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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

EVALUATION OF ASPHALT ADDITIVES, PART I

by Joe W. Button,
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INTRODUCTION

Highway engineering is a field which requires the judicious use of materials manufactured by nature. Naturally occurring soils serve as the foundation for highway pavements. Some serve faithfully and well. Others cause problems at every opportunity. Nature's products are used in pavement bases and asphalt mixtures, often with relatively minor refinements. Many of these products are remarkably well suited to meet our needs. It is the duty and responsibility of paving engineers to optimize the use of these materials to the maximum benefit of the taxpayers and the driving public. A host of man-made products are now available which can be used to improve the rheological and/or adhesive properties of nature's own asphalt cement. The laboratory evaluation of five of these asphalt additives is the subject of recent studies, ***Investigation of Asphalt Additives*** — FHWA/RD-87/001 and ***Asphalt Additives for Increased Pavement Flexibility*** — 471-2F, (1,2), at the Texas Transportation Institute.

The primary objective was to evaluate performance of materials added to asphalt concrete mixtures for the purpose of reducing the pavement cracking and/or rutting potential. The laboratory test program was designed to examine stiffness, brittleness and flexibility at low temperatures and high loading rates, and evaluate the resistance to fatigue-type tensile loads such as those caused by vehicular loading and thermal variations. Increases in flexibility must not, however, be gained at the expense of structural stability.

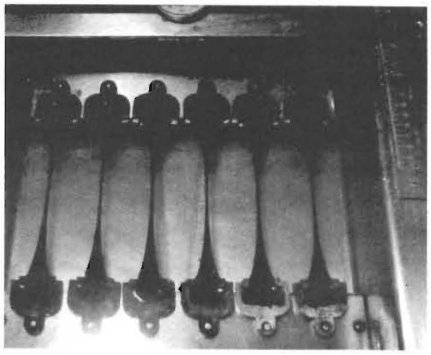

FIGURE 1 Ductility testing of asphalt samples.

The research (1,2) consisted of a systematic identification of promising types of asphalt additives designed to reduce plastic deformation and cracking in asphalt concrete pavements. Asphalt cements with and without additives were tested in the laboratory to determine chemical, rheological, elastic, fracture and thermal properties; as well as sensitivity to heat and oxidation, and compatibility between asphalts and additives. Asphalt concrete mixtures were tested to determine stability, compactibility and water

INSIDE...

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susceptibility; as well as stiffness, tensile, fatigue and creep/permanent deformation properties as functions of temperature.

Findings from this study clearly show that, to date, no asphalt additive is a cure-all; however, for certain conditions of traffic, pavement substrate, asphalt paving materials and climate, the data indicate that certain carefully selected and properly applied asphalt additives have the potential to provide cost-effective extensions to pavement service life.

DESCRIPTION OF MATERIALS

Asphalt Additives

The products selected for evaluation in the study include:

1. Latex (emulsified styrene-butadiene-rubber);
2. Block Copolymer Rubber (styrene-butadiene-styrene);
3. Ethylene-Vinyl Acetate;
4. Finely dispersed Polyethylene; and
5. Carbon Black.

Styrene-butadiene latexes are available in a wide variety of monomer proportions, molecular weight ranges, emulsifier types and other variables. Two products were included in the investigation, Latex XUS 40052.00 from Dow Chemical USA and Ultrapave 70 from Textile Rubber and Chemical Co. Both are anionic and contain about 70 percent solids and 30 percent water.

Thermoplastic block copolymer rubber was obtained from Shell Development Company. Kraton TR60-8774 (a blend of equal parts Kraton D-1101, 3-block styrene-butadiene-styrene polymer, and Kraton DX-1118, 2-block styrene-butadiene polymer) was supplied as dry crumbs.

Two ethylene-vinyl acetate (EVA) resins differing in monomer ratio, solubility, softening point and melt index were studied. These included Elvax 150 from DuPont Company and EX 042 from Exxon Chemical Americas. Elvax 150 was used in the mixture study.

Information on the Novophalt high-shear blending process indicated that almost any polyolefin (polyethylene or polypropylene or related $C_n H_{2n}$) was satisfactory for processing. Scrap or recycled polyethylene is often used. Dispersions containing six polyethylene resins, which varied in density, molecular weight and melt index, were prepared. Dow 526 was selected for use in most of the study.

Only one carbon black product, Microfil-8, supplied by Cabot Corporation, was evaluated. Microfil-8 is a mixture of approximately 92 percent high-structure, HAF grade carbon black plus 8 percent oil (similar to the maltenes portion of asphalts) formed into soft pellets dispersible in asphalt.

Asphalt Cements

Asphalts for this study were obtained from two sources known to produce asphalt of substantially different composition and temperature susceptibility. Three grades of paving asphalt were obtained from each source: AC-5, AC-10 and AC-20 grades from a Texas Coastal refinery and AR-1000, AR-2000 and AR-4000 grades from a California refinery which processes crude oil originating in the San Joaquin Valley. While the Texaco asphalts have a relatively high asphaltenes content and low content of nitrogen bases, the San Joaquin Valley asphalts have a relatively low asphaltenes content and a high content of nitrogen bases; the latter component is a solvent for asphaltenes and makes asphaltenes compatible with the other maltenes fractions. These properties of the asphalt are related to the relative miscibility with, or solvent power for, polymers such as the rubbers and resins used as additives.

RESULTS OF TESTS ON BINDERS

Blending of Asphalts and Additives

Dispersions of the additives and the asphalts were prepared using methods described in Reference 1. Standard rheological tests were per-

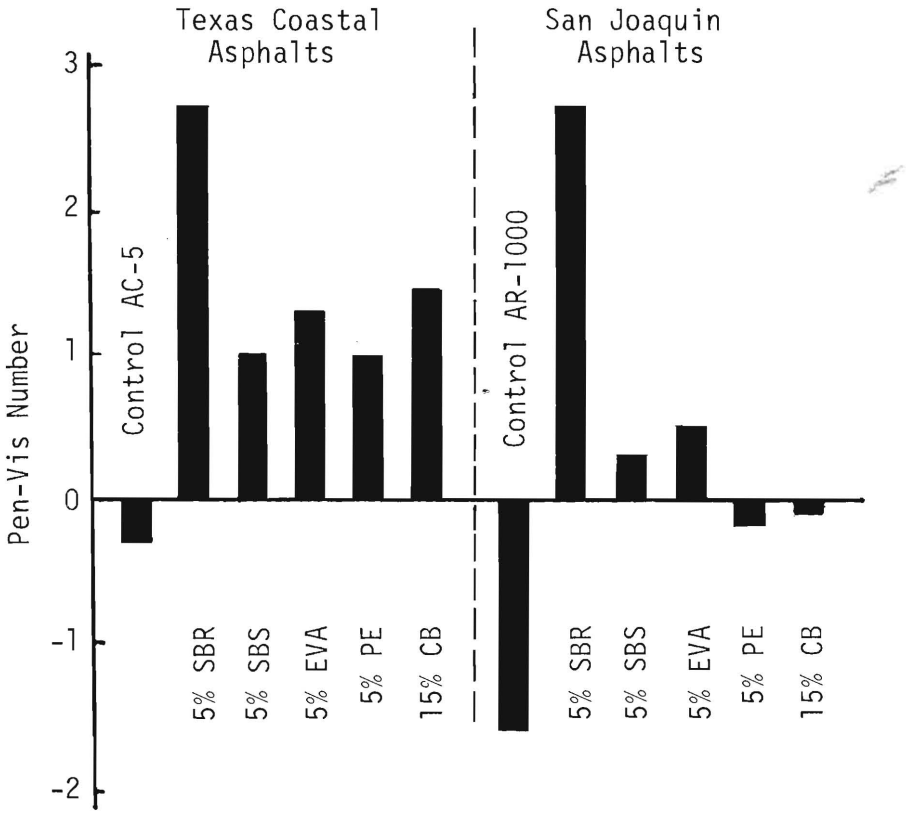

FIGURE 2 Penetration-viscosity number for asphalts and blends. (Smaller values indicate greater temperature susceptibility.)

formed on the blends. All five additives demonstrate the ability to decrease temperature susceptibility of both asphalts (Fig. 2). Since the additives were much more effective at increasing high-temperature viscosity than in decreasing low-temperature penetration, they were incorporated in the soft asphalts for evaluation in the mixture study. Generally, the additives increase the high-temperature viscosity to resist rutting, while not appreciably affecting the cracking resistance of the low-viscosity base asphalts at low temperatures.

FORCE DUCTILITY

The force ductility test is a modification of the asphalt ductility test. The test has been described (3,4,5) as a means to measure tensile load-deformation characteristics of asphalt and asphalt-rubber binders.

