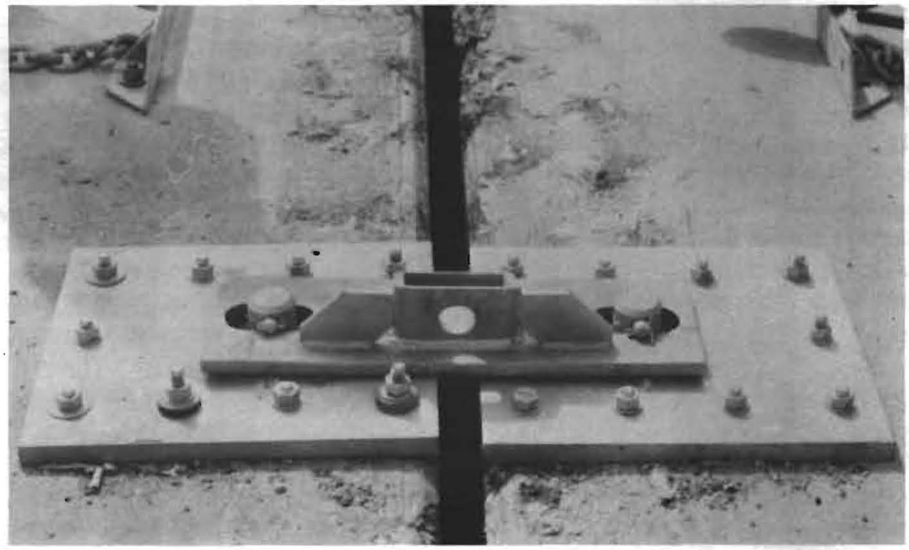

FIG. 7: The split-plate front anchor.

SPECIAL THANKS TO:

Mr. Ralph Apodaca, District 2,
Mr. Ernest Morris, District 14,
Mr. Clyde Bennett, District 15
for information on the LMA installations in their respective districts.

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FIG. 8: Swinging the preassembled unit into place 10/31/89, IH-35.

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TRAFFIC CONFLICT TECHNIQUES FOR SAFETY ANALYSIS: FHWA-IP-88-026

PURPOSE

This study provides guidelines on how to use traffic conflict surveys as a standard procedure for determining whether operational and roadway characteristics are contributing to a safety problem at highway intersections. The traffic conflict surveys help determine if an intersection has an abnormally high traffic conflict rate and serves as an accurate substitute for long-range studies of hazardous intersections that depend on information gathered from accident reports. With the information contained in this study, traffic engineers can determine if a traffic problem exists at a site, why it exists, how to alleviate it, and how to find corrective measures that will reduce future conflicts and accidents.

BACKGROUND

The conventional way of determining whether a safety problem exists at a highway intersection is to review and analyze historical accident reports from the site. This method requires traffic engineers to wait an average of three or more years for accidents in order to collect enough data to make an analysis. It also depends on the often biased, inconclusive, or incomplete information contained in accident reports and does not reflect the large number of accidents for which no reports are ever filed.

A traffic conflict survey is an alternative that relies on first-hand information collected by trained observers at traffic sites. By analyzing observers' data on number and types of traffic conflicts at an intersection over a given period of time, the traffic engineer can determine whether a hazardous traffic situation exists and whether he should recommend corrective action. The traffic conflict survey has the advantage of using quantified, observable, timely data in place of accident reports as a basis for drawing conclusions about an intersection's safety. It can be started and completed in a short period of time and used to predict average accident rates as accurately as estimates based on historical accident reports. It is also cost effective.

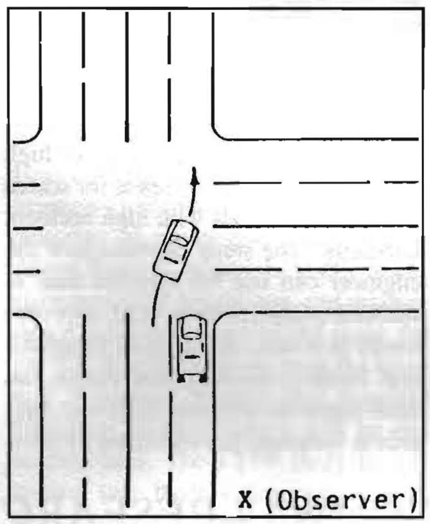

FIG. 1: Lane-change conflict.

APPROACH

The study is divided into a number of "how-to" sections—training observers, conducting the survey, analyzing the data, interpreting the results, making decisions and recommendations, and evaluating the survey's effectiveness.

The first section provides an overview of traffic conflict surveys and procedures. It defines a traffic conflict as a potential accident situation involving two vehicles where one or both drivers take evasive action such as braking or weaving to avoid a collision. The evasive action must result from an unusual or unexpected situation, for example, when the first driver slows down going through a clear intersection and causes the second driver to brake. Normal traffic movements, such as slowing down to make a turn, are not considered traffic conflicts. This section then defines the standard types of traffic conflicts which observers will classify at traffic sites—"opposing left turn traffic conflict," for example, and "slow-vehicle, same direction traffic conflict." Explanatory illustrations are included.

The second section of the study describes how to conduct a one- to two-week training session for observers so that the information they provide is accurate and reliable. The study provides daily learning goals, examples of traffic situations, and ways the traffic engineer can measure and minimize observer differences in classifying traffic conflicts.

The third section of the study provides step-by-step instructions on conducting a traffic conflicts survey. The section explains when to conduct a survey and what preliminary information a traffic engineer will need, including a list of study sites, the recording period, the number of observers needed, and what kind, how much, and at what times the data should be collected.

Following this preparation, observers conduct the survey as outlined in an ***Observers' Manual***. Once the data is in, it must be compiled and presented in several steps: an initial review, a data summation, and a graphic summation through photographs or diagrams.

The fourth section explains how an engineer should analyze and interpret the data. The study notes that, in the past, one major problem with using traffic conflict surveys for safety analysis was the uncertainty concerning how many conflicts constitute a safety problem at a given intersection. The survey contains tables that address this question with numbers and guidelines the traffic engineer can use in making his decisions.

The survey explains how best to define abnormal limits for a site and provides a five-step process for developing daily conflict values for a particular area or intersection characteristic. The survey also describes how to determine possible causes for an abnormally high conflict rate and how to use the traffic conflict data to confirm or even supplement information contained in accident reports.

The next section explains how to use the traffic conflict data to select countermeasures that will eliminate or reduce the safety problem. As a guide, two countermeasure selection tables are included which provide a list of possible causes for each type of traffic conflict situation and the countermeasures that are generally most effective.

The traffic conflict survey technique allows immediate evaluation of a countermeasure through conflict observations before and after the change is made. In addition, data from traffic conflict surveys can be used to extrapolate the number of accidents that will occur if changes are not made. Research has shown that predictions based on conflict reports are as accurate as those based on accident reports.

Because many types of safety improvements require justifications based on costs and benefits related to accident rates, it is often difficult for high conflict locations to compete for scarce improvement funds with high accident locations. The study explains how the engineer can use the conflict data to establish priorities for making improvements at a site. It also lists programs and funding sources that states can draw upon to improve roadway hazards at locations not identified by accident experience.

The study concludes with a bibliography and two appendices, one of data forms that traffic engineers can use and the other of a sample computer program that will calculate daily conflict rates.

FINDINGS

As more highway agencies conduct traffic conflict studies, conflict and accident data can be pooled by highway agencies so that larger validation and more widely applicable accident prediction values can be obtained. While these future enhancements are desirable, they do not inhibit an agency from immediately implementing traffic conflict studies to obtain the numerous benefits that are not possible with accident-based analysis. This report is available from the D-10R Technology Transfer Library. For more information on the traffic conflict survey technique, contact Lewis Rhodes, D-18STO, (512) 465-6330, Tex-An 258-8330.

