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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

PROFILOGRAPHS AND CONSTRUCTION QUALITY

by John V. Moser in cooperation with Jon G. Whitney and John P. Hutto
District 20

Knowing how rough a pavement is after it is newly placed or rehabilitated is important. This initial roughness is a primary factor in figuring the service life of the pavement. A rough pavement results in negative public feeling, higher user costs and earlier rehabilitation requirements. Although the present Surface Dynamics Profilometer is a good device for obtaining accurate road roughness profiles, its equipment investment and operating costs are high. Using it for construction sites all over the state is a difficult, economically impractical task. A rapid, simple, inexpensive method which can be correlated to the Present Serviceability Index (PSI) as given by the Surface Dynamics Profilometer would be most desirable. With these criteria in mind, Beaumont District (District 20) decided to use a California-style profilograph on two rigid pavement projects. The profilograph correlates well with the SD Profilometer, is less expensive than most currently used roughness measuring devices, is easy to understand, has low operating costs and requires no special skills from the operator *(1)*. Furthermore, it can be used to check PCC pavement the day after the concrete has been poured; a roughness-measuring vehicle must wait for a minimum of seven days. Waiting seven days to check the initial paving operation can lead to seven days of paving problems, whereas the profilograph can detect many roughness problems before another pour is made.

Paving operations are in progress

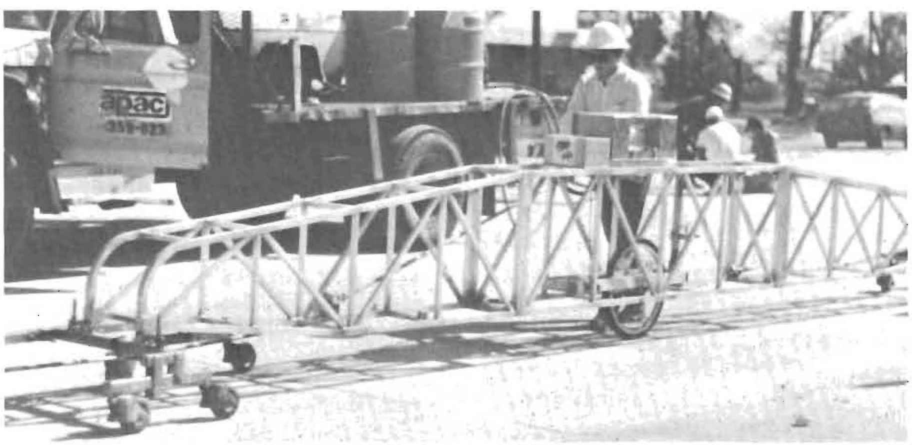

FIGURE 1: California-style profilograph used in District 20.

INSIDE...

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on two large projects within District 20. Project MA-F 426(21), Control 177-3-62, US 59, Liberty County is 219,140 sq. yd. of 12-inch concrete paving and Project F 312(10), Control 0028-07-043, US 90, Jefferson County is 164,569 sq. yd. of 12-inch concrete paving. The two current projects did not have specification requirements for the profilograph, but the project personnel found that the machine proved very useful in checking pavement to insure an acceptable riding surface. A number of times the paving production was having problems that would not have been evident without the use of the profilograph.

The California-style profilograph is a 25-foot, rolling straightedge made of lightweight aluminum which is supported by six wheels on both ends, and has a bicycle-type tire in the center for the recording wheel. The profilograph is carried in three 8-foot 4-inch sections on a trailer. It can be set up in 10 minutes by two people. The machine is hand propelled and only requires one person for its operation (Fig. 1).

Displacement of the center wheel results in vertical changes on a profile trace. The profile trace (profilogram) of a road section is then used to compute a Profile Index by counting all the scallops which extend outside the center of a .2-inch blanking band on the trace. The heights of all scallops extending outside the blanking band more than .03 of an inch and continuing for at least 2 feet (.08 inch on a 1 inch = 25 feet profilogram), are accumulated and the Profile Index is calculated in "inches per mile in excess of the blanking band." How the Profile Index relates to PSI is discussed in Research Report 569-1F, ***Profilograph Correlation Study with Present Serviceability Index.***

The US 90 project used a slipform paver at a 24-foot width. The grade control ran off of a stringline with metal rod supports at 25-foot intervals. The profilograph was recording low spots every 25 feet. The cause was insufficient tension in the grade control string (Fig. 2). A non-rolling 12-foot straightedge that was moved longitudinally along the pavement was not showing the problem. These low spots were easy to correct by tightening the grade string, but might have gone unnoticed without the aid of the profilograph. Also on this project a sag of 0.10 feet in a distance of 50 feet was detected by the profilograph, but the 12-foot straightedge only detected a maximum sag of 0.03 feet in fifty as it moved along the pavement (Figs. 3 - 4).

The Cleveland Bypass project, US 59, also used a slipform paver at a 24-foot width. The grade control for the paving was running off of a stringline with pins at 50-foot intervals. The project personnel were checking headers with a straightedge at the beginning of each pour and were not observing any problems with the riding surface; however, the profilograph was showing a dip after each header. The problem appeared to be the straightedge operation itself. This theory was confirmed when the use of different straightedge personnel by the contractor corrected the problem.