Examples of typical stress-strain curves are shown in Figure 3. The initial slope of the stress-strain curve in the linear region under primary loading is referred to as the "asphalt modulus" (5). A second slope or loading was observed for certain blends. Athough the data are limited, the stress-strain curves may be indicating compatibility between the additives and the asphalts. The polymeric additives have been shown to be more compatible in the San Joaquin Valley asphalt than in the Texas Coastal asphalt (1). Those polymers that are compatible, i.e., "dissolved" in the asphalt or develop a continuous network of microscopic strands, are characterized by a secondary loading which exhibits significantly more stress than the unmodified asphalt. In the Texaco asphalt, only Kraton exhibited the second peak. In the San Joaquin Valley asphalt, Kraton, latex and Elvax exhibited the second peak. Carbon black and polyethylene (Novophalt) do not "dissolve" in any asphalt, but exist as a discontinuous dispersion in the continuous asphalt phase, and did not show the second peak in either asphalt.

Area under the stress-strain curve could be considered total work or energy required to produce failure (Fig. 4). AC-5 and AR-1000 containing an additive exhibited marked increases in energy required to produce failure. The data also indicated that the changes in stress-strain properties imparted by these additives are highly dependent upon the properties of the base asphalt.

Figure 5 shows that a relationship exists between maximum stress of the asphalt binders and tensile strength of corresponding paving mixtures. It appears that the force ductility test may be useful in predicting changes in mixture tensile strength when asphalt additives are employed.

MIXTURE TESTS

Results from laboratory tests on paving mixtures containing the additives and asphalts discussed

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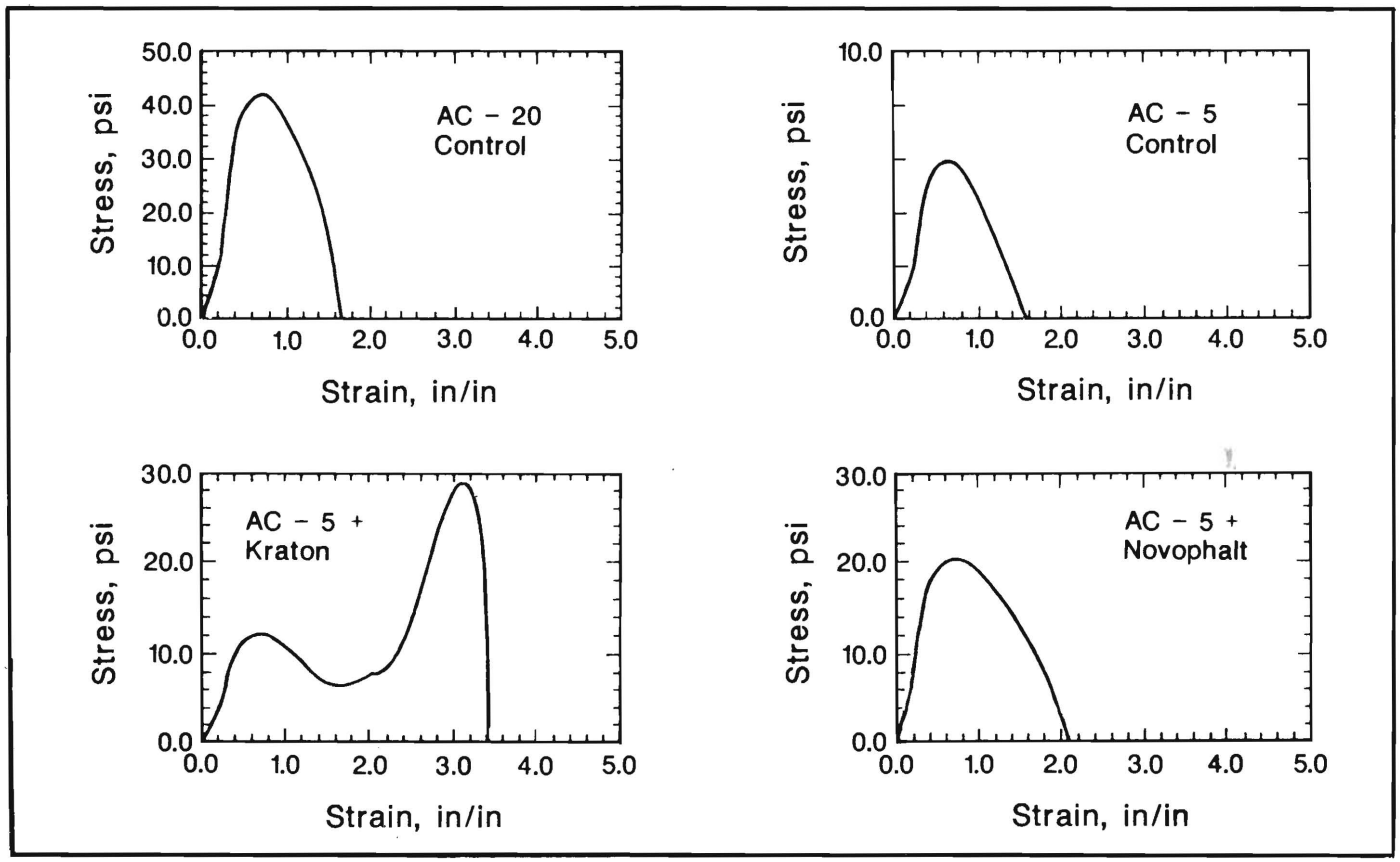


FIGURE 3 Typical stress-strain curves from force ductility tests at 30.2°F and 5 cm/min for unmodified Texas coastal asphalts.

FABRIC INTERLAYERS FOR WATER DAMAGE PREVENTION

The Federal Highway Administration's research project, "Laboratory Evaluation of Thin Interlayers for AC Reflection Crack Retardation," has funded several states' studies in an effort to develop laboratory screening tests. Under this project funding, Caltrans generated laboratory tests for estimating the effects of various fabric interlayers on AC overlay properites such as:

1. water permeability;
2. susceptibility to flexural fatigue reflection cracking;
3. susceptibility to vertical shear fatigue reflection cracking;
4. susceptibility to horizontal shear failure (slipping).

Since the failure of AC pavement can often be traced to water damage to the base, the interlayer permeability testing and discussion is perhaps the most interesting part of Caltrans' ***Laboratory Testing of Fabric Interlayers for Asphalt Concrete Paving***, FHWA/CA/TL-84/06, by Roger D. Smith. A water permeability test apparatus developed by Chevron was used on samples representing 14 paving fabrics. Permeability of these samples was compared to the permeability of a "tack-coat-only interlayer" of 0.25 gal/yd^2 asphalt (without fabric) and of control specimens (i.e., no interlayer treatment of any sort). Limited permeability testing of *cores* from actual cracked pavement with fabric interlayers was also done.

Smith observes:

> Although some interlayers performed better than others, it should be noted that all interlayer treatments provided a significant reduction in permeability. Even those specimens with only the heavy tack coat interlayer (no fabric) generally exhibited very low permeability. This suggests that the primary role of the fabric (from the standpoint of permeability) may be to distribute and secure the tack asphalt as a continuous, uniform membrane within the AC mat.

Concerning the core samples from cracked AC overlays of both AC and PCC pavements, Smith says:

> In the case of AC over AC, it was observed that even after cracking occurs, the fabric remains intact and continuous to provide waterproofing.
>
> In the case of an AC overlay on PCC pavement, however, it was concluded that once a crack becomes visible, the fabric interlayer has usually ruptured, with loss of the waterproofing effect....

Even though no explanation

Continued on page... 9

MCKINNEY MAINTENANCE INNOVATIONS

by Steven Golding and Kathleen Jones
D-10 Research

Dallas District's McKinney maintenance section has developed several valuable innovations. Benny McCormack, the McKinney maintenance supervisor, has had a hand in most of them. Two of the developments involve motor graders and one involves asphalt kettles.