STRATEGIC HIGHWAY RESEARCH PROGRAM: TEXAS INVOLVEMENT IN LTPP

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INTRODUCTION

The phenomenal cost of maintaining, rehabilitating, and operating the $1 trillion Interstate Highway System is a matter of serious concern [Ref. 1]. Approximately $400 billion will be spent replacing and rehabilitating pavements in the U.S. before the end of the century [Ref. 1]. The country cannot afford to spend such massive amounts of money on highway maintenance. The answer to this problem lies in more research to develop new materials, equipment, and processes. It has been discovered that the highway industry spends much less on research compared to other industries. In 1982, fifteen hundredths of a percent of highway revenues was funnelled back into research [Ref. 1]. A more disturbing fact is that highway research spending has steadily declined over the previous decade [Ref. 1].

The Strategic Highway Research Program (SHRP) was initiated to improve present methods of highway design and maintenance procedures. A SHRP pre-implementation study was conducted in the 1984 - 86 period and it was ready and operational when funding became available in April 1987 [Ref. 2]. A total of $150 million or one quarter of one percent of total highway allocation was awarded for the financial year period between 1987-1991 [Ref. 2]. The first SHRP contracts, worth $16 million, were awarded on October 6, 1987 [Ref. 2]. SHRP covers the following four strategic research areas which are described below [Ref. 2]:

1. Asphalt—$10 million per year for five years;
2. Long Term Pavement Performance (LTPP)—$10 million per year for five years with a possible additional fifteen years;
3. Maintenance Operations—$22 million for five years;
4. Concrete & Structures—$22 million for five years.

LONG TERM PAVEMENT PERFORMANCE (LTPP) STUDY

The Long Term Pavement Performance (LTPP) Study is the first comprehensive research program on long term pavement performance since the accelerated AASHO Road Test which was completed in 1960. LTPP is gathering pavement information on specific pavement performance factors of design, traffic, materials, and environment.

LTPP products are expected to include better predictive models for use in design and pavement management, much better understanding of the effects of many variables on pavement performance, and new techniques for design and construction. The costs for the LTPP study program is less than one-thousandth of the nation's pavement expenditures for the 20-year duration of the study [Ref. 2].

LTPP has the following objectives [Ref. 3]:

1. *Evaluate existing design methods*— The evaluation of existing design methods will depend on the nature of the design method itself. The predictive equations that will be developed from the LTPP program can be used to evaluate the designs using a particular method. Most existing design procedures will be evaluated through the application of the LTPP predictive equations to the pavement thickness designs that results from that design procedure.
2. *Improve design methodologies and strategies for the rehabilitation of existing pavements*—Rehabilitation is the least understood facet of pavement management. We do not possess sufficient knowledge regarding the numerous interactions between the condition of the existing pavement prior to rehabilitation and the features of the rehabilitation itself. The predictive equations from the LTPP data will be used as a basis for improved design methodologies and strategies for rehabilitation.
3. *Improve design equations for new and reconstructed pavements*— Predictive equations will be developed for the significant distress and performance measures. The "calibration" of mechanistic-empirical models for design will be undertaken. These new or calibrated models may be structured into a design procedure that will limit distresses and performance measures to acceptable levels.
4. *Determine the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance*— The primary approach for determining the effects of the significant parameters will be the development of predictive equations and the statistical evaluation of the separate variables and their interactions with each other.
5. *Determine the effects of specific design features on pavement performance.*

The ultimate aim of LTPP program is to create a National Pavement Data Base (NPDB). The NPDB will contain inventory information and performance histories of pavements with various design features, materials, traffic loads, environmental conditions, and maintenance practices. Most of the input for the NPDB will be drawn from the General Pavement Studies and Specific Pavement Studies, which will be described later. The LTPP study is collecting two basic categories of data items [Ref. 4]:

1. *Inventory data*—Refers to those items that remain constant over the monitoring period.
   - (a) Describe pavement cross-section and material properties of its structural constituents;
   - (b) Describe the environment in which the pavement test section exists;
   - (c) Obtain the historical traffic and axle-load data prior to the long-term monitoring effort;
   - (d) Obtain previous maintenance records;
   - (e) Obtain previous resurfacing or rehabilitation records.
2. *Monitoring data*—Includes those items that will change with time and will require periodic measurements or updating during the monitoring period.
   - (a) Distress and serviceability—monitored once every other year;
   - (b) Traffic—monitored 7 days per month;
   - (c) Axle load data (weigh-in-motion)—monitored 7 days per season;
   - (d) Skid testing—monitored once by the state;
   - (e) Deflection testing—monitored once every other year.

This experimental program consists of two types of studies, which are General Pavement Studies (GPS) and Specific Pavement Studies (SPS).

GENERAL PAVEMENT STUDIES (GPS)

GPS can be defined as one large experiment which is categorized by certain site selection factors. Factorial experiments will be conducted to identify significant factors in pavement design like environment, pavement type, and traffic. The primary goal of the GPS is to develop a national database for the LTPP study by evaluating existing inservice pavement sections with a suitable range of characteristics. The primary goal of selecting sections is to structure a national study of existing pavement types that have a suitable range of environmental, traffic, and structural characteristics.

A total of 1210 sections are targeted for evaluation [Ref. 5]. These sections represent diverse environmental areas throughout United States and Canada, including Hawaii and Puerto Rico. To implement GPS, U.S.A. and Canada have been divided into four different regions; North Atlantic, Southern, North Central and Western. Texas is in the Southern Region with Brent Rauhut Engineering of Austin as the regional contractor. Eighty-eight of these sites, or approximately 10 percent of the total number, are in Texas [Ref. 6]. Following are the eight pavement types monitored by GPS and the corresponding number of test sites in Texas [Ref. 6]:

GPS-1: AC Over Granular Base—37 sections are being studied.

GPS-2: AC Over Stabilized Base—9 sections.

GPS-3: Jointed Plain Concrete (JPCP)—3 sections.

GPS-4: Jointed Reinforced Concrete Pavement (JRCP)—4 sections.

GPS-5: Continuously Reinforced Concrete Pavement (CRCP)—19 sections.

GPS-6A: AC Overlay of ACP—Asphalt stiffness properties, strength of the original pavement and overlay thickness are the structural effects of interest. Currently, 5 sections are being studied.

GPS-6B: AC Overlay of ACP—Similar to GPS-6A except that the original condition of the pavement surface prior to overlaying is studied instead of overlay stiffness. Three sections are being studied.

GPS-7A: AC Overlay of PCC—Structural characteristics of interest are overlay thickness and original pavement type. Two sections are being studied.

GPS-7B: AC Overlay of PCC—Condition of pavement prior to overlay is an additional characteristic being studied. Nine sections are being studied.

GPS-9: Unbonded PCC Overlay of Concrete Pavements—3 sections.

For all GPS pavement types, the variables moisture, temperature, subgrade, and accumulated traffic loads were selected as sampling design factors. These four criteria were common to the selection of GPS sections for all studies. As of July 24, 1989, 726 sections were being used for GPS purposes [Ref. 6]. These sections were selected from initial and follow-up recruitment efforts. A large number of sections are still required to fill the revised overlay studies, GPS-6B and GPS-7B. The sections for these two new studies possibly could come from the existing asphalt concrete studies (GPS-1 and GPS-2) and the three PCC studies (GPS-3, GPS-4, and GPS-5).

A two-tiered experimental approach will be used because tiered format permits a flexible analysis of all or portions of the data. Each primary tier cell, sixteen total, is a subdivision of one of the key factors mentioned above. Pavements belonging to any one of the primary tier cell have approximately the same traffic, climate and subgrade soil. Two pavement sections are being used to conduct experiments for each cell.

Material sampling and field testing (MS & FT) operations, currently underway in Texas, are very crucial for a GPS site to obtain data on layer thicknesses and in situ properties of the individual layers. MS & FT operations on the GPS test sections (Fig. 1) in the Southern Region are conducted within a 1250 foot long, one lane wide section which is closed to traffic [Ref. 7]. The actual test section is 500 feet long in the lane adjacent to the outer shoulder with 100-foot sections at the end for MS & FT operations [Ref. 7]. Falling weight deflectometer (FWD) tests are conducted within the 500-foot section [Ref. 7]. Following is a brief description of work at a GPS site in the Southern Region [Ref. 7].