When the profilograph showed waves at midpoints of the pins, the District personnel had the contractor reduce the spacing of the pins from 50- to 25-foot intervals to correct this problem. The profilograph was used to ride the inside and outside wheel path of the riding lanes, to get an accurate idea of ride the public would experience.

The department project inspectors on these two jobs have indicated that they are very happy with the profilograph and that it is a very useful tool in providing a smoother riding surface. The use of the profilograph seems to make the contractor's personnel more aware of the pavement finish.

The State Department of Highways and Public Transportation does not have project specifications written for the use of the profilograph. Caltrans has been successful with the use of the machine and has incorporated profilograph specifications into certain paving projects. AASHTO has recently published an end-result specification for PCC pavements based on measurements with the

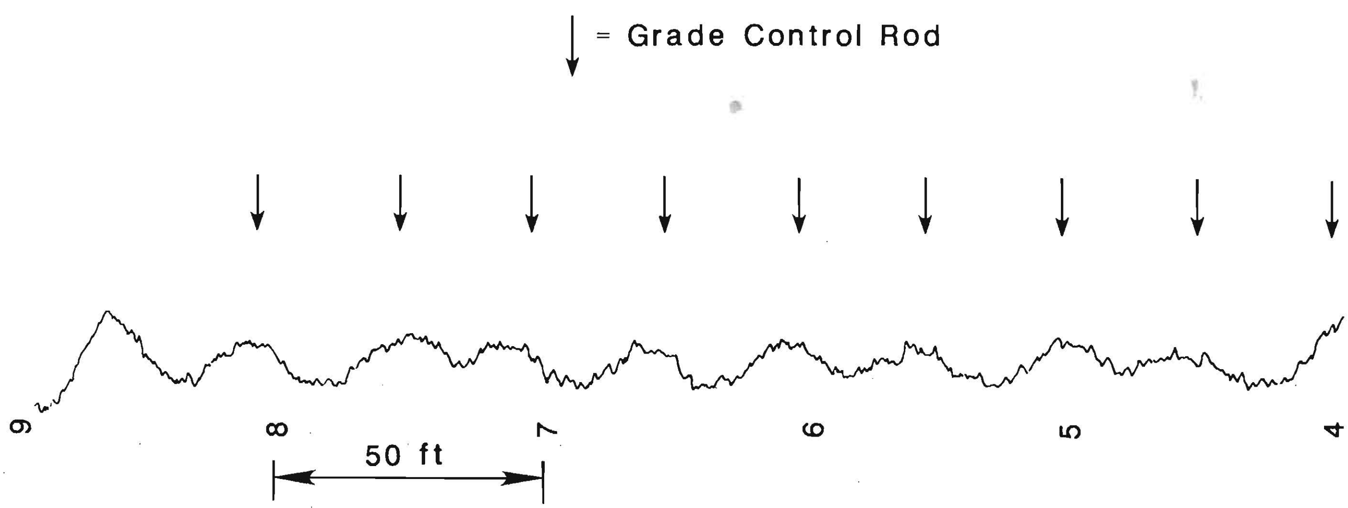

FIGURE 2: Profilograph indicates sagging string line.

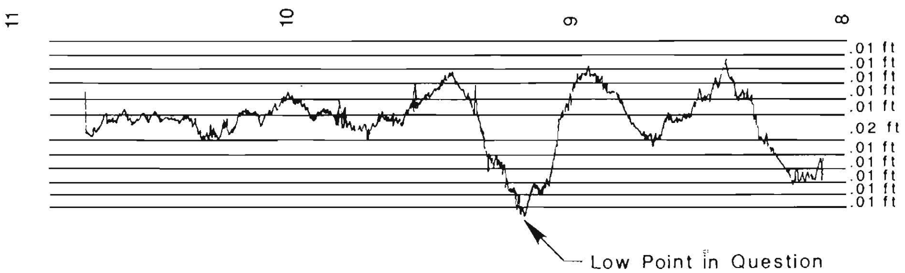

FIGURE 3: Profile trace showing low point.

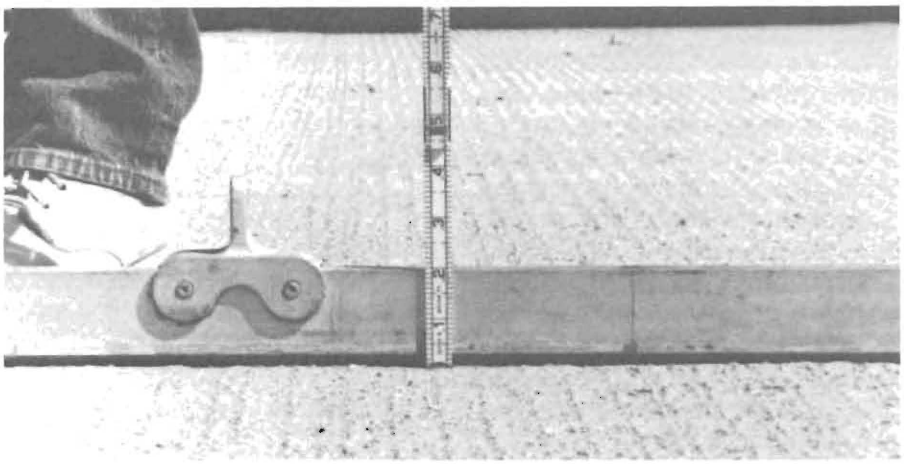

FIGURE 4: Low point confirmed.