Four years ago, Mr. McCormack was burned by hot sealant when it ruptured the high-temperature fluid hose on a crack sealing kettle and melted the protective plastic sheath. Not wishing to repeat the experience, he got some 2-inch, cloth fire hose from the District warehouse, cut the fittings off the fire hose, inserted the kettle's new high-temperature hose in the fire hose, and clamped the fire hose down at each end (Fig. 1). Early last fall, the kettle's high temperature hose burst again. This time the hot

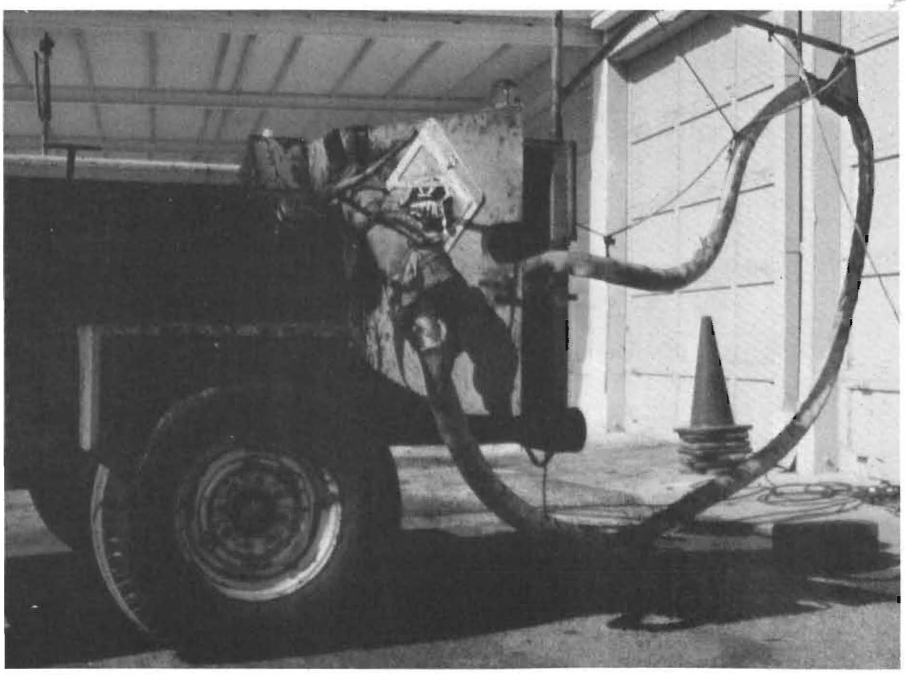


FIGURE 1 Cloth fire hose encasing high-temperature hose.

sealant was contained by the cloth fire hose and no one was burned. An added advantage of encasing the high-temperature hose in cloth fire hose is that the fire hose helps keep the material warm. Several other maintenance sections in the Dallas District have also started using cloth fire hose over their kettle hoses. The fire hose should be removed periodically so the high-temperature hose can be inspected for deterioration.

The first maintainer item is a variation of a technique developed ten to fifteen years ago by McKinney personnel. This original technique involves mounting a section of maintainer blade perpendicular to the regular blade (Fig. 2). This arrangement enables the operator to push material from under the guard rails when pulling the shoulder, instead of having to do it by hand. Unfortunately, traffic has to be shut down on one lane in order to have enough room to maneuver the extra length back and forth. Mr. McCormack's recent variation of this method is simply to offset the narrow, high tensile cutting blade on the maintainer (Fig. 3). At first, an offset of 3 feet of blade was tried, but it proved too flexible. Two feet is the current offset and it works very well. Offset as shown in Figures 4 and 5, the blade sweeps in an arc under the rails with the forward motion of the maintainer. It is swung sideways to clear the post. This method doesn't move material as far down the backslope as the older way, but it takes less space and requires less manpower: this operation can be worked entirely on the shoulder without closing a lane. As well as moving material from under guard rails when reprofiling shoulders, the offset blade can be used to raise and level the guard rail, too.

Certain model 1982/83 models of maintainers have relatively exposed, rear-placed fuel tanks. To help prevent the fuel tank from rupturing if the maintainer backed into something, or if another vehicle struck the maintainer in the rear, McCormack and the McKinney personel built a framework. The framework, of 2-inch diameter pipe and square section steel, bolts on through

FIGURE 3 Benny McCormack and Robert Victory with the offset blade.

FIG 2 The original modification.

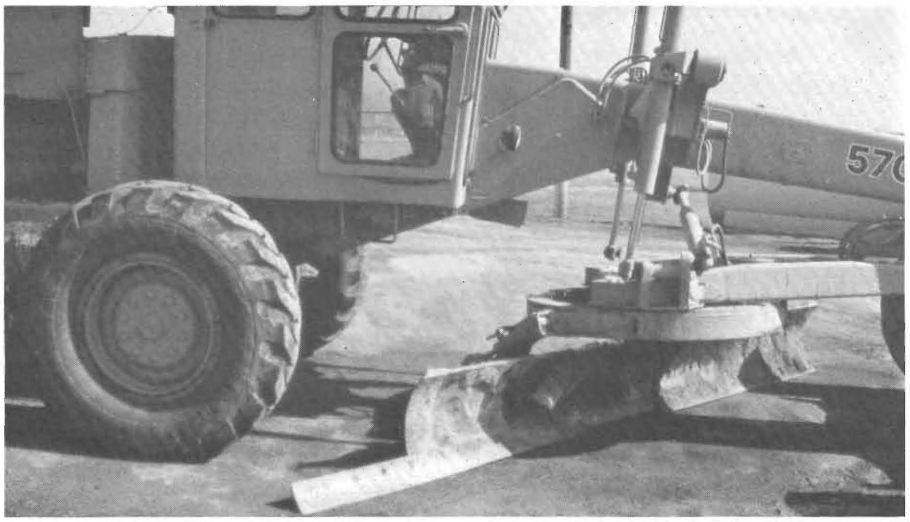


FIGURE 4 The offset blade in position.

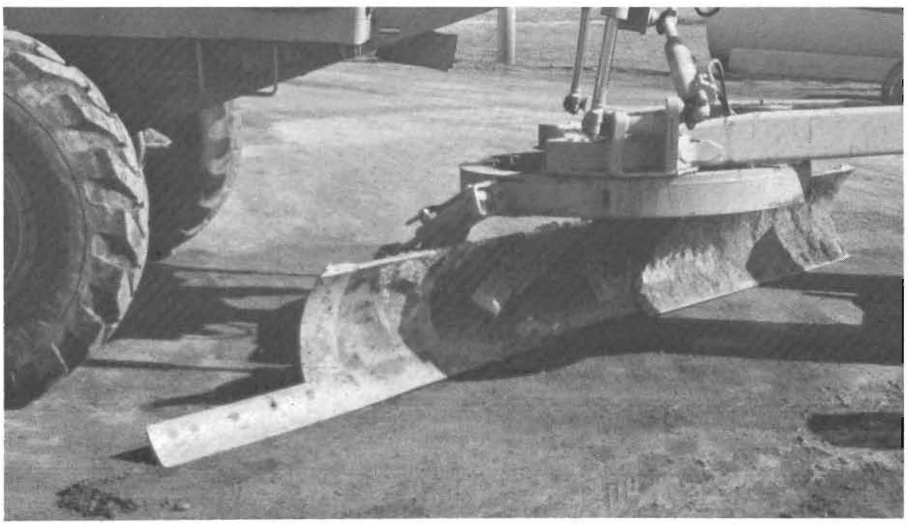


FIGURE 5 Close-up of offset blade.

holes drilled in the maintainer's frame (Figs. 6-7). Note also the hitch and the toolbox which have been added to the framework.

FIGURE 6 The framework protecting the fuel tank.

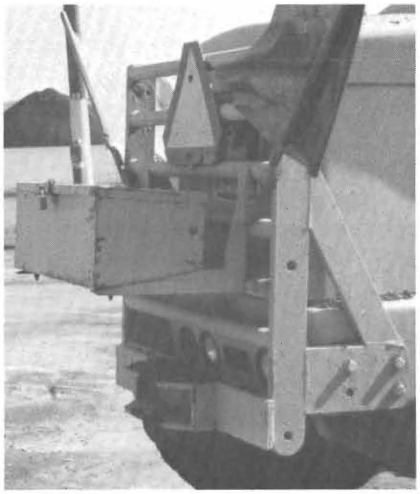


FIGURE 7 Note toolbox and hitch mounted on the framework.

T2 STS (Tex-an) number has CHANGED.

The NEW PREFIX IS 241.

PRODUCT EVALUATION

by Rick Norwood
Research and Development Administrator

Since the Department is interested in new developments in products and materials, and pursues a vigorous program of testing and evaluation, where does one go to find out what's going on?

Until the culmination of two recent developments, the answer to that question was buried in the files of several Divisions and Districts. There existed no centralized storehouse of the data, and no systematic method for its dispersal.

In March of 1986, the Department formed a new Product Evaluation Committee (PEC) comprised of members from four divisions; Equipment and Procurement (D-4), Materials and Tests (D-9), Transportation Planning (D-10) and Safety and Maintenance Operations (D-18). The members are mid-level managers responsible for product evaluation within their own Divisions, and therefore are interested in developing a more organized, coordinated and visible system for evaluating products.