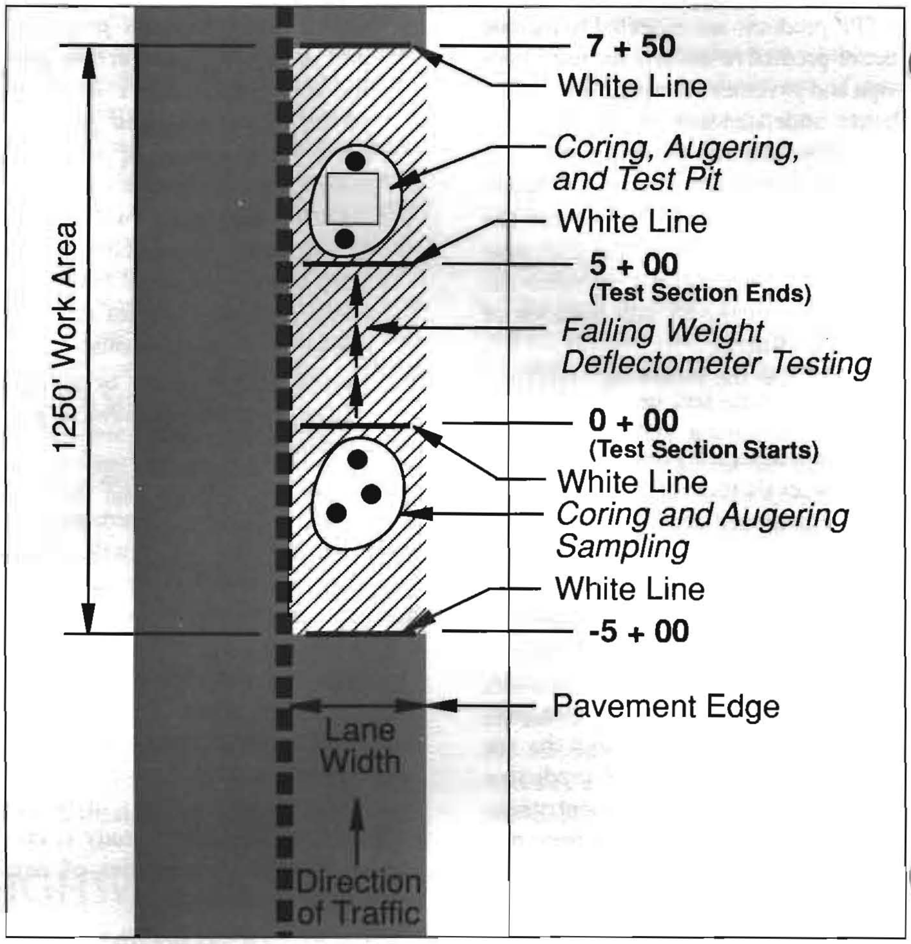


FIGURE 1: Layout of testing area for GPS sites.

Falling weight deflectometer (FWD) tests are conducted at the 12-inch auger sampling and the test pit sampling locations, before these samples are taken. Then, FWD testing is conducted within the 500-foot test section itself. Pavement response to FWD testing is measured at many different locations in the test section. Examples of such locations are the mid-lane, pavement edge, and joints and cracks. A sequence of four loads is used at each test point, and testing time varies from about 3 to 6 minutes.

After deflection testing, sawing for the pit and coring operations begins. Four-inch diameter asphalt cores and 6-inch diameter concrete cores are needed for laboratory tests. For asphalt pavements, one 12-inch by 12-inch block is sawed out for laboratory testing. A truck-mounted drill rig is used for coring operations, and a 12-inch auger is used for drilling.

A 4-foot by 6-foot test pit is the best method for in situ density testing of AC pavements because surface preparation of the exposed base course is required for nuclear density testing. The test pit is located at the "exit" end of the test section. For AC pavements, bulk samples of base, subbase, and subgrade are obtained by auger from 12-inch diameter core holes at one end and from the test pit at the other end. No test pits are used for PCC pavements. Instead, three 12-inch diameter core holes are used for bulk sampling on both ends. Patching operations are conducted upon conclusion of MS & FT operations.

The list of responsibilities for state highway agencies and SHRP for the GPS program are outlined in Table 1 [Ref. 4].

Sampling, coring, boring and test pits have been completed for half of the sections in Texas [Ref. 6]. The remainder of the tests will be completed by April 1990 [Ref. 6]. Profilometer tests will be conducted in the spring [Ref. 6]. All of the state sites have been monitored by PASCO, which is a device used to measure visual distress.

SPECIFIC PAVEMENT STUDIES (SPS)

SPS is a study of unique or new pavement types. SPS sections need to be constructed. SPS emphasizes particular design factors that are not well covered in the GPS studies. The three

***LTPP** continued on page 18.*

AESTHETICALLY PLEASING BRIDGE RAIL: TEXAS TYPE T411

Research has developed railing to withstand impact loads from vehicles of ever-increasing size; however, aesthetic considerations have been overshadowed by safety and structural requirements. The objective of Research Study 1185, *Aesthetically Pleasing Bridge Rails*, is to develop aesthetically pleasing, structurally sound railings that can serve as alternative railings in cities or urban areas.

The first report, *Aesthetically Pleasing Concrete Beam and Posts Bridge Rail—Texas Type T411*, written by T. J. Hirsch, C. E. Buth, W. Campise, and D. Kaderka, presents a new, open-type concrete bridge rail. This bridge rail is constructed of reinforced concrete 32 inches high by 12 inches thick and contains 6 inch wide by 18 inch high openings at an 18 inch center-to-center longitudinal spacing (Fig. 1). The use of pilasters is optional since they did not contribute to the bridge rail strength as built and crash tested.

The bridge rail was crash tested and evaluated in accordance with NCHRP 230 for Service Level 2. Two crash tests were required: a 4,500 lb passenger car at 60 mph and 25° impact angle; and an 1,800 lb passenger car at 60 mph and 20° impact angle.

In both tests, the bridge rail contained and redirected the test vehicle with no lateral movement of the bridge rail. There were no detached elements or debris to present undue hazard to other traffic. The vehicle remained upright and relatively stable during the collision. The occupant/compartment impact velocities and 10-millisecond occupant ridedown accelerations were within the limits specified in NCHRP Report 230. The vehicle trajectory at loss of contact indicates no intrusion into adjacent traffic lanes (exit angles of 0° and 5.9°). These tests also met the safety evaluation guidelines proposed in the new *AASHTO Guide Specification for Bridge Railings.*

Although the Texas Type T411 will cost significantly more than the standard concrete safety shape, such decorative rails provide good aesthetic value. The Department can get community involvement for aesthetics on bridge projects. Presently, the City of Lampasas is working with the Department putting money into three bridge projects using the T411 rail. This type of positive community involvement is good for the Department. The FHWA is also interested in the T411 and agreed to fund the extra cost as an experimental feature on a Brownwood bridge project. The Texas Type C411, a combination pedestrian/traffic rail version of the T411, is intended for use on the Colombia/Laredo International Bridge, which is currently being designed. Plans are to include the Texas flag and the Mexican eagle as part of the decoration. For more information, please contact Mr. Mark Bloschock (D-5) Tex-An 254-5059, (512) 371-5059.