California-style profilograph. This specification defines acceptance criteria, measuring requirements and incentive/disincentive clauses. One objective of CTR's new Research Study 1167, ***Development of Specifications for Roughness of Rigid and Flexible Pavements***, is to adapt the AASHTO specification for Texas' needs and evaluate it during field trials, hopefully in the 1988 construction season.

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TRAFFIC CONTROL: FROM CAMPFIRES TO COMPUTERS

by Ann Lancaster
Technical Writer
Texas Transportation Institute

Traffic engineers today are faced with complex urban traffic problems. These situations include everything from guiding heavy traffic volume through intersections, perhaps with the aid of police officers, to creating more effective traffic signal devices. Problems such as these, however, are not new to traffic officials. Dating back to the earliest of times, methods for effectively directing traffic have been applied.

Perhaps one of the earliest types of traffic "signal" known to man was the campfire used by prehistoric hunters. Fires enabled the hunter to find his way back home, just as the flaming brand guided a returning fisherman to safe harbor.

Historical references indicate that maintained tower lights, another means of guiding traffic, date back 2600 years ago. The most notable, and probably the tallest tower ever built, was the Pharos of Alexandria, Egypt, built in 230 B.C. Further land travel guidance was introduced when the Romans created the milestone marker. In addition, the Romans instituted the use of directional signs on their roads, which included one-way street movement. Although traffic for the first 1800 years A.D. appears to have been undertaken by regulation, devices and means of all kinds were soon in the making to enhance and coordinate traffic flow.

Eighteen-fifty through 1920 was an era of rapid innovation in traffic control in both Britain and the U.S. Starting out with modifications to railroad manually operated semaphores and colored kerosene lamps (installed at the intersection of George and Bridge Streets near the Houses of Parliament in 1868), traffic control devices progressed to the prototype of electric traffic signals. This device, conceived and built by a Salt Lake City policeman in 1912, had a four-sided wooden housing with 8 inch red and green lenses. It was mounted on a pole, wired directly into trolley power cables overhead, and was actuated by a policeman.

In 1928, the world's first fully traffic-actuated signal was installed by Charles Adler, Jr., in Baltimore. This device was described in *Public Safety* (March 1928):

> The device involves the use of a three-color automatic signal controlled by the actual traffic movement along the minor thoroughfare. Suspended at the intersection, the signal normally displays the green light for travel along the more important highway

and the red light for vehicles in the intersecting channel. These lights remain fixed until an automobile approaches along the minor road. Facing the red light, the driver of this car comes forward at slow speed. Near the corner he finds a microphone—an ordinary telephone transmitter— affixed to a post . . . . The motorist has only to sound his motor horn when he is close to the transmitter. The vibrations engendered by the blast are picked up by the microphone and communicated to the mechanism of the signal. Actuated by these vibrations, the mechanism shifts electrical circuits and changes the lights on the main artery from green to amber followed by red. The same operation causes green to appear for the crossroad . . . . The new position of the lights remains fixed for ten seconds, or for such cycle as may be predetermined by the adjustment. At the end of the cycle the lights are restored to normal . . . . *(1, p. 73-74).*

Although this method of signalling may seem a bit quaint, it paved the way for sophisticated traffic signals. One of the most successful software systems used today in signalized control of intersections is the PASSER II system. PASSER II, Progression Analysis and Signal System Evaluation Routine, is used in over 1000 operating agencies domestically and in several foreign countries to coordinate signalized intersections on major streets. Developed by the Texas Transportation Institute for the Texas State Department of Highways and Public Transportation, the program has been widely used since 1980. The latest version, PASSER II-84, is being refined in an ongoing TTI study. Edmond C. P. Chang, assistant research engineer, and his research team are working on "Enhancements to PASSER II-84," which will result in a new PASSER II-87 model.

Many traffic engineers prefer maximizing synchronized green phases (or bandwidths) using time-space diagrams. Optimizing traffic signals involves determining the proper settings of cycle length, green time interval, phase sequence, and offsets between signals. The resulting optimization depends on the relationships of distances between signalized intersections, travel speed, cycle length, roadway capacity, and side friction along the arterial. PASSER II is a user-friendly computer program for analysis control of arterial street traffic signals. It optimizes signal phase sequences with either 1) left turn first, 2) through movement first, 3) leading left, or 4) lagging left. Besides coordinating signal timing plans to maximize progression, PASSER II is also used to: 1) evaluate existing signal timing plans, and 2) investigate possible traffic engineering improvements to: a) geometric layouts, b) intersection and arterial capacity analysis, and c) traffic signal control. Future implementation of PASSER II will result in cost-effective reduction in urban arterial congestion, fuel consumption, and vehicle emissions. The modifications being made in the ongoing PASSER II enhancement study are expected to provide for even more widespread use by federal, state, county, and city transportation agencies, as well as by private consultants, when the PASSER II-87 model is released later this year.