What became evident very early to the PEC was that there is a lot of product evaluation going on in the Department under other names.

New materials and methods are being evaluated all over the state under the Federal Highway Administration's (FHWA) National Experimental Evaluation Program (NEEP). When a District's construction plan contains a feature which the FHWA views as experimental, the District is required to develop a work plan to analyze and report on the effectiveness of the experimental feature. D-10 monitors this program and coordinates preparation of the reports.

Many Districts are pursuing their own investigations. D-9 conducts extensive testing of new materials, D-4 evaluates new equipment and vehicles, and D-18 has an extensive program involving field testing of safety and maintenance products. The Department's Cooperative Research Program, managed by D-10, evaluates and field tests many new materials, as well.

The first development was the formation of the PEC whose main goals are:

1. To provide a systematic method for evaluating products;

2. To maintain a centralized data base of products evaluated and being evaluated;

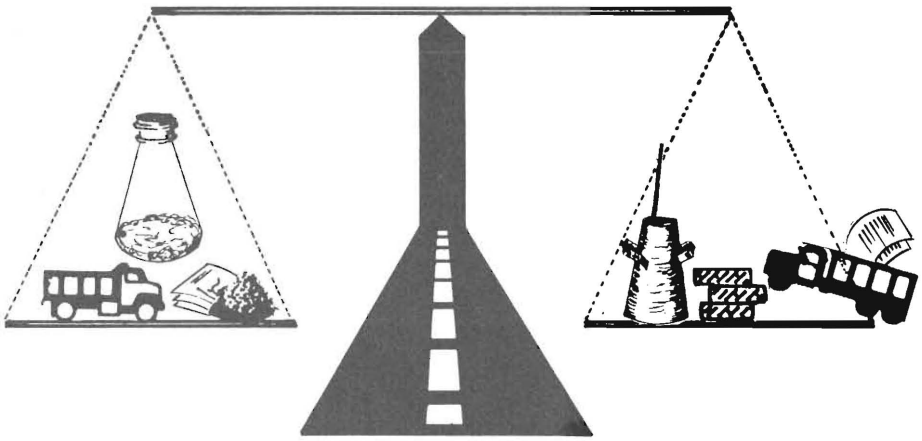
3. To assure that product information is disseminated and that it is easily available.

Each of these goals is based on the PEC's basic philosophy of providing assistance to the Districts.

Goal 1: Let's Have a System!

The first goal is in response to the Districts' need for a satisfactory way to handle vendors who are selling products. When faced with a vendor, one immediately wonders: "Who else in the Department has looked at this product?" and "Is this new product really worth my time, or is it just the same old snake oil?"

A revised product description form now requires the vendor to explain the product in detail. This form is the first step in getting the product into the evaluation system. If a District chooses to utilize the system, the District's only responsibility is to provide the vendor with the form. The vendor is responsible for filling the form out and getting it to the PEC. When the PEC receives the vendor's form, the committee begins the consideration process, keeping the vendor informed at each stage. This system is designed to support and assist the Districts in handling repeated calls from vendors. It also provides for a systematic



WEIGHING THE PRODUCTS

review of all products offered. The PEC meets once a month, so disposition of the product and feedback to the vendor is timely.

Goal 2: Let's Make Info Retrieval Easy!

The second goal of maintaining a data base of products evaluated is an obvious and essential part of the program. The PEC, at this point, is attempting to collect information on as many products which have been, or are being, evaluated across the state. This information will be stored in a data base on the Department's mainframe in Austin. The data base is a subfile of the larger Technology Transfer System (TTS) which will begin a phased implementation to the Districts, through Automation Division (D-19)'s DISOSS system, sometime in the autumn of 1987. However, information is already available from the PEC on past and current product evaluations.

Goal 3: Let's Keep Folks Posted on What's Happening!

The final goal, that of disseminating the information and, maybe more important, making it easily available, is being approached from several directions:

1. *The PEC's "Working File" of Products*

The PEC maintains a "working file" of products under evaluation which is updated monthly at PEC meetings. The file also contains products evaluated in past years. The committee has entered this file onto a microcomputer data base for easy searching and maintenance. Though some information on past evaluations is incomplete, the information in this file represents important documentation of the Department's efforts in this area. This file is available from the PEC.

2. *The Research Publication Process*

Many products evaluated under the Department's Cooperative Research Program are being included on the PEC's working file. Results of those evaluations are published in research reports which are advertised in the Department's ***RESEARCH DIGEST.*** Evaluations performed by Districts and Divisions may be published by D-10 as ***INFORMATION EXCHANGE REPORTS*** or in our newsletter, the ***TECHNICAL QUARTERLY*** or as an ***INNOVATIONS*** flyer. For further information regarding these publications, or the research program, contact D-10 Research at 241-7403 (512/465-7403).

3. *The Technology Transfer System (TTS)*

Currently the Technology Transfer T^2 Branch of the D-10 Research Section is working closely with D-19 to develop a comprehensive data base of research information for Departmental access and use. This data base contains several subfiles, one of which is the products evaluated by the Department. This file will be maintained by T^2 through input from the PEC.

As discussed earlier, by use of keyword searching on their remote terminals, Districts and Division will have access to a wide range of research and technical information, including product evaluation information.

For Further Information....

1. *On using the PEC Process* If a vendor requests your review of his product, you may elect to use the PEC's Product Evaluation Form. This will save you time and uncertainty in dealing with the myriad of products being offered. Copies of the PEC form are available by writing to:

Mr. R.E. Flaherty
State Dept. of Highways & Public Transportation
Equipment & Procurement Division
11th & Brazos
Austin, Texas 78701-2483

2. *On Product Information* Further information on the product evaluation process, or on products currently being evaluated, is available by writing to:

Mr. Al Luedecke
State Dept. of Highways & Public Transportation
Attn: D-10 Research Section
P.O. Box 5051
Austin, Texas 78763-5051

or calling STS at 241-7403 (512/465-7403).

BROWNWOOD'S BOMAG MPH 100 RECLAIMER

by Steven Golding and Kathleen Jones
D-10 Research Section

Most districts have a number of farm-to-market roads in the 20- to 30-year-old range. These FM's are near the end of their life cycle. Many are being subjected to more and heavier traffic than they were designed to carry. Some are beginning to fail in places. With the current widespread economic problems, districts don't have sufficient resources to reconstruct their entire network of FM roads. There is a need for an effective, economical method of repairing short sections base failures on FM roads. In the last two years, four districts, Abilene (District 8), Amarillo (District 4), Brownwood (District 23), and Corpus Christi (District 16) have purchased Bomag MPH 100R reclaimers for this purpose (Fig.1). Several other districts, including

FIGURE 1 The Bomag MPH 100.

Lufkin (District 11) and Odessa (District 6), have had experience with reclaimers/ pulverizers made by Bomag, Caterpillar, Wirtgen and other manufacturers through contract work. These pulverizer/ reclaimers are being used to turn old, failed pavement into graded base without having to haul the old material out or bring in new stabilized base.

The districts which have purchased Bomags have been sharing them with neighboring districts. Abilene purchased a Bomag over a year and a half ago. Brownwood, on the basis of the District 4 machine, purchased one last fall. The following article details District 23's use of the Bomag reclaimer.

District 23's FM roads, for the most part, have base that can be improved by lime. The Bomag is used to pulverize individual failed pavement and base sections and at the same time mix in lime to create stabilized base. Once the base is stabilized, the lanes affected are resurfaced.

When a section of FM road has 'holes' pavement undulations that indicate base failure or has broken up in serious pattern cracking, a Brownwood maintenance supervisor can decide to use the Bomag reclaimer on it. Currently, Bill Glaze, of the special job crew, Brown Co., has learned the operation and maintenance of the Bomag in detail. He has been in charge of the Bomag jobs to date. Mr. Glaze is training two people in each county's maintenance section to use the machine.

A typical operation involves six people, two on maintainers (one of whom doubles as the Bomag's driver), two on compactors and two driving trucks (one truck for water, one for lime). First, bags of lime are placed on the old pavement surface. Even though the entire bag is placed, rather than opened and emptied, this is the slowest, most labor-intensive part of the operation. In the future, when the Bomag is used for reclaiming jobs of several miles, the District plans to use lime slurry pumped through one of the Bomag's two

FIG.2 Lime bags spaced 6 feet apart.

computer-controlled pumps. Since the riding course and base equals a depth of 6 to 8 inches, placing the bags 6 to 7 feet apart yields approximately 3 percent lime (Fig. 2). This percentage of lime seems to work well in Brownwood's soil conditions.