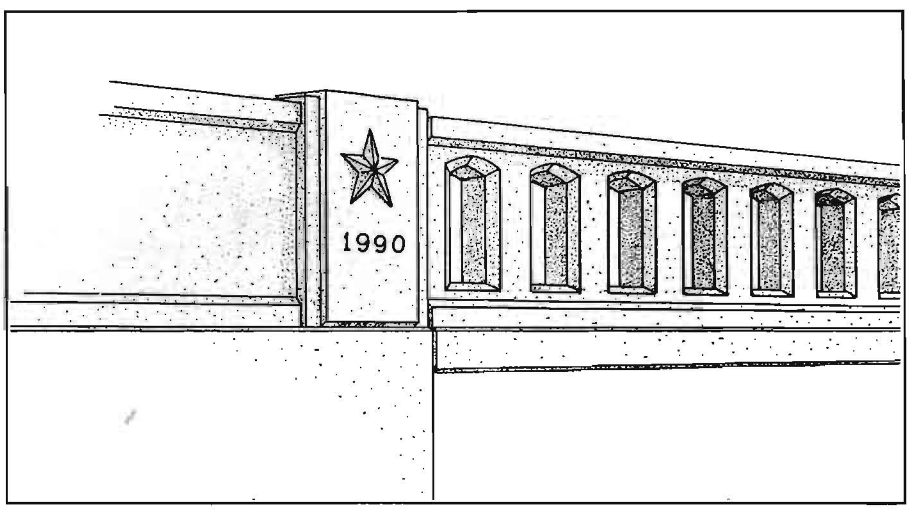


FIGURE 1: Rendering of the Texas Type T411.

AESTHETICS AND DESIGN: SLENDER CONCRETE SIGN BRIDGES

by Kathleen M. Jones
Technology Transfer
Transportation Planning Division

Design is a series of trade-offs. Geometrics have to answer traffic needs. How much right-of-way is available coupled with how much right-of-way can be bought will dictate, to some extent, what kind of structures can be built. Practical matters such as outfall, and other drainage concerns, must be considered. Vertical curves need to be minimized. Human factors must also be considered: forests of multiple bridge columns in an urban setting confuse the drivers' eyes causing stress and fatigue. Structures are pervasive in the urban landscape, and the public is getting more outspoken about ugly bridges. All these factors: capacity, geometrics, economic feasibility and aesthetics, were balanced by Billy A. Hardie, District Designing Engineer of Fort Worth District, in a unified slender concrete design of a major widening and reconstruction project on IH-35W.

This IH-35W project is between IH-30 and IH-20 south of Fort Worth. The right-of-way available in this 41/2-mile section varied from 285 feet to 315 feet. Out of this width, 8 lanes of freeway and 6 of frontage road needed to be carved (Fig. 1). These geometric constraints, combined with not wanting to create drainage problems and vertical curves by excavating deeply for underpasses, meant that the underpass bridges would have to be constructed with slender bents and narrow concrete box beams to save space. The bents were designed to be flush with the retaining walls or formed into part of the concrete safety-shape barrier. To echo the functional clean lines of the underpass bridges, Mr. Hardie and his staff designed the pedestrian walkways to be narrow box beams on slender bents as well (Fig. 2). That left only one other major highway appurtenance to account for, the sign bridges.

FIG. 1: 8 lanes of freeway, 6 of frontage road in 285 ft. of ROW.

FIGURE 2: Pedestrian walkway.

The sign bridges were going to be a problem. Not only would the metal trusses of standard sign bridges clutter the horizon, confusing the eye and giving a claustrophobic feel, but also the wide footings needed for standard sign bridges would encroach on the 22 foot median. Clean lines and narrow footings were called for. Mr. Hardie and his staff designed a slender concrete sign bridge (Fig. 3). An extensive literature search indicates that this may be the first time this concept has been tried.

The sign supplier, of course, was not set up to do a job like this. Mr. Hardie wrote to the Austin Divisions

FIGURE 3: A slender concrete sign bridge.

explaining the design constraints and aesthetic value and received approval for the change. In the median, the narrow, 15-inch supports for the sign bridges were formed all the way from the subgrade to the top in one operation. The top of the median barrier was widened on a 20:1 taper from 8 inches to 15 inches around the supports so as to be flush with them (Fig. 4). The supports on the edge of the shoulder were designed to look like part of the retaining wall or were incorporated into the concrete safety-shape. Precast narrow box beams were set on dowels on top of the slender supports. Single pedestal supports with short concrete box beams were made for the four changeable message signs (Fig. 5) that are part of the automated traffic control network being developed for Fort Worth. Other single sign supports, not requiring bridges, were designed to be part of the retaining wall or traffic barriers (Fig. 6).

Building the slender concrete sign bridges requires design-shaped forms and heavier equipment to erect. They also take longer to erect than standard sign bridges, and swinging the box beams onto the supports can be a problem if traffic is already on the facility. However, the greater initial cost is offset by a longer service life that is virtually maintenance-free, as well as by the aesthetic value.

What started as a geometric constraint problem, ended as a unified aesthetic design concept in Fort Worth. The long, horizontal lines of the slender concrete structures open up the view and reduce psychological "squeeze" on the driver, just as the narrow bents and footings incorporated with the barriers solve the physical space problem in the right-of-way. Various textures and patterns in the retaining walls enhance the visual interest, breaking up the large expanses of concrete. By being responsive to aesthetics, as well as the other important design factors, Mr. Hardie and his staff developed a plan for an urban landscape of functional, clean lines in which all the parts function in harmony, rather than settling for a jumble of structures designed piecemeal.

FIG. 4: Footing flush with median barrier.

FIG. 5: Support structure for changeable message sign.

FIG. 6: Side-mounted sign on retaining wall.

AUSTRALIAN ROAD BLENDED WITH ENVIRONMENT

A new National Highway between the large iron ore mining center of Newman and the coastal area of Port Hedland will be, when completed, a two-lane sealed highway 416 kilometers in length.

At one point the road descends from the Hamersley Plateau, passing for a distance of 21 kilometers through the Munjina East Gorge in the Hamersley Range National park. This segment of road spans two rivers, crosses 160 creeks of various sizes, passes through a sculptured road cut one kilometer long, passes beneath unstable cliffs for four kilometers.

The unstable cliffs posed the greatest technical challenge, with individual cliffs containing up to 300,000 tons of rock precariously poised above the road. Conventional mountain road construction had to be set aside. Instead of cutting the road into the slopes below the cliffs, the road was built up and out from the slopes, leaving a ditch to catch falling rocks. In one particularly dangerous section, a spring tensioned fence was built to catch bouncing rocks and then slide them down the slope. Conventional crash rails were modified to prevent flying rocks from reaching the road.

This solution created another problem because the raised embankment blocked the creek in the narrow gorge. Dam building techniques were used to create a zoned embankment with rockfill on the steep outer slopes. When selectively dressed with the sparse topsoil, the slopes were erosion-resistant and matched the angles, texture and color of the natural slopes.

The Australian Road Federation says, "Constructing a new highway through a National Park is a rare but emotive issue. The project was dominated by environmental needs, but the grandeur of the gorge and the rugged nature of the country imposed engineering challenges which required innovation and attention to detail.

"Apart from creating technical solutions, the engineers had to create massive sculptures, 'spray paint' sections of work with wet soil, match paint with natural colors, mould the works into the landscape and maintain natural flows of water to endangered vegetation."

Environmental damage was virtually eliminated by having no borrow pits for 20 kilometers. All construction equipment was kept within the actual width of the road, avoiding unsightly cracks and scars. This involved careful matching of the quantity and quality of material from the large one-kilometer cut with the requirements of the zoned fill.