Future strategies for controlling traffic problems are constantly evolving. Texas Transportation Institute researchers are in the forefront of developing and applying new Artificial Intelligence/Knowledge-Based Expert Systems computer technology to urban congestion management. The AI/KBES application permits engineers to interact with three elements: 1) characteristic traffic data, 2) theoretical or simulation results, and 3) the specific hypothesis for measuring the effects of traffic control system measures. The Expert System design will assist engineers in solving traffic management problems as a part of the PASSER II-84 enhancement study. Traffic engineering Expert Systems are especially useful for assisting users in solving repeatedly occurring design problems, sharing common working experience for mutual learning, and providing alternative design concepts for the future.

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BRITISH BIODEGRADABLE TEMPORARY MARKING PAINT

Britain's Department of Transport (DoT) has approved the use on all highways and roads of a temporary road marking paint system that is biodegradable and can be flushed away by a high pressure water jet without damage to the environment. The solvent-based acrylic polymer paint, trademarked Tempro 200, comes in a variety of colors and is guaranteed to stay on the ground for at least two months while meeting skid resistance and luminosity requirements.

Intended for temporary directional markings during construction periods on much-traveled roads and highways, Tempro can be applied by brush, roller, or spray. It dries in about 25 minutes and leaves a water, chemical and wear-resistant film of up to 200 microns thickness. The temporary road marking paint was developed by a division of IMI, the British chemicals conglomerate.

from *AASHTO International Transportation Observer, April 1987.*

TRANSIT FINANCIAL PERFORMANCE: COST RECOVERY AND NET COST ANALYSIS

by Ken Kaemmerle
Texas Transportation Institute

Cost recovery analysis can be used to measure the incidence of fare policy on the users of different categories of transit service within a system. This article describes the methodology used in a financial performance analysis of the Metropolitan Transit Authority of Harris County and how the results of the analysis can be used to guide policy-makers.

WHO PAYS FOR TRANSIT?

In accordance with the generally accepted principle of transportation funding in the United States, the costs of mass transit services are shared by users and the general public. In Texas, public funding for transit services largely comes from federal grants and local property or sales tax revenue. The user's share of the payment for transit service comes in the form of passenger fares. The question of what share of costs is paid by each of the two groups is answered by public policy and economics. Public policy may deem that fares be kept low in order to provide an incentive for transit use. Economic principles may dictate that fares not be raised above certain levels at which transit service will no longer be competitive with alternative transportation modes *(1)*. It is within these limits set by public policy and economic principles that transit managers must determine a schedule of fares (the tariff) that will provide the revenue required for the user share of service cost.

Beyond the question of the total amount of revenue to be raised by the farebox is the question of whether, and to what extent, fares should be differentiated according to the service provided. Most transit systems offer some form of "premium" service. The most common is express routing where during the weekday rush hours a bus travels with limited stops between the suburbs and the central business district. In almost all cases, a higher fare is charged for this service. The rationale for the higher charge is that the service is worth more. Another form of fare differentiation is the zone fare. Though not used as frequently today as in the past, the zone fare has as its objective the recovery of a greater share of costs from those who use the service more, i.e., take longer trips. The zone fare at least implicitly recognizes the principle of cost recovery based on the level of service consumption.

The concept of setting fares to recover the cost of service is attractive to policy-makers who are concerned with equitably distributing the user's share of costs. Failure to do so will result in a cross-subsidization of cost where some users are charged more in order that other users can be charged less *(2)*. Research conducted for the SDHPT examined the services and fare structure of the Metropolitan Transit Authority of Harris County (METRO) to determine the extent to which user charges covered costs *(3)*. The methodology used to analyze the METRO system is valuable not only for fare policy analysis but also for management evaluation of a system's efficiency. The methodology is described below.

COST RECOVERY ANALYSIS

Cost recovery analysis is simply a comparison of the cost of providing a service with the revenue collected from users of the service. The *cost recovery ratio,* determined by dividing revenue by cost, is the measure of comparison used in this study. A cost recovery ratio of 1.0 represents a service for which revenue exactly covers the service cost. *Cost recovery ratio* should not be confused with the *operating ratio.* The latter is a ratio of cost to revenue, as opposed to revenue to cost, and only operating costs are included.