After the lime bags are placed, the Bomag makes a tapered cut into the pavement and is run at approximately 20 feet-per-minute. The Bomag, with its 128 carbide-tipped steel cutter teeth (Figs. 3-4), pulverizes the surface to the required depth: 7 inches for most Brownwood FM's. On this first pass, a 3500 gallon water truck is stiff-hitched to the front of the Bomag. The water truck supplies water to the spray bar above the 6½-foot cutter drum at the rate of about 20 to 25 gallons-per-minute (Fig.5). The computer-controlled pump allows precise control of the volume of water,

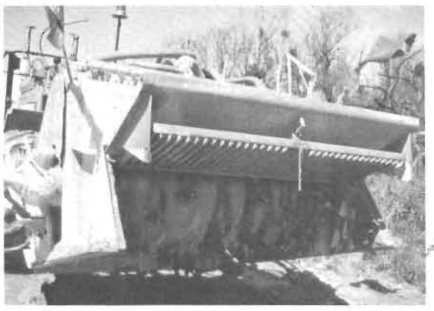


FIG.3 The spray bar and cutter drum.

independently of the speed of the Bomag. The application rate can be

FIGURE 4 The carbide-tipped teeth.

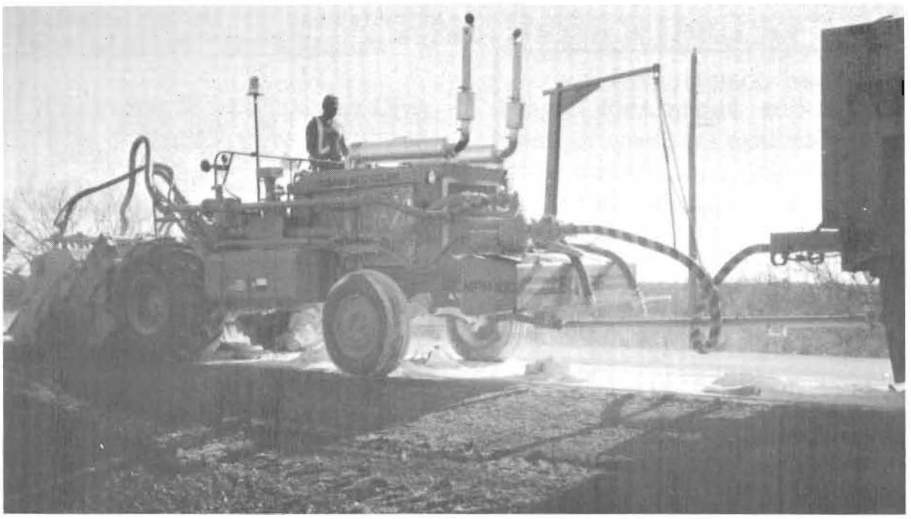


FIGURE 5 First pass, the Bomag hitched to the water truck.

FIGURE 6 Second pass, front view.

fine-tuned for varying soil conditions. The water not only aids in compaction and bonding of lime to clay particles, it cools the cutting teeth prolonging their usefulness.

The material which has spread out to the side of the Bomag is bladed back in the pulverized strip by the maintainers. The Bomag then makes a second pass, without water, at a rate of 40 to 50 feet-per-minute, further mixing and pulverizing the lime-pavement-base mixture (Fig. 6). After the second pass, all the pulverized material is windrowed out of the strip by the maintainers. The bottom is rolled with a pneumatic compactor. The pulverized material is bladed back into the strip in 3-inch lifts. Each lift is compacted with the pneumatic roller after it is placed. The top lift is finished with a steel-wheeled roller. The district is hoping that a soon-to-be-delivered vibratory steel-wheeled compactor will do the job in fewer passes.

The Bomag can pulverize faster than the maintainers can blade the material in and out on the various passes; therefore, in order to have the section stabilized, compacted and able to bear traffic by the end of the day, the length of the section is often limited to between 1000 to 2000 feet (352 lime bags at six feet apart). The Bomag is usually finished at around 1:30 p.m. At this point the teeth of the Bomag's cutter drum are cleaned and inspected. Prompt attention to and maintenance of the teeth can save time and money. Dull teeth cut more slowly and put more strain on the Bomag's engine as they try to pulverize, but putting on new teeth before they are needed not only wastes money, it also wastes time because it takes about three hours to change a set of teeth. The Brownwood Bomag, after 388 hours of use, has just received its third set of teeth. Mr. Glaze stresses the importance of proper machine maintenance to his trainees. Recently, a Bomag factory representative visited a Brownwood reclaiming job site and wrote up a report indicating that Mr. Glaze has the best run operation he has seen.

To determine how much effect the reclaiming treatment has had, a number of cores were taken from reclaimer-treated sections and adjacent nontreated sections. The laboratory analysis will be available from Mr. Robnett Martin, District 23 Maintenance Engineer.

The initial cost of a Bomag MPH 100 reclaimer is approximately $175,000. An average total cost per project can be gained from looking at the costs involved in two jobs, one on FM 504 in McCulloch County and one on SH 206 north of Coleman County. The McCulloch County job had to contend with a lot of rain; it took 18 work days to complete. More than a half-dozen patches were made ranging from 175 to 500 feet in length. Total area treated was 11,290 square yards. All patches were seven feet wide and pulverized to a depth of six to seven inches. The total cost including materials, equipment and labor was $30,000. The price per square yard was $2.65. The SH 206 job consisted of two patches pulverized to a depth of eight inches. One patch was 14 feet wide by 345 feet long and cost approximately $2.45 per square yard. The other was 8 by 630 feet and cost about $2.25 per square yard. The total cost including materials, equipment and labor was $2,600. The job took 84 person-hours to complete.

Mr. Wes Heald, District 23 Construction Engineer, has said that with the advantage of not having to tear up the already deteriorated FM roads by hauling base over them for repairs, the Bomag is "one of the best things we've got going."

Continued from page... 4

is offered, it should be noted that the following fabrics consistently provided very low permeability: Reepav T376; Biuthene; Duraglass B-65.

The Caltrans report is available on loan through the D-10 Research Library, Digest Item 87-3 #5. Call Librarian Kevin Marsh at (512) 465-7644, STS 241-7644, to order.

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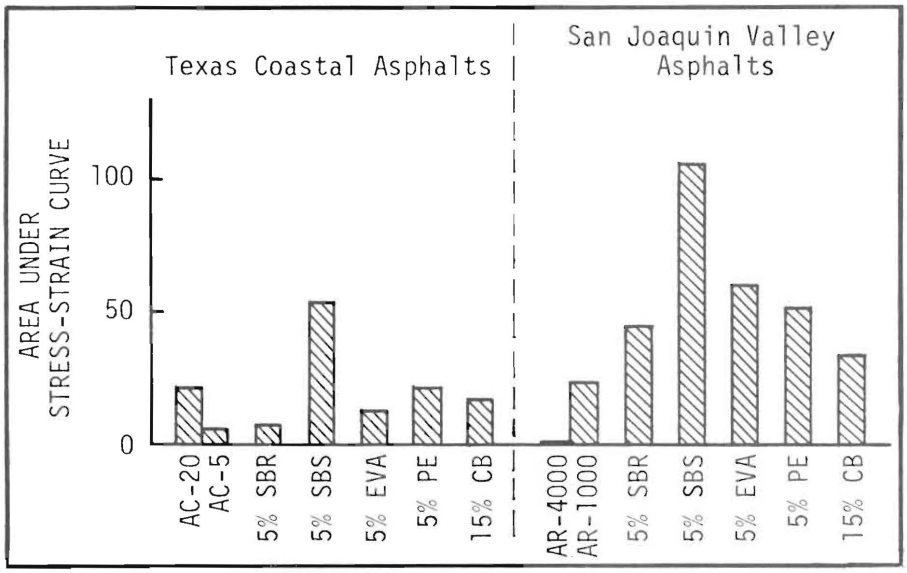

FIGURE 4 Work or energy required to rupture asphalts and blends in Force-ductility tests at 39°F and 5 cm/min.

herein will be presented in the next issue of the ***Technical Quarterly.***

FIELD TESTS

Side-by-side test pavements containing these additives have been installed in Districts 1 and 21 (Paris and Pharr). The test pavements are one-half mile in length. The dense-graded hot mix asphalt concrete surface courses are 3-inches thick. Two control sections (no additive), one 3-inches thick and one 4-inches thick, were installed at each location to aid in determining thickness equivalencies and assess the benefit-cost aspects of the additives. Several other single-additive test pavements have been installed around the state to supplement the evaluation and gain experience in the use of additives. Performance of these field trials will be evaluated to substantiate conclusions drawn from the laboratory experiments.