*From **World Highways** 39 (February 1988): 5.*

WEEDS CAUSE BIG LAWSUITS

A single-vehicle accident on a county gravel road in July 1979 resulted in fatal injuries to a passenger in the small pickup truck involved. The vehicle overturned in the roadway when the driver swerved to avoid an automobile entering the roadway from a farm driveway. The entering vehicle reportedly had stopped with its front near the edge of the traveled portion of the roadway. This position was necessary because of the sight restrictions in the farmstead's windbreak. In the resulting lawsuit, the county contributed a five-figure amount to the settlement, which was reached without a trial. A two-vehicle collision in July 1981 occurred when a west-bound small pickup truck failed to yield to a stop sign and was struck broadside by a southside vehicle. The passenger in the pickup was injured and initiated a lawsuit against the county involved. Witnesses for both sides agreed that weeds and grasses growing in the right-of-way in the northeast quadrant obscured the view of a westbound driver unless a vehicle was stopped so that it encroached slightly on the traveled portion of the northsouth gravel road. This case settled without a trial, and the county contributed a five-figure amount to the award. In each of these cases, the common factor was the presence in the highway right-of-way of vegetation growth that was alleged to have contributed to the accident. Most counties had adopted policies that substantially limit spraying, mowing, and cutting to control weeds and brush. Although these policies have been adopted in the interest of economy, they have received widespread support for their scenic enhancement and wildlife preservation. While these environmental objectives are laudable, counties should be alert to the possible need for spot control of vegetation at locations where the motoring public's safety would other wise be seriously compromised.

***Rural Technical Assistance News**, University of Maine, Spring, 1987.*

An unusual construction technique is underway in Belgium, where the Ben Ahin Bridge, with a single off-center pylon, is being built to cross the River Meuse. The structure, with a main deck 294 meters long, is being built parallel to the banks of the river, and when the deck is complete the 16,000 ton structure will be rotated through 70 degrees to cross the river.

*From **World Highways** 39 (February 1988): 6.*

A REVIEW OF AGGREGATE SPECIFIC GRAVITIES

The following article reviews the various types of aggregate specific gravity. Specific gravity of a material is the ratio between the weight of a given volume of the material and the weight of an equal volume of water. Specific gravities of aggregates are important because they are used in determining density and other void characteristics of the compacted asphalt mixture. They are also necessary in the proportioning of the aggregate and asphalt in mixtures containing lightweight aggregate. Specific gravity is used in measuring the following five characteristics that are necessary in the design and control of compacted asphaltic concrete mixtures:

(1) *Density*—This is the ratio of the actual bulk specific gravity of the compacted bituminous mixture specimen to the theoretical maximum specific gravity of the combined aggregate and asphalt contained in the specimen, expressed as a percentage.

(2) *Air voids*—The small air spaces that occur between the coated aggregates. Density and void content are directly related. The percent solids plus the percent air voids equals 100 percent. Decreasing air void content generally increases pavement fatigue life, reduces thermal cracking, decreases moisture damage, and decreases aging due to oxidation. A certain percentage of air voids is necessary to allow for additional compaction by traffic. Loss in pavement stability occurs when the air void content becomes too low.

(3) *Optimum asphalt content:*

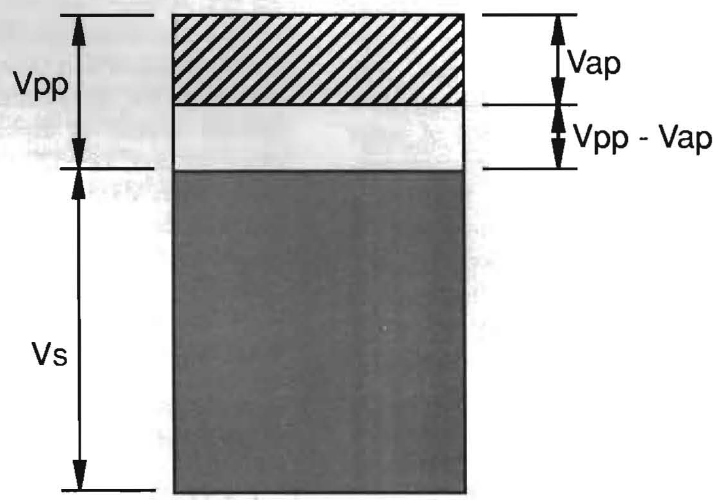
(a) Total asphalt content—The amount of asphalt that must be added to the mixture to produce the optimum density.

(b) Effective asphalt content—The volume of asphalt not absorbed by the aggregate; or, the amount of asphalt that effectively forms a bonding film on the aggregate surfaces.

(4) *Voids in the mineral aggregate (VMA)*—Voids that exist between the aggregate particles in a compacted asphaltic concrete mixture. This is the space filled with asphalt plus the air void content.

(5) *Voids filled with asphalt*—The volume of asphalt divided by the VMA. This is not being considered for specification use at this time.

There are three types of specific gravities which are used in the equations to calculate the above-mentioned factors; bulk, apparent, and effective specific gravity (Fig. 1). Two forms, bulk and apparent specific gravity, are determined directly by testing aggregates in the lab. The difference between the two is in the volume being considered. By definition:



Vs = Volume of solids
Vpp = Volume of water permeable pores
Vap = Volume of pores absorbing asphalt
Vpp - Vap = Volume of water permeable pores not absorbing asphalt
Ws = Oven-dry weight of aggregate
γw = lg/cm^3 = Unit weight of water (for simplicity, metric measurements are used in these calculations)

1a. Bulk specific gravity $= G = \dfrac{Ws}{(Vs + Vpp)\,\gamma w}$

1b. Apparent specific gravity $= G_A = \dfrac{Ws}{(Vs\,\gamma w)}$

1c. Effective specific gravity $= G_e = \dfrac{Ws}{(Vs + Vpp - Vap)\,\gamma w}$

FIGURE 1: Relationship of different types of specific gravities [Ref. 2].

(1) Bulk specific gravity is the ratio of the oven-dry weight of the aggregate to the bulk volume of the aggregate particles. The bulk volume of the aggregate is equal to the volume of water displaced by the aggregate in a saturated, surface-dry condition. Bulk specific gravity of an aggregate considers all aggregate pores in the volume determination (Fig. 1a). When this specific gravity is used, it is assumed that pores which absorb water do not absorb asphalt. [Ref. 1, Tex-201-F]

(2) Apparent specific gravity is the ratio of the oven-dry weight of the aggregate to the apparent volume of the aggregate particles. The apparent volume of the aggregate is equal to the volume of water displaced by the impermeable portion of the aggregate. The volume of the pores that become filled with water are not included (Fig. 1b). When apparent specific gravity is used, it is assumed that all water-permeable pores absorb asphalt. Apparent specific gravity is always heavier than bulk specific gravity for a given sample because it is based on a smaller volume. [Ref. 1, Tex-202-F]

The third form of specific gravity used by the Department is the effective specific gravity. It is the only aggregate specific gravity determined through the testing of the asphaltic concrete mixture. The volume does not include the pores and capillaries in the aggregate that absorb asphalt (Fig. 1c). The effective specific gravity is between the bulk and apparent specific gravities and can be approximated roughly by averaging the two values. The method of calculating the effective specific gravity involves the use of data from tests for determining the theoretical maximum specific gravity of asphalt mixtures (Rice Method, Tex-227-F [Ref. 1], or the J. Rogers Martin Method, C-14 [Ref. 3]). The theoretical maximum specific gravity of a bituminous mixture is the bulk specific gravity of that mixture when compacted to zero air voids. When this value is known, the effective specific gravity of the aggregate can be calculated. The effective specific gravity value is the most appropriate value to be used in most hot-mix calculations because it discriminates between water-permeable and asphalt-permeable pores.

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ALTERNATIVE FUELS: NEEDS AND PROBLEMS

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INTRODUCTION

It might seem unusual to talk about alternative fuels at a time of cheap gasoline. It would be highly illogical to try to substitute gasoline, which is the most suitable fuel for transportation at the present time, during a period of low crude oil prices, but economics is not the only reason that motivates policy decisions nowadays. Environmental issues are in the limelight, which is not surprising, considering the fact that the danger facing the existence of the human race, as a result of environmental neglect, has finally been recognized by the international community. Gasoline emissions from automobiles contribute toward ozone depletion and towards the much dreaded greenhouse effect. The early 70s taught us the problems of being at the mercy of the oil producers. There are many inherent problems in depending upon petroleum as the sole source of energy.