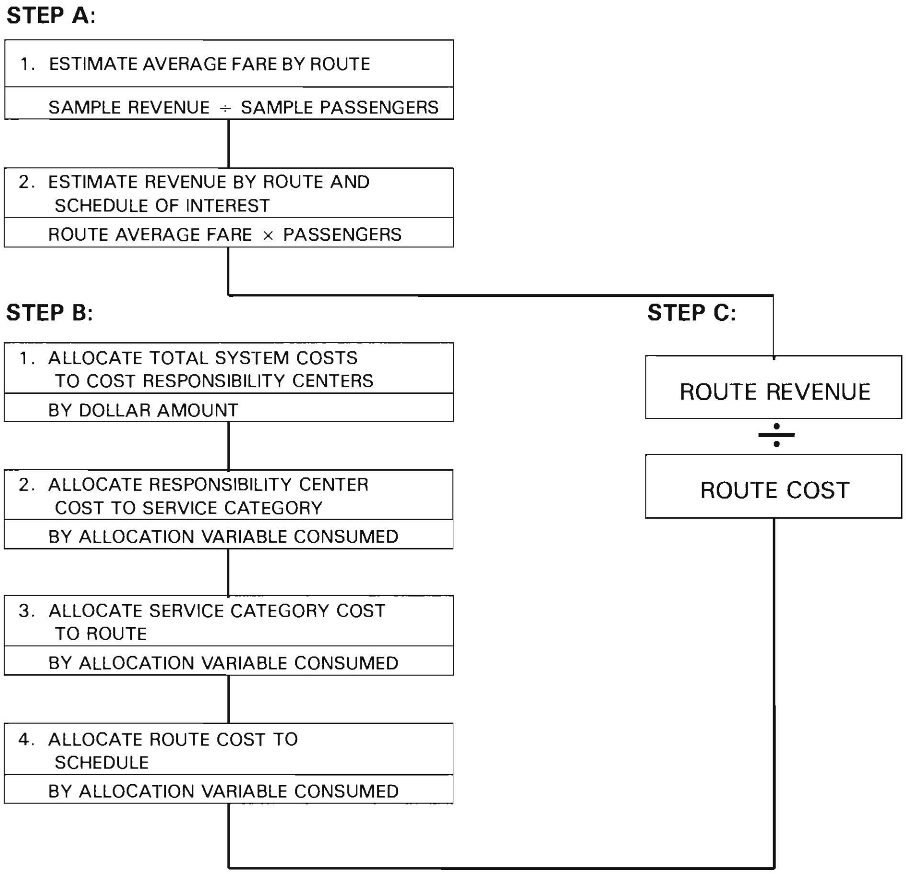
A cost recovery ratio can be calculated for an entire transit system, service elements of the system (local service, express service, etc.), individual routes, runs or even trips. Cost recovery ratios can also be determined for different schedules (base period, peak period, evening, etc.). Necessary for the analysis are cost and revenues for the unit of service which is being analyzed. This information is provided by a cost allocation methodology and a revenue reporting system. Perhaps somewhat surprisingly, few transit systems collect and analyze cost and revenue data at less than the system level.

Cost Allocation

Cost allocation methodologies are well described in the literature *(4)*. A fully allocated cost methodology assigns both fixed and variable costs to some increment of the service. The most common allocation model assigns variable costs by either miles or hours, and fixed costs by the number of peak hour buses. Maintenance costs, for example, might be allocated by the number of miles operated by the fleet. Fixed administrative costs, on the other hand, could be allocated by peak vehicles since they tend not to vary with the number of miles the existing fleet operates.

The METRO cost allocation methodology is extremely detailed. Responsibility center costs are allocated to one of eight service categories by one or more of nine

FIGURE 1: Cost recovery analysis – steps in determining a route cost recovery ratio.



variables. For example, expenses associated with the responsibility center "driver's wages" are allocated to four service categories (local, METRO park and ride, contract park and ride, and charter), by two allocation variables (vehicle hours and pay hours). The result of this detailed cost allocation is a very realistic representation or model of where expenses are incurred and how large the expenses are. However, the METRO allocation methodology stops after allocating costs to one of the METRO service categories. There is no further allocation of costs to routes or schedules.

For the analysis discussed in this article it was necessary, therefore, to make a further allocation of costs to routes that would permit a determination of the number of peak and base schedule hours operated on each route. This was done using METRO's run and block summaries in which hours and miles by hour of the day are reported. Figure 1 shows a schematic of how costs were allocated.

Revenue Allocation

Revenue must be matched with the cost expended in producing the service under consideration. If the level of analysis is for a specific route over a three - month period, then the revenue collected on that route for that period must be determined. Many transit systems record revenue by route which greatly simplifies the analysis. If revenue-by-route data are not available, then revenue must be estimated using sample data to calculate an average fare for the route. Multiplying the average fare by the number of passengers on the route gives an estimate of route ridership.

METRO does not record revenue by route but does sample ridership by route and by fare type (adult, express, senior citizen, etc.) for one week each month. The sample data were used to estimate revenue by route. The sample data are also reported by hour of the day. This made it very convenient to estimate route revenue by peak and by base schedules. The revenue allocation process is also shown in Figure 1.

Treatment of Capital Costs

Analysts differ in opinion on whether capital costs should be included in cost recovery analysis. This analysis has included capital costs since the capital cost associated with transitways and park-and-ride facilities represent an element in the cost of METRO park-and-ride service not present in local service. Capital costs have been allocated by the number of weekday peak buses used on a route. The following formula was used to allocate capital cost between the peak and base periods.

$$PVF = \frac{PVI}{PV} + \left(\frac{PVH}{TVH} \times \frac{BV}{PV}\right)$$

$$BVF = \frac{BVH}{TVH} \div \frac{BV}{PV}$$

where: PVF = peak vehicle factor
BVF = base vehicle factor
PVI = peak vehicle increment (additional vehicles over base)
PV = number of peak vehicles
BV = number of base vehicles
PVH = peak vehicle hours
TVH = total vehicle hours

The formula basically assigns an extra increment of cost to the peak period for the additional investment in vehicles required for peak service.

Net Cost per Revenue Passenger

The cost recovery ratio permits a comparison of the cost efficiency of service on different routes. Routes with the same ratios but different costs and different fare structures can be said to be equally efficient in terms of cost recovery. What the ratio does not tell policy-makers is whether routes are equally effective in providing service for the comparable levels of public investment. Therefore, a second measure of a route's financial performance has been created.