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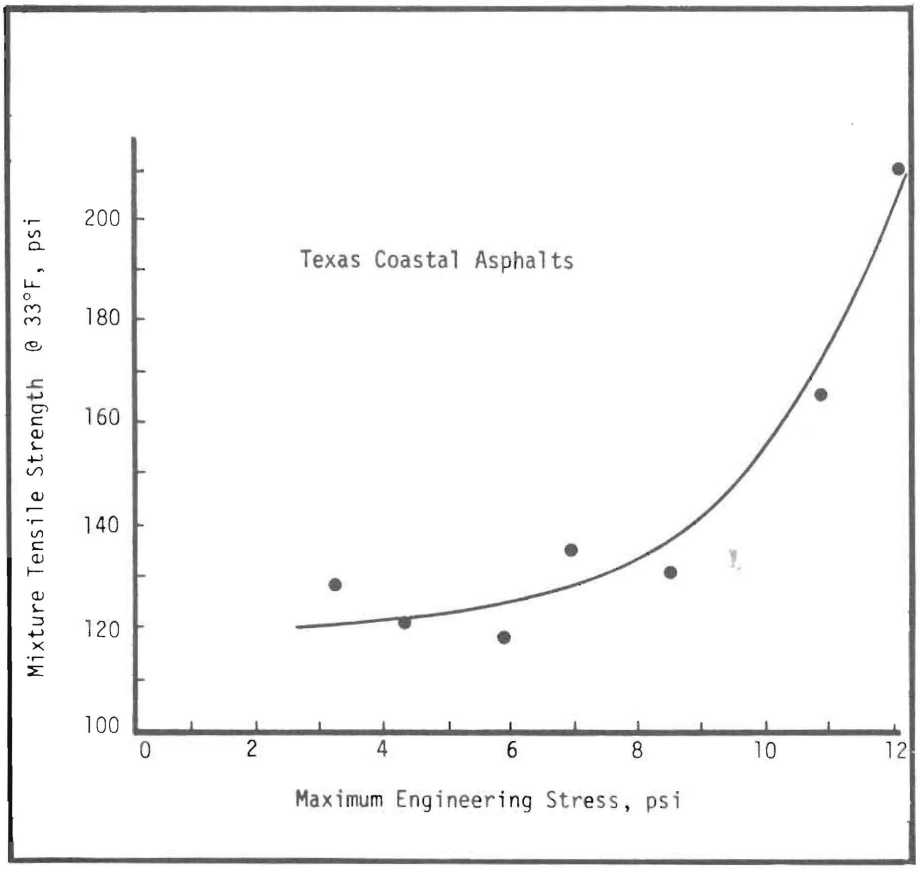

FIGURE 5 Mixture tensile strength as a function of maximum engineering stress. (Mixture tensile strength was measured at 33°F and 2 in/min using Indirect Tension test. Force-ductility data at 4°C after RTFOT were used.)

ENGINEERING SEMINARS

The Public Works Training Division is presenting three courses in July 1987. The titles are, "Basic Traffic Engineering," "Risk Management to Reduce Highway Tort Liability," and "Traffic Signal Design." D-18TS is sponsoring the courses so employees of the Texas State Department of Highways and Public Transportation (SDHPT), Texas municipalities and counties may attend at no charge.

RISK MANAGEMENT TO REDUCE HIGHWAY TORT LIABILITY, July 7-9, AUSTIN:

This course is designed to help the SDHPT, cities, counties and other agencies reduce tort liability lawsuits through the risk management process. This process includes the identification of risks, determination of an appropriate risk management method and implementation and monitoring of the method.

Persons who are responsible for design, construction and maintenance of roadways sections in both office planning and field construction, and attorneys representing governmental entities who are responsible for preparing and defending tort claims cases are the intended audience.

This three-day course will present the key concepts and principles of highway risk management. The initial two days will be devoted to introducing the risk management concepts and engineering-related topics. The final day will be devoted to lawsuit activities. Each participant will receive a reference handbook that addresses the key elements of risk management, tort liability, case law and pertinent legal references and publications. Cost to private individuals, $190.

BASIC TRAFFIC ENGINEERING, July 14-16, ABILENE:

This course is intended for technical personnel in state and local transportation agencies who need to obtain fundamental knowledge of traffic terminology, concepts and methods.

Program highlights of this three-day short course include philosophy of traffic control, signs, control markings, signal systems, traffic studies, municipal liabilities in traffic control, traffic program management, public relations in traffic, traffic accident studies, pedestrian-automobile interface and bicycle facilities. Cost to private individuals, $225.

TRAFFIC SIGNAL DESIGN, July 28-30, BEAUMONT:

This course is intended for technical and professional personnel who need training in traffic signal design. It will also help technicians and professionals primarily engaged in the day-to-day work of designing

Continued ⟶

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 STS 241-7947.

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TECHNICAL QUARTERLY

State Department of Highways and Public Transportation, Transportation Planning Div. (D-10R), Technology Transfer, Bldg.1/Flr.5, P.O. Box 5051, Austin, TX 78763-5051

Cindy King — Director

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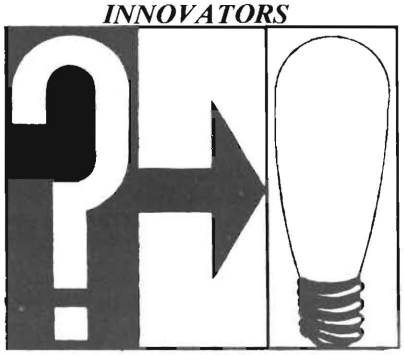
and operating traffic signals and/or traffic systems.

This three-day course includes sessions on traffic signal studies, fixed-time and actuated traffic signal timing; signal design; signal coordination; plans and specifications; and aspects of traffic control. Cost to private individuals, $225.

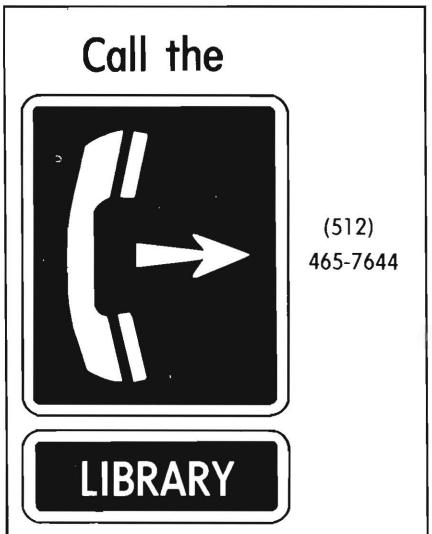
To register for these courses, call the Public Works Training Division (409) 845-2989 or (STS) 857-2989.

ATTENTION SDHPT INNOVATORS



A number of maintenance sections in every district in the State place hooks on work area signs to attach signs to the backs or sides of dump trucks to eliminate the need for a sign truck on certain types of jobs. This system is quite workable, but it could be improved. For one thing, the signs and tripod-type temporary sign supports are fairly heavy; they could cause back strain when lifted off the truck. For another, the sign face is exposed to extra wear when it's hanging from a traveling dump truck.

Some type of rack designed to fit on the side or under the bed of the dump truck would solve both problems, as well as providing space for taller, spring-loaded temporary sign supports that would bring the work signs up closer to the standard height for work zone signing. Your designs or ideas for designs for work zone sign supports and sign storage racks for dump trucks should be sent to Lewis Rhodes, State Dep't. Highways and Public Transportation, Safety and Maintenance Operations (D-18T), La Costa, (512) 465-6330, STS 258-8330.



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The D-10 Research Library can send you copies of articles and publications summarized in ***The Research Digest, Technical Quarterly*** and ***The Annual Listing***, as well as perform information and literature searches. Call Librarian Kevin Marsh with your requests.

TECHNICAL QUARTERLY

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FREEWAY CORRIDOR TRAFFIC MANAGEMENT

by Herman E. Haenel
Freeway Operations Engineer

Transportation is the nation's lifeline. The great majority of people accept this statement without much thought — taking the street and highway systems for granted. Most people do not realize the significance of this statement, but without a good transportation system, cost for delivery of goods and services will increase. Even today these cost increases are eroding each person's living standard and the economic health of Texas. Since the urban arterial system involves a major part of corporate administration and interchange of goods and services, it is a major part of the transportation system. Congestion and lack of mobility on city freeways and streets causes a significant economic loss to the state. It has been estimated that approximately five billion dollars were lost due to congestion on the urban freeway and street systems in Texas during 1985 (1,2,3). This loss is a major one to the Texas economy.

The maintenance and improvement of our urban lifeline presents a broad area for study. This [article] addresses one aspect of the subject — a virtually untapped potential which provides tremendous dividends — freeway corridor traffic management.