Transportation is very relevant to the problem of oil dependence because it is such a fuel inflexible sector since all present substitutes are either too expensive or inferior. Because of the need for energy in a portable, concentrated form, transportation is generally regarded as the highest value use category for petroleum-derived liquid fuels. In 1985, the transportation sector accounted for nearly 63 percent of U.S. petroleum consumption [Ref. 1]. The United States is, by far, the most dominant transportation oil consumer among the nations belonging to the Organization of Economic Cooperation and Development (OECD), accounting for nearly 60 percent of all OECD consumption [Ref. 1]. The trend in the United States is towards a greater use of petroleum products by transportation. The dependence of other sectors, such as electricity generation, on oil have reduced tremendously since the 1978-79 oil price jump.

THE URGENT NEED FOR ALTERNATIVE FUELS

The primary economic reason for the development of alternative fuels would be to shield the country from the ill effects of sharp price fluctuations. Sharp oil price increases, which are brought on by cutbacks in oil production or "supply shocks", are causes of recession. The theory that energy price collapses cause economic booms has not been proved and is certainly not valid in Texas where the oil price collapse of 1986 caused widespread unemployment, a severe decline in the fortunes of the real estate sector, and the subsequent collapse of banks and the savings and loans institutions. Divergences between consumption and production are precursors for sharp oil price increases. A situation of excess consumption over production, which is also known as a consumption excess gap, induces a price increase, whereas a reverse situation, known as a production excess gap, induces the opposite effect [Ref. 1]. The two worst 20th-century crude oil price escalations occurred in 1915-1920 and 1978-1981, after the two most prolonged gaps of excess growth rates in oil consumption over domestic oil production [Ref. 1] When these gaps were reversed oil prices were inevitably driven down. The unusually severe recessions that followed both the worst U.S. oil price jumps indicates the need for balance in the energy sector to achieve and maintain economic stability.

The process for reestablishing balance after a major price movement historically has been quite long and has involved recessions after the upward price movement. Historically, initial gaps precede price shocks that cause subsequent declines in economic activity. Since the widening of these gaps appears to be predictable well in advance of these price shocks, steps should be taken to correct the situation.

The transportation sector was less responsible for initiating the 1968-1973 gap than were other sectors. Even though the other sectors did increase their oil consumption during 1968-1973, they were able to rapidly reverse these increases so that they contributed far more to the closure and reversal of the gap than did transportation. It was far easier for the other sectors to switch fuels than the transportation sector. In fact, transportation's growth momentum combined with its inflexibility in fuel substitution and in conservation caused this sector to consume more oil in 1985 than in 1973, while each of the other sectors managed to reduce their consumption. Since the first oil price shock in 1973, the total oil consumption of this country has dropped 7.8 percent despite an 11 percent increase in consumption by transportation from 1975 to 1985 [Ref. 1]. The success of American efforts to reduce oil consumption in the transportation sector will be crucial in preventing or reversing the next oil consumption excess growth gap. This capability must be developed to thwart the calamitous consequences of the possible recurrence of the early 1980s.

Another very good reason to promote feasible alternative fuels is that the United States may not be able to deal with another energy crisis reminiscent of the oil embargo of the early 1970s. The United States is running out of economically recoverable petroleum. Proven oil reserves have fallen from a level of 38 billion barrels in 1973 to about 27 billion barrels in 1988 [Ref. 6]. Exhaustion of domestic U.S. petroleum reserves reduces the nation's ability to deal with consumption excess growth gaps by increasing domestic petroleum production. Therefore, the nation must:

(a) Increase exports to earn the necessary foreign exchange to purchase imported oil.

(b) Improve the thermodynamic efficiency of equipment that uses petroleum products.

(c) Develop domestically produced substitutes for petroleum products.

(d) Import substitute fuels that are less costly.

Environmental reasons are another major factor for the search for alternative fuels. The ozone problem and the greenhouse effect will be household words in the 1990s. The depletion of the ozone layer threatens to expose the Earth's population to harmful ultraviolet rays increasing the rates of skin and other cancers. The problem has become serious enough to force the industrialized nations to enforce a ban on the use of fluorocarbons—the major culprit in the problem.

The greenhouse effect is caused by the accumulation of carbon dioxide and other trace gases in the atmosphere. These gases form a shield that prevents heat, in the form of infrared rays, from escaping. The earth's radiation balance is upset, and the eventual global warming can increase temperatures from 1°C to 5°C [Ref. 3]. This warming could shift global precipitation patterns, disrupt established crop growing regions, raise the sea level by approximately a meter, and eventually melt portions of the polar ice caps, threatening coastal cities worldwide with inundation. Several other trace gases, methane, nitrous oxide, ozone and chlorofluorocarbons, could contribute to about 50 percent of the total greenhouse temperature increase 50 years from now [Ref. 3].

Globally, fossil fuel burning now accounts for 56 to 94 percent of the total net carbon dioxide release—values in excess of 75 percent are more likely—and greater contributions are expected in the future [Ref. 3]. Motor vehicles account for about 90 percent of the carbon monoxide in the atmosphere [Ref. 9]. If the average efficiency of the whole U.S. fleet, including trucks and buses, were improved to 29 mpg from the 1985 figure of 14.5 mpg, carbon dioxide emissions would be reduced by 50 percent [Ref. 3]. There are now about 80 urban areas with total population of about 40 million people which do not meet EPA carbon monoxide standards [Ref. 9]. Seventy areas with a total population over 76 million people have violated federal ozone standards, and this situation can only be rectified if there is a 40 percent reduction in the hydrocarbon emissions in at least a third of the nation's largest cities [Ref. 9]. In 1987, Houston's ground level ozone problem was the second worst in the country, next to Los Angeles.

THE PROBLEM OF FUEL SUBSTITUTION

As was mentioned earlier, petroleum substitutes for transportation would be difficult to develop or market during a period of low oil prices. The present alternatives are either too inferior or too expensive. It would also be unwise to make a commitment to an alternative fuel without considering its environmental impact. The most commonly proposed alternatives to petroleum are electricity, methanol, compressed and liquified natural gas (CNG and LNG), and hydrogen (LH_2 and hydride).

The process of fuel substitution can be described as occurring in two steps. Firstly, price shocks stimulate consumers and investors to reduce oil consumption by using alternative fuels as much as possible. Secondly, producers of energy-intensive products begin programs of research and development to implement new technologies that are more thermodynamically efficient or use more abundant, less expensive fuels or both. Several years of sustained high prices, well above recent price levels, must occur to cause the widespread adoption of new oil-substituting and oil-conserving technology. A. J. Sobey of General Motors indicates that a price of $20 per barrel would be suitable to initiate the process of fuel substitution based on some low cost non-American gas sources [Ref. 1].

The 1990s have been predicted to be an age of OPEC dominance in the oil market again. Such a statement may raise the specter of another energy situation similar to the early 1970s but such fears may be unnecessary. The OPEC cartel has a vested interest in not allowing the oil price to return to its former peak of $34 per barrel. High prices will initiate a conservationary trend among consumer countries and unleash another slump in the oil industry. Saudi Arabia is the dominant force in OPEC by virtue of having the world's largest reserves and resources. The Saudis will be able to control the production to ensure that the oil price does not rise too much. The official OPEC target is $18 per barrel [Ref. 10]. This price is not high enough to encourage consumers to conserve or to explore and develop their own oil fields and flood the market. Therefore, the price of gas and oil in the 1990s could be expected to increase only modestly, which does not help the competitiveness of alternative fuels versus gasoline. The cheap price of imported oil does not help matters much either.

To solve the problem, fuels and technologies should be priced at their social cost or full economic cost instead of their private cost [Ref. 3]. While gasoline is currently the cheapest fuel on a private basis, it certainly is the most expensive if we were to account for the cost of air pollution and the expense of defending the oilfields in the Middle East in terms of money and human lives. Research and development should be directed at fuel and vehicle combinations with low external costs, especially those that do not produce environmental problems and aggravate world tensions.