Public investment in transit service can be defined as the net cost of service, i.e., total cost less passenger revenue. When net service costs are divided by the number of passengers, the resulting value is a measure of the public's cost per passenger. This has been defined in this study as the *net cost per revenue passenger*. To understand the significance of this measure, consider two routes. Route A has a daily cost of $1,000 and carries 1,000 passengers, each paying a fare of $0.50. Route B has a daily cost of $500 and also carries 1,000 passengers paying a fare of $0.25. Both routes have cost recovery ratios of 0.5. However, the net cost per revenue passenger on route A is $0.50 and on route B, $0.25. Assuming that the amount of public funding for service is relatively fixed, additional service with the characteristics of route A will deplete the public funding resources more rapidly.

RESULTS OF METRO ROUTE ANALYSIS

Weekday cost and revenue data for the METRO system during the first quarter of fiscal year 1986 were used in the study. Revenue and cost were determined as described in the preceding paragraphs and were analyzed on a route-by-route basis for three major service categories: local, express and park-and-ride service. The results of the analysis are summarized in Tables 1 and 2.

The analysis of METRO routes shows that park-and-ride routes cover a larger percentage of their operating costs than do either local or express routes. This is true for each of the schedules identified although there is very little park-and-ride and express service during the base schedule periods. Peak park-and-ride cost per hour was $133 compared to $72 for local service. The local fare during the study period was $0.60 while park-and-ride fares averaged $1.60. The cost allocation procedure found that despite the higher cost of park-and-ride service, the costs were offset by higher fares.

The results of the analysis of net cost-per-revenue passenger provide a different picture of the premium services. The average cost to the public of a trip taken on a local route was $2.16 and slightly less during the peak period. During the peak period the cost to the public of a transit trip on either an express or park-and-ride route was twice that of the local service cost.

RELEVANCE OF THE ANALYSIS

The results of the analysis of METRO transit service provide important information to transit managers and policy-makers. These results *must* be reviewed in light of local policies which dictate service levels and fare structures. METRO, for example, has a system-wide cost recovery objective. Were that policy objective to require that each component of the system recover a comparable percentage of service costs, local fares would have to be increased or services reduced. Alternatively, should policy-makers choose to equalize the public's share of cost for all services, the park-and-ride and express fares would have to be increased substantially. Cost recovery analysis does not answer these difficult policy questions. However, the analysis does identify the incidence of fare policies which is a valuable and necessary piece of information in the policy-making process.

TABLE 1: Cost recovery ratios for METRO Services, 1st Quarter FY 1986 weekdays.

(in percentages)

Service	All Schedules	Peak Schedule	Base Schedule
Local	17.67	18.35	16.99
Express	15.28	13.80	22.27
Park & Ride	26.55	25.49	41.57
All	20.11	20.02	17.82

TABLE 2: Net cost-per-revenue passenger, 1st quarter FY 1986 weekdays.

(in dollars)

Service	All Schedules	Peak Schedule	Base Schedule
Local	2.16	2.01	2.33
Express	3.86	4.30	2.54
Park & Ride	4.19	4.22	3.80
All	2.33	2.45	2.36

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INNOVATIONS STREAMLINE CRACK SEALING

by Bill Stark
Highway Maintenance Supervisor
Oregon Highway Division

In the past, our rubberized asphalt crack sealing operations have included a truck with driver pulling the melter, a man operating the applicator wand filling the cracks, and a third man following behind striking off the excess material with a squeegee. I have never been very satisfied with the results of using the squeegee. This is mostly because there is always waste, and the squeegee spreads the product out beyond where it is needed.

So, a few years ago we devised a different method of striking off the seal, which (1) eliminates the use of the squeegee, (2) does a better job, and (3) eliminates the need for the third man.

The key to our present method is a round disk attached to the end of our applicator wand, which takes the place of the extra man and the squeegee.

We are very pleased with the way the disk is performing. The disk will apply a band of material uniform in width and thickness over the crack. We feel this is doing a much better job of putting the product where it does the most good, and improves the work cosmetically as well.

I do not believe this item can be purchased; however, it can be made in a few minutes with a small amount of welding. First, you need a 30 degree pipe elbow. This should be the same size pipe as the wand, which will usually be 3/4-inch. Second, a proper disk is needed. We found that a conical 4-inch washer works best for us.

These are sometimes called compression washers, and are most commonly used for wooden beam construction. These can be obtained from almost any fastener supplier. To make the attachment, simply weld the elbow to the washer and thread this onto the end of the wand. If the results you get are too wide or too narrow, just vary the size of the washer.

FIG 1: Washer attached to wand.

FIG. 2: Conical washer close-up.

Another item we are using is an insulated blanket placed over the melter to hold as much heat as possible in the product overnight. The blanket has heat resistant outer coverings similar to vinyl, and a new type of heat resistant insulation sewn inside. This was made to order by a local vendor.

Along this same line, we have found that covering the exhaust vents from the propane burners with a coffee can also helps to hold the heat overnight. **Please note:** Do not cover these vents unless the burners and propane supply are turned completely off.

Some additional operator tips are to use a boom with limber springs to suspend the applicator hose, and use swivel quick fittings on both ends. This will make handling the hose and applicator a much easier chore by reducing fatigue. For further information contact Bill Stark, District 2B, Milwaukie, Oregon, (503) 280-6092.