Freeways are planned and designed to be free flowing arterials. Many urban freeways, however, are frequently congested. Freeways in larger metropolitan areas experience congestion not only during the peak periods due to heavy traffic, but also during the off peak periods due to incidents, maintenance operations and special events. Since much of the city's commerce (movement of goods), business transactions and service activities is carried out during the off peak periods, it is as important to provide free flowing traffic during off peak as well as peak periods. A California study has shown that over one-half of the urban freeway congestion is due to nonrecurring conditions (such as occur during off peak conditions) which include incidents, freeway maintenance, holiday weekends and special events. The closing of one lane of traffic along a six lane freeway due to an accident or maintenance activity, for example, reduces the capacity in the three lane direction of travel by 50 percent (5). Lane closure places the freeway in a peak period condition during the off peak period.

Congestion has existed on urban freeways serving central business districts (CBD) of major cities for at least the last 30 years. Although we normally relate congestion to the CBD, congestion has also been spreading into the suburbs and outlying areas of these larger cities. High-rise offices, industrial parks, shopping centers and high density housing are being constructed in these areas. This trend is expected to continue. The result is that the problems of congestion are becoming metropolitan in many areas and even regional in some areas.

Urban traffic volumes are expected to increase by 40-50 percent in Texas during the next 20 years. In some urban areas, it is anticipated that this growth will be at least 80 percent above current traffic volumes. Even with increased freeway reconstruction, it will not be possible to keep up with the increasing traffic demand.

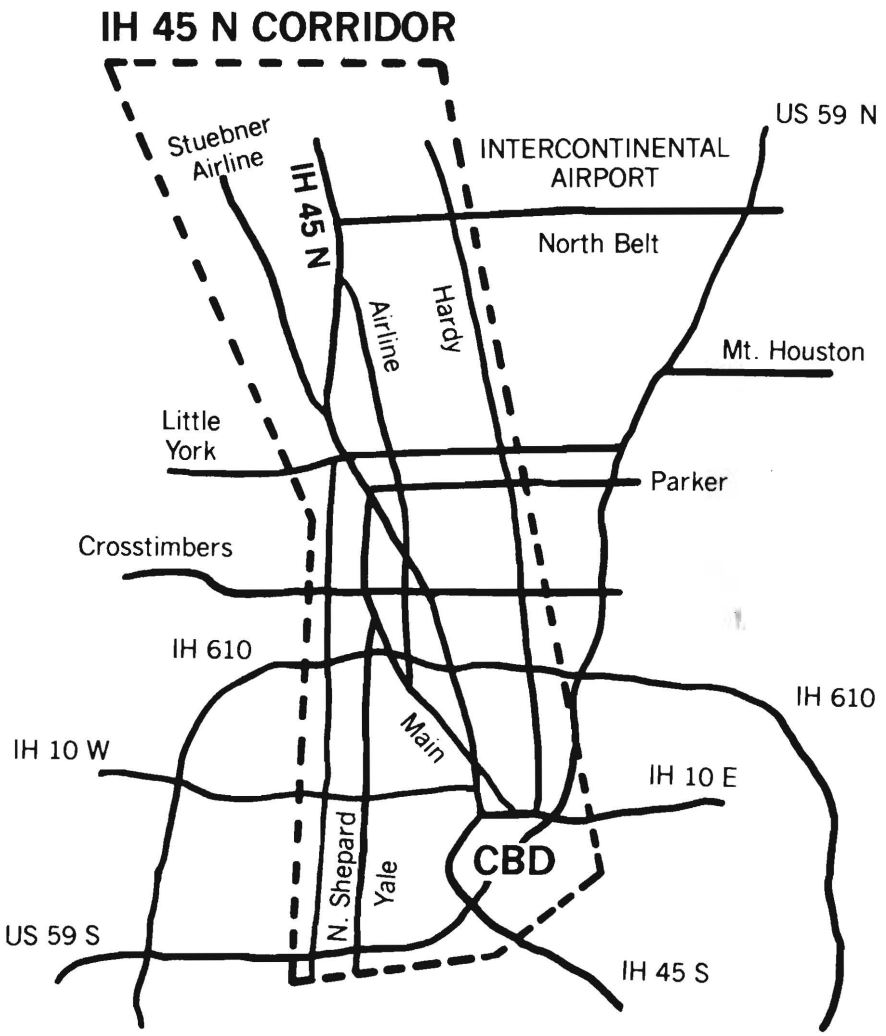

FIGURE 1 Location of IH-45N freeway corridor, Houston, Texas.

There is a need to achieve the optimum operation of a freeway and its parallel corridor street system in conjunction with freeway reconstruction to further meet the problems which future traffic demand will bring. This optimum operation can be achieved by incorporating freeway corridor traffic management into the present generation of freeway construction and reconstruction programs. There is a tremendous investment in the combined urban freeway and corridor street system such as the I-45 North Freeway Corridor shown in Figure 1. A small added cost for traffic management will permit our obtaining the full benefits from this system.

Traffic management involves both remedial improvements for problem locations and organized real-time surveillance and control along the freeway and city streets. These include:

a. Locating bottlenecks and problem locations along the freeway corridor during both peak and off peak periods and eliminating or reducing the effects of congestion by:
   (1) providing low cost geometric improvements along freeways and streets,
   (2) controlling freeway input past the bottleneck area,
   (3) improving traffic signal operations along streets, and
   (4) diverting traffic as needed;

b. Providing rapid movement of public transportation and other high occupancy vehicle traffic along freeways and streets;

c. Managing traffic around incidents through utilization of trained personnel in conjunction with surveillance and control;

d. Removing accident-related vehicles and stalled vehicles rapidly, once they are located, from the freeway or major arterial street to assure that free flow is restored as quickly as possible;

e. Providing accident investigation sites (AIS) a distance away from the freeway main lanes for safe accident investigation;

f. Gathering traffic data for use in evaluating existing traffic operations, making improvements and preparing for maintenance and construction activities, special events and anticipated incidents;

g. Managing traffic around the maintenance work zones and areas of freeway construction through utilization of trained personnel in conjunction with surveillance and control;

h. Managing traffic during special events by encouraging use of public transportation, providing trained personnel for directing traffic and providing information to motorists concerning alternate routes to the events; and

i. Involving city, county, and state traffic engineers, police enforcement personnel and public transportation agency personnel as a team to work together in all aspects of the traffic management activities mentioned above.

The freeway corridor traffic management activities listed above are provided through low cost traffic system management (TSM) projects, retiming of traffic signals, computer control, entrance ramp control, changeable message signs, television and electronic surveillance and trained personnel (police, traffic and maintenance personnel) for managing traffic.

The cost of freeway corridor traffic management is relatively low, while the benefits are high. It is estimated that the installation of freeway main lane and frontage road traffic control and surveillance installation is between $350,000 per mile and $500,000 per mile. If a high occupancy vehicle (HOV) lane is provided within the median area of the freeway, the total cost increases to between $450,000 per mile and $600,000 per mile. These costs include electronic (loop) and television surveillance, freeway and frontage road control, changeable message signs and coordination between city and state computers. A study of the reconstruction of the Houston freeways shows that the cost for freeway main lane, HOV lane and frontage road traffic control and surveillance is approximately 4 percent of the cost for the reconstruction of urban and suburban freeways. In addition to the above costs, it is estimated that improved operation along the corridor streets will cost an additional $90,000 to $150,000 per corridor mile. The operation and maintenance of the freeway corridor system (including personnel, equipment and facilities for real-time management) can be expected to be approximately 7 percent of the initial cost per year (1,9).

The benefits provided by freeway corridor traffic management are significant. As shown in Table 1, it is estimated that the overall movement of vehicles on the freeway main lanes and frontage roads during periods of recurring and nonrecurring congestion can be increased by an average of 25 percent with an average increase in freeway main lane speed of 9 mph and an average decrease in delay of 68 percent through the utilization of freeway corridor traffic management (1). This estimation includes increased throughput and reduced delay during peak period recurring congestion and off peak period nonrecurring congestion (e.g., incidents). The results of studies for existing freeway control and surveillance projects show freeway main lane accidents can be expected to be reduced an average of 31 percent (8). Based on past experience, a reversible HOV lane within the freeway median should increase the freeway person-carrying capacity by two lanes during the peak hours. For an eight lane freeway with an HOV lane, this would equate to an additional 50 percent increase in vehicle capacity in the peak direction of flow during the peak hour. Relating the increase in person throughput, and the decrease in accidents and delay to cost, the benefit-to-cost ratio calculates to be an average of 16 to 1 (1,6,7). As shown in Table 1, the utilization of at least one TSM type improvement

along city streets can also be expected to increase the efficiency of operation along the streets by 16 to 30 percent (4,8). Even greater efficiency can be obtained along a street by combining several of the city street improvements shown in Table 1. Improving the arterial street system will increase the utilization of the streets for both long and short distance trips, thereby reducing the demand on the freeway system at entrance and exit points. These arterial street improvements will also provide additional capacity when traffic is diverted from the freeway during periods of nonrecurring congestion.