Active government intervention would certainly help the cause. Active government efforts during the 70s helped in the transition from leaded to unleaded fuels [Ref. 4]. Strong governmental enforcement with disregard to market forces would be crucial if matters become urgent. This "command-and-control" approach is effective when only a small number of people or corporations or organizations need to be dealt with [Ref. 4]. Also, too much publicity regarding the introduction of any alternative fuel should be avoided. The press tends to stress the negative aspects of any new technology, especially if it is government sponsored, and this adverse publicity would kill any potentially innovative effort. Any new technology will experience "teething" problems in the initial stages and must be given a chance to prove itself. For example, the gasoline engine, itself, was considered infeasible during the horse-and-buggy era.

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EDITOR'S NOTE

This article is the first in a series on issues surrounding alternative fuels. Part 2 will discuss types of fuel alternatives, their advantages and disadvantages. Future articles will deal with such subjects as availability of alternative-fuel-capable equipment, alternative fuel reserves and fueling station infrastructure, the relationship of legislation to alternative fuel technology feasibility, etc. District and Division personnel are invited to submit articles or suggestions for articles for this series.

WORK ZONE SAFETY EMPHASIZED

A contractor may be doing the road work, but moving traffic safely through work zones is the highway authority's responsibility. As lawsuits against governments have multiplied dramatically, safety in work zones has come under increased scrutiny. One in eight accident studies brought to the attention of noted highway consultant R. L. Carstens now involves work zone accidents. Ten years ago it was one in 100. Every governmental entity with jurisdiction over highways should become familiar with proper work zone traffic control devices. These are described in Part VI of the Manual of Uniform Traffic Control Devices (MUTCD).

Use uniform work zone traffic control signs and devices so drivers know what to expect. One of the newest is the traffic control paddle, a two-sided sign on a staff. One side has the red octagonal STOP sign, the reverse has an orange SLOW sign. The instructions provided by the paddle are much clearer to drivers than the many possible movements of a flagman's flag. Planning work zone traffic control should follow seven principles:

- Keep the motorist's respect and the agency's credibility. Don't lie to the public.
- If work is not in progress, or a hazard is not there, take down, fold over or cover signs.
- If there is no need for traffic-channelling devices, remove them.
- Do not tell drivers to expect a hazard that is not there. If you do, they may not believe other signs and devices used on the project.
- Do not assume that drivers and pedestrians will see or recognize the workers or hazards in the work area.
- Maintain the controls as if every driver were approaching the area for the first time.
- Understand the philosophy of good work area traffic control, so you can perform your work with a minimum of exposure to traffic. Watch for problems and any damaged or missing devices.

From ***Crossroads****, University of Wisconsin-Madison, Winter, 1989.*

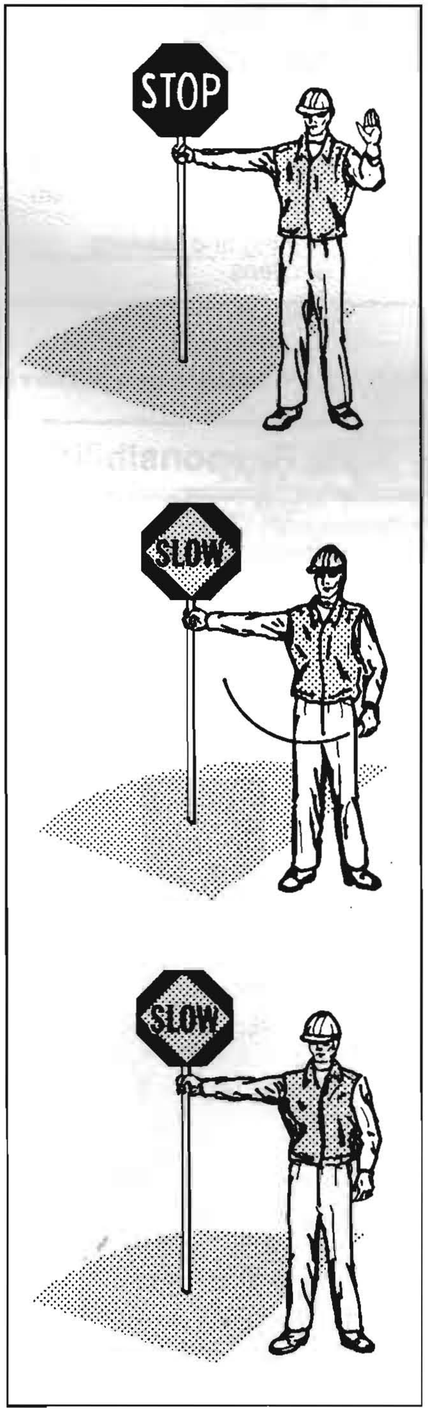
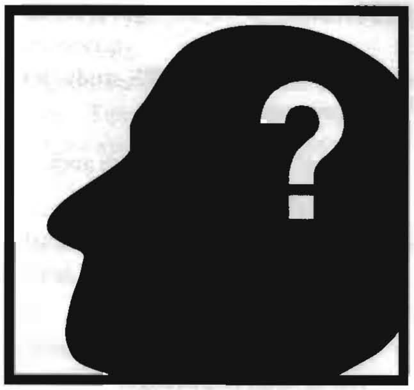


FIG. 1: Use of paddle by flagger.



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NO TIME TO READ?

Many of us face this problem: too much reading, too little time. Here are some tips on how you can maximize a limited amount of reading time:

- **Schedule** specific blocks of time each week for business reading (and stick to your schedule).
- **Prioritize** your reading material. Read the most important information first.
- **Skim** each piece of material to quickly determine if you need to read further. Look at the table of contents first. Then read the headline and first sentence of sections and paragraphs. The greatest goal of speed reading is to not read material you aren't interested in or that isn't needed.
- **Delegate** reading to people in your department. Let then know what kind of information they should forward to your attention.

From ***CAPSULES****, Southern Rural Development Center, 0 (May 1989).*

LTPP continued from page 9.

criteria to include in a SPS study in the LTPP program are:

1. potential new knowledge about the study's design factor effects;
2. the need for widespread observation of factor effects across several different climates; and
3. the inability of the GPS to provide the desired knowledge.

The SPS studies are categorized as follows [Ref. 6]:

SPS-1: Strategic Study of Structural Factors for Flexible Pavements

SPS-2: Strategic Study of Structural Factors for Rigid Pavements

SPS-3: Maintenance Effectiveness of Flexible Pavements

SPS-4: Maintenance Effectiveness of Rigid Pavements

SPS-5: Rehabilitation of Asphalt Concrete Pavements

SPS-6: Rehabilitation of Jointed Concrete Pavements

SPS-7: Bonded Concrete Overlays of Concrete Pavements

SPS-8: Environmental Effects

SPS-9: Asphalt Program Related Study

Each of these sections are 500 feet long, with markings every 100 feet [Ref. 6]. The site verification for the SPS test sections requires 1 to 2 days [Ref. 6]. Site selections are made to avoid significant variations from cut to fill, to avoid large culverts, and to avoid significant variations in traffic. These specially designed SPS test sections will be arranged in such a manner that each of them have the same subgrade, climate, and traffic. It is hoped that sections near GPS projects can be used as test sites in an effort to cut costs and to reduce the search for new pavement test sections.

The list of responsibilities for the SHRP and the state for the SPS program are outlined in Table 2 [Ref. 6]:

Texas has a considerable number of candidate test sections in the SPS-3 and SPS-4 program (Figs. 2 and 3). The goals of the SPS-3 and SPS-4 program are:

1. establish effectiveness of common maintenance treatments in prolonging pavement life;
2. develop methods for evaluating cost-effectiveness of maintenance treatments; and
3. develop information on the effective timing of the application of maintenance treatments.

The pilot section for the SPS-3 program was constructed on December 5, 1989, in San Antonio [Ref. 6]. Twelve SPS-3 sites have been nominated [Ref. 6]. Nominations are currently being sought for SPS-5 and SPS-6 sites. Texas

TABLE 1: Division of responsibilities for the GPS program.