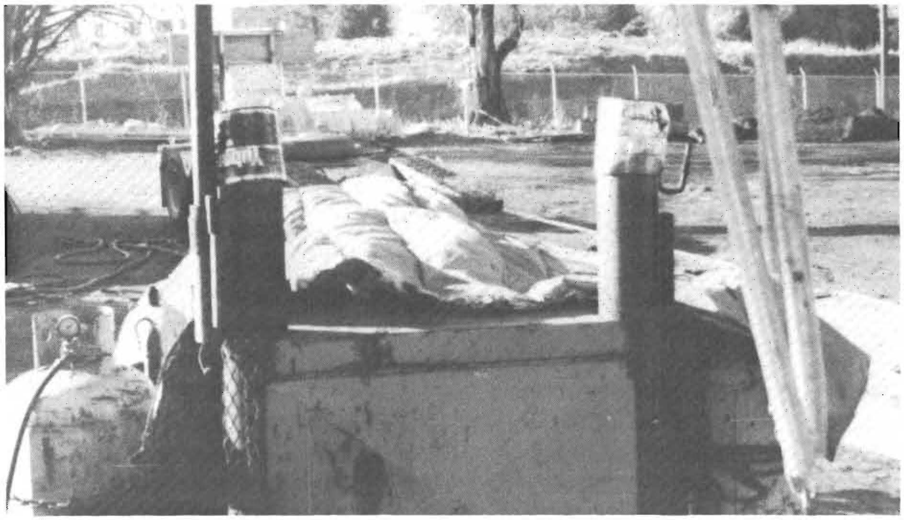

FIG. 3: Coffee cans and insulated blanket save heat.

EVALUATION OF ASPHALT ADDITIVES, PART II

by
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INTRODUCTION

*As discussed in the last issue of the **Technical Quarterly,** five asphalt additives were evaluated in comprehensive laboratory and field test programs **(1,2)** at the Texas Transportation Institute. Results were presented from tests on the asphalt-additive binders. This issue gives selected results from tests on asphalt-aggregate mixtures.*

TEST RESULTS ON ASPHALT CONCRETE MIXTURES

Mixture Preparation

The aggregate used in the mixture tests consisted of subrounded, silicious river gravel and a similar sand with limestone crusher fines added to improve stability. This aggregate blend was selected because it produces a relatively binder-sensitive mixture which accentuates the properties of the binders more than a high-stability mix.

The asphalts used in this segment of the study include Texas Coastal and San Joaquin (California) Valley products. Texas Coastal AC-20 in the control mixtures and Texas Coastal AC-5 modified with the five additives, latex, block copolymer rubber, ethylene-vinyl acetate, finely dispersed polyethylene and carbon black, were the primary binders for the mixtures. San Joaquin Valley AR-4000 in control mixtures and AR-1000 modified with additives comprised the secondary binders. The additives were incorporated into the mixtures using methods which simulate field conditions as closely as possible. For example, latex and carbon black were added to the hot asphalt-aggregate mixture and stirred for an extra one minute period during mixing; whereas, the other three additives were preblended in the asphalt cement before combining with the aggregate.