Freeway traffic management is being provided on a fully integrated system basis in Los Angeles, Chicago, Long Island, New York, Detroit, Minneapolis and Seattle. As traffic conditions have worsened in Texas, the Texas State Department of Highways and Public Transportation (SDHPT) and the cities have increased their activities toward the development of fully integrated freeway corridor management systems in the following areas:

a. Ramp meter control has been installed at 120 entrance ramps;

b. Additional lanes have been provided along freeways and streets through the combination of narrow lanes, use of freeway shoulders and street parking lanes;

c. Freeway traffic management programs are being formulated in several urban Districts (e.g., the Fort Worth District has developed a 20-year metropolitan wide plan and the Houston District is developing a similar plan);

d. Traffic management teams have been organized in 12 urban districts. These teams consist of personnel from city, county, state and public transportation organizations;

e. Close city/state working relations have developed in designing systems for the future incorporation of freeway control and surveillance systems in Houston, Fort Worth, Austin, El Paso and Corpus Christi;

f. Loop detectors and conduits are being included in freeway reconstruction projects;

g. A flexible freeway corridor surveillance and control system, which is known as PEGASUS (PEople, Goods And Services Urban System), is being developed by the State. This system consists of a modular set of computer and communications equipment and a group of software models which can be combined to function in any future city/site freeway corridor traffic management system;

h. Initial development of work for obtaining combined city/state central control centers, such as that shown in Figure 2, has been carried out in several cities. These control centers will permit city and state (and public transportation) personnel to work together in managing traffic from a central location within a city;

i. Provisions have been made for handling traffic along high occupancy vehicle lanes;

j. Closer coordination between traffic, design, construction and maintenance personnel has been achieved for handling traffic through maintenance and construction work zones;

k. Closer coordination between

TABLE 1 Benefits obtained through freeway corridor traffic management.

Freeway*	
Increase in Main Lane and Frontage Road Flow (Avg.)[1]	25 %
Increase in Speed (Avg.)[1]	9 mph
Reduction in Accidents (Avg.)[8]	31 %
Reduction in Minute-Miles of Congested Travel (Avg.)[5]	68 %
Benefit to Cost (Avg.)[1,6,7]	16 to 1
High Occupancy Vehicle Lane	
Passenger Movement on I-45N Transitway in Houston [10]	7,250 passenger per peak period (equivalent of two lanes of freeway in one direction during each peak hour) with savings of 566,000 passenger hours of delay (equivalent of 453,000 vehicle hours of delay) per year.
City Streets	
Computer Control with Timing Optimization[4]	
a. Increase in Speed (Avg.) for Interconnection of Pretimed Signals	25 %
b. Increase in Speed (Avg.) for Interconnection of Traffic Actuated Signals	16 %
Improve Signal Timing for Pretimed Interconnected Signals[4]	
a. Increase in Speed (Avg.)	17.5 %
Street Widening[8]	
a. Increase in Speed (Avg.)	30 %
b. Reduction in Delay (Avg.)	40 %
Addition of Turning Lanes[8]	
a. Increase in Speed (Avg.)	10 mph
One-Way Network[8]	
a. Increase in Speed	18 to 25 %
b. Reduction in Vehicle Delay (Avg.)	30 %
Addition of Bus Bays[8]	
a. Increase in Speed	4-5 %
b. Reduction in Vehicle Delay (Avg.)	7 %
Bus Travel Time Saved for Transit Priority Signal Techniques (Avg.)[8]	40 sec/mile

* Improvements shown do not include the addition of main lanes developed through shoulder and narrow lane applications.

traffic and design personnel has been achieved for obtaining improved geometric, guide sign and pavement marking designs.

The SDHPT and cities will continue to develop the freeway corridor traffic management program in urban areas.

Every aspect of freeway corridor traffic management mentioned in this article will not be needed along all urban freeway corridors at present or immediately following the completion of freeway reconstruction, but some of these activities are needed along all of them. Combining needed portions of the freeway corridor traffic management system with freeway reconstruction will ensure that overall transportation planning and operation will improve, the length of the peak period and off peak congestion will decrease, the number of accidents will decrease, the total freeway corridor throughput and vehicle speed will increase and the delay to the motorist will decrease. In addition, it will be possible to achieve increased safety for maintenance and construction personnel and assure fewer frayed nerves as motorists travel the freeway corridor system. Transportation is the nation's lifeline and the implementation of freeway corridor traffic management will help keep the lifeline intact and functioning for the overall benefit of the Texas economy and the safety and well being of all its citizens.

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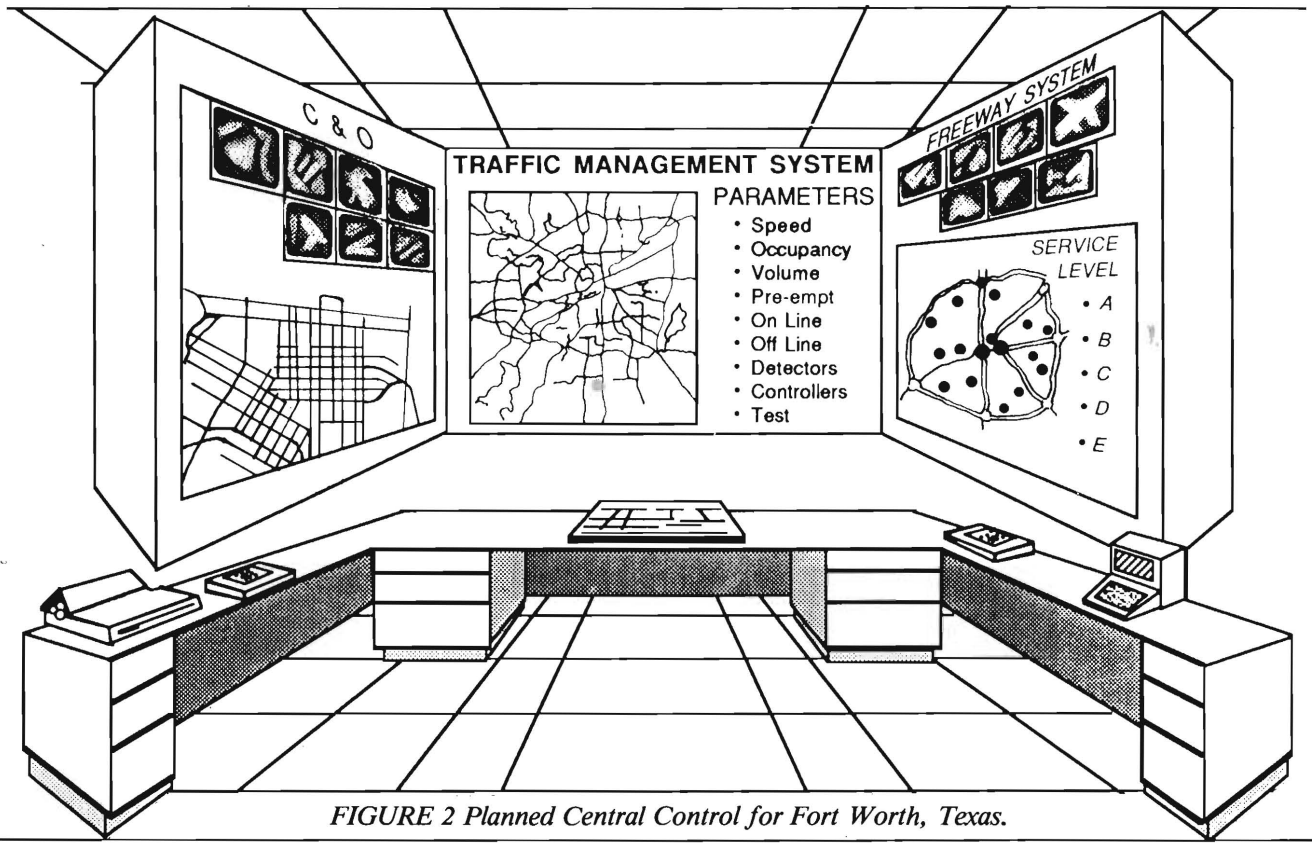

FIGURE 2 Planned Central Control for Fort Worth, Texas.