State Responsibilities	SHRP Responsibilities
• Maintenance Data • Rehabilitation and Reconstruction Data • Traffic Counts, AVC, WIM • Skid Resistance Data • Traffic Control • Construction of Specific Pavement Studies Sites • Materials and Testing Patch Report • Signing and Marking Sections	• Quality Control • Data Collection and Calibration • Data Management • Environmental Data • Training • Deflections • Profile Roughness • Distress Survey • Materials and Testing for GPS

TABLE 2: Division of responsibilities for the SPS program.

State Responsibilities	SHRP Responsibilities
• Development of the Experimental Design • Coordination Among Participating Highway Agencies • Final Acceptance of Test Sites • Development of Standard Data Collection Forms • Assistance with Special Sampling Requirements • Coordination of Materials Sampling and Testing • Development of a Comprehensive Database and Data Entry • Control of Data Quality • Data Analysis and Reporting	• Participation in Experimental Design Implementation Plans • Nomination of Test Sites • Preparation of Plans and Specifications • Selection of Construction Contractor • Construction of the Test Pavements • Provision of Traffic Control for All Test Sites • Data Collection • Materials Sampling and Testing • Collection and Reporting of Pavement Inventory Data • Conducting and Reporting of Maintenance Activities • Collection and Reporting of Traffic and Load Data

is not participating in SPS-7 and is undecided about participation in the SPS-8 and SPS-9 programs.

BENEFITS

There are considerable benefits for the participants in this research program. These benefits are outlined below:

1. A better working knowledge of pavement performance can be obtained.
2. Refined calibration of Falling Weight Deflectometer tests can be obtained.
3. It improves the accuracy of present road plans or updates them.
4. It provides abundance of improved traffic data.
5. More cooperation will be instilled among participating federal, state and district authorities.
6. The National Pavement Database will be an extremely useful tool for future pavement management efforts.
7. The savings accrued from the research done would be enormous for Texas alone. An approximate annual savings of $4 million could be achieved in asphalt operations.
8. The districts may find solutions to localized problems by participating in the SPS program by adding pavement test sections with designs unique to their districts.

For up-to-date summaries on LTPP activities, see ***SHRP'ER FOCUS: The Texas District SHRP Coordinators Newsletter***, a new quarterly publication published by the Highway Design Division (D-8). The first issue is scheduled for February. Contact Mr. James Sassin (D-8), Tex-An 258-8106, (512) 465-6106, for further information.

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7. Brent Rauhut Engineering (Southern Region LTPP Coordination Office). ***Material Sampling and Field Testing of GPS Test Sections, Southern Region***. Austin: Brent Rauhut Engineering for SHRP, 1989.

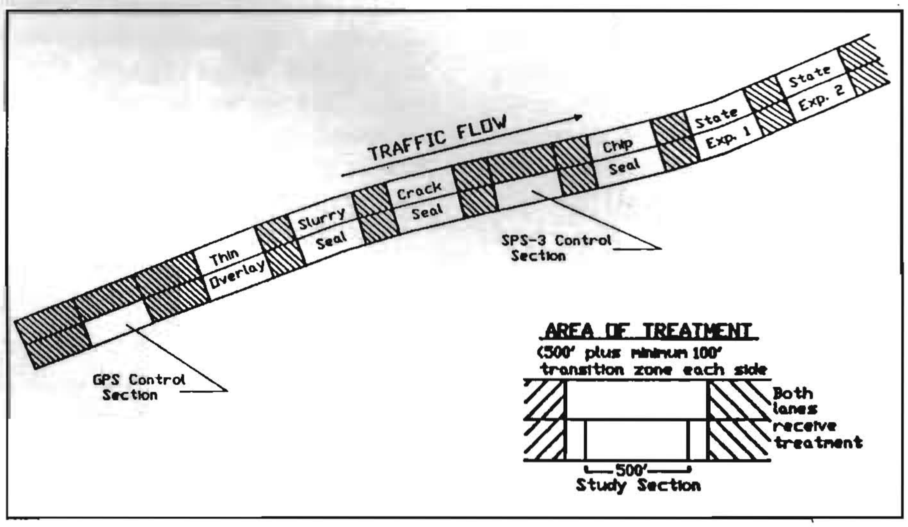


FIGURE 2: Proposed construction layout of SPS-3 AC maintenance treatments.

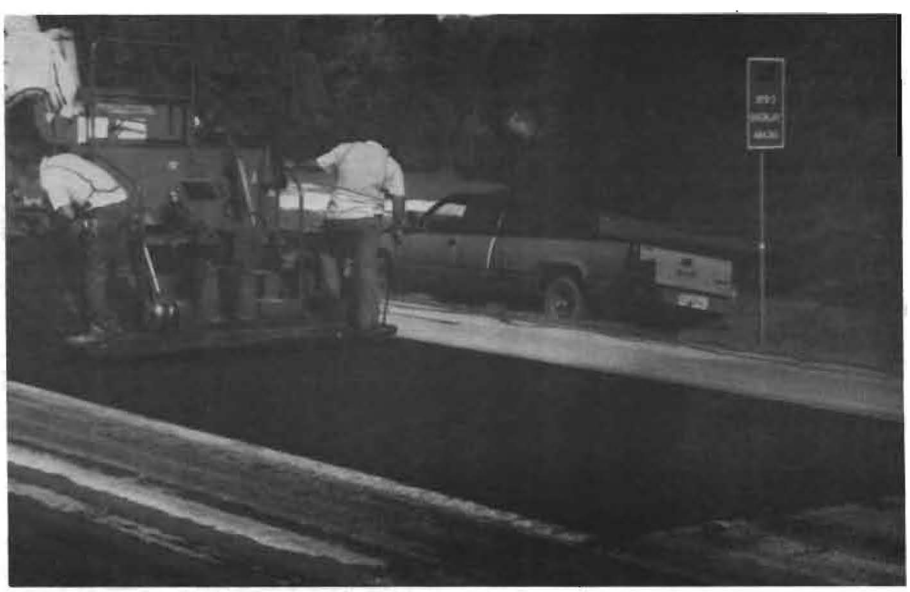
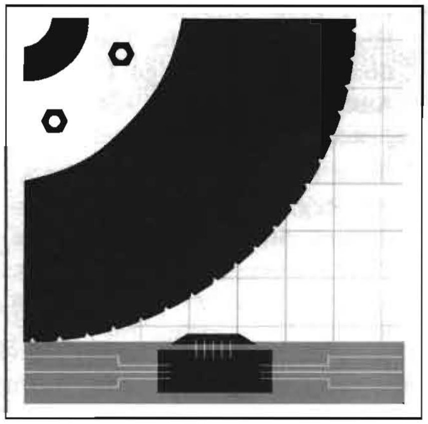


FIGURE 3: Construction of an SPS-3 site in District 15.

NATIONAL TRAFFIC DATA ACQUISITION CONFERENCE AND EXPO



The SDHPT will be hosting the National Traffic Data Acquisition Technologies Conference and Expo in Austin, Texas, on August 26-30, 1990, at the Stouffer Austin Hotel. Sponsors include the American Society for Testing and Materials, Texas A&M University, University of Texas at Austin and the Federal Highway Administration.

The conference will present the latest data collection and weigh-in-motion (WIM) equipment and site installation techniques to provide participants with possible technical solutions and techniques for meeting the growing demands of traffic data acquisition. Conference sessions will be enhanced by exhibits of numerous displays on data collection equipment and procedures. Insert schedule

~~A site inspection of the techniques currently being used in Texas will allow participants to view the following installations firsthand: Permanent and portable WIM, piezo cable WIM, automatic traffic recorders and various automatic vehicle classifiers.~~

The conference is targeted at traffic engineers, traffic analysts, transportation planners, design engineers, highway safety engineers, law enforcement personnel, trucking industry policy makers, data collection manufacturers and researchers in related fields.

For additional information on the conference or registration information, please contact Ms. Tanya Pavliska at 512-465-7936 or Tex-An 241-7936.

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