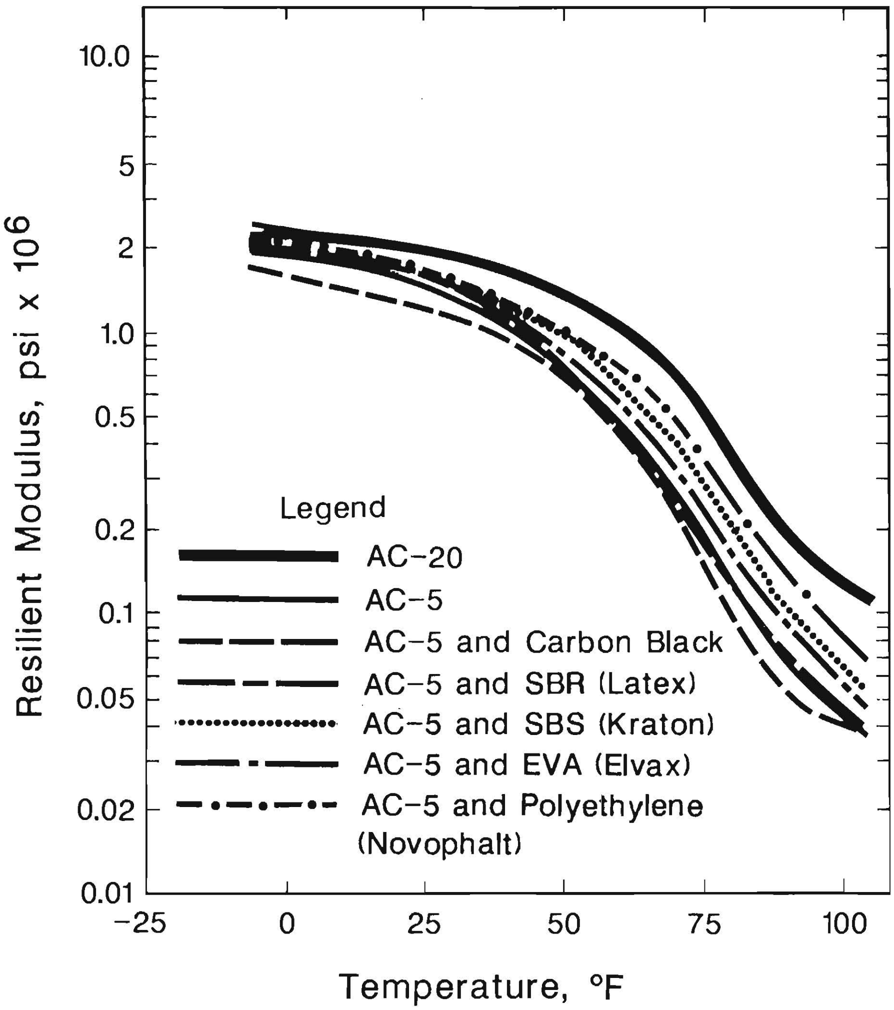


FIGURE 1: Resilient modulus as a function of temperature for river gravel mixtures containing Texas asphalts with and without additives.

Optimum binder content was determined using the Marshall method with emphasis on uniform air void content (density). The Marshall method was selected because it is much more sensitive to binder properties than the Hveem method. Optimum binder content for most of the mixtures was about 4.5 percent. Mixtures containing carbon black require a slightly higher binder content (4.75 weight percent) because the carbon-black-modified binder has a significantly higher specific gravity. Special care was exercised in an attempt to produce compacted specimens with approximately equivalent air void contents.

Basic Mixture Properties

Marshall and Hveem stability (Table 1), indirect tension (Table 2), and resilient modulus (Fig. 1) tests were performed on unmodified and modified mixtures composed of river gravel with two asphalts. No single additive demonstrated the ability to produce mixtures with consistently higher values of stability, stiffness or strength.

After collection of significant data, it was surmised that the design asphalt content selected for the latex-modified mixture with Texas Coastal asphalt was slightly higher than it should have been. As a result, the latex mixture probably exhibited lower air void content, stability and stiffness than it should have.

Moisture Resistance

The modified, accelerated Lottman *(3)* moisture treatment procedure was utilized on mixtures containing both asphalts. It appeared that, generally, the additives have little effect on moisture susceptibility of the mixtures made using the materials included in this study.

Extraction and Recovery with Additives

Asphalt concrete containing the asphalts and additives studied herein were extracted, and the binders were recovered. There were differences in the relative effectiveness of the hot (reflux) and cold (centrifugal) extraction methods. Some of the results with the San Joaquin Valley asphalts were contrary to those found for the Texas Coastal asphalts. The limited number of tests did not establish

TABLE 1: Stability of mixtures containing river gravel

Type of Mixture	Asphalt Content, percent	Air Void Content, percent	Hveem Stability	Marshall Stability	Test Flow
Texas Coastal Asphalts					
Control: AC-20	4.5	5.0	43	1600	8
Control: AC-5	4.6	4.3	43	900	9
AC-5 + 15% Microfil-8	4.8	5.5	42	900	8
AC-5 + 5% Elvax 150	4.5	4.9	46	1100	9
AC-5 + 5% Kraton D	4.5	4.6	47	1300	7
AC-5 + 5% Latex*	5.0	4.1	41	1000	10
AC-5 + 5% Novophalt	4.6	5.5	51	1300	8
San Joaquin Valley					
Control: AR-4000	4.6	4.4	49	1200	7
Control: AR-1000	4.5	4.1	48	700	6
AR-1000 + 15% Microfil-8	4.7	5.0	50	1200	7
AR-1000 + 5% Elvax 150	4.5	5.2	44	600	7
AR-1000 + 5% Kraton D	4.5	4.8	46	900	6
AR-1000 + 5% Latex*	4.5	5.1	48	800	6
AR-1000 + 5% Novophalt	4.5	5.3	46	950	5

*Latex is 30% water or 70% solids; therefore, 3.5% solids by weight of asphalt were used throughout the study.

TABLE 2: Tensile strength of mixtures made using Texas asphalt and river gravel.

	Tensile Strength, psi								
	0.02 in/min			*0.2 in/min*			*2.0 in/min*		
Type of Mixture	*25°C (77°F)*	*1°C (33°F)*	*-15°C (-26°F)*	*25°C (77°F)*	*1°C (33°F)*	*-15°C (-26°F)*	*25°C (77°F)*	*1°C (33°F)*	*-15°C (-26°F)*
Control: AC-20	*45*	*211*	*413*	*83*	*342*	*395*	*121*	*369*	*374*
Control: AC-5	*16*	*128*	*327*	*28*	*244*	*440*	*63*	*376*	*522*
AC-5 + 15% Microfil-8	*15*	*132*	*319*	*33*	*217*	*424*	*64*	*360*	*450*
AC-5 + 5% Elvax 150	*22*	*119*	*381*	*48*	*241*	*512*	*87*	*444*	*425*
AC-5 + 5% Kraton D	*27*	*136*	*404*	*54*	*300*	*472*	*112*	*428*	*502*
AC-5 + 5% Latex	*15*	*121*	*348*	*31*	*239*	*352*	*74*	*399*	*437*
AC-5 + 5% Novophalt	*28*	*167*	*393*	*58*	*329*	*444*	*119*	*436*	*387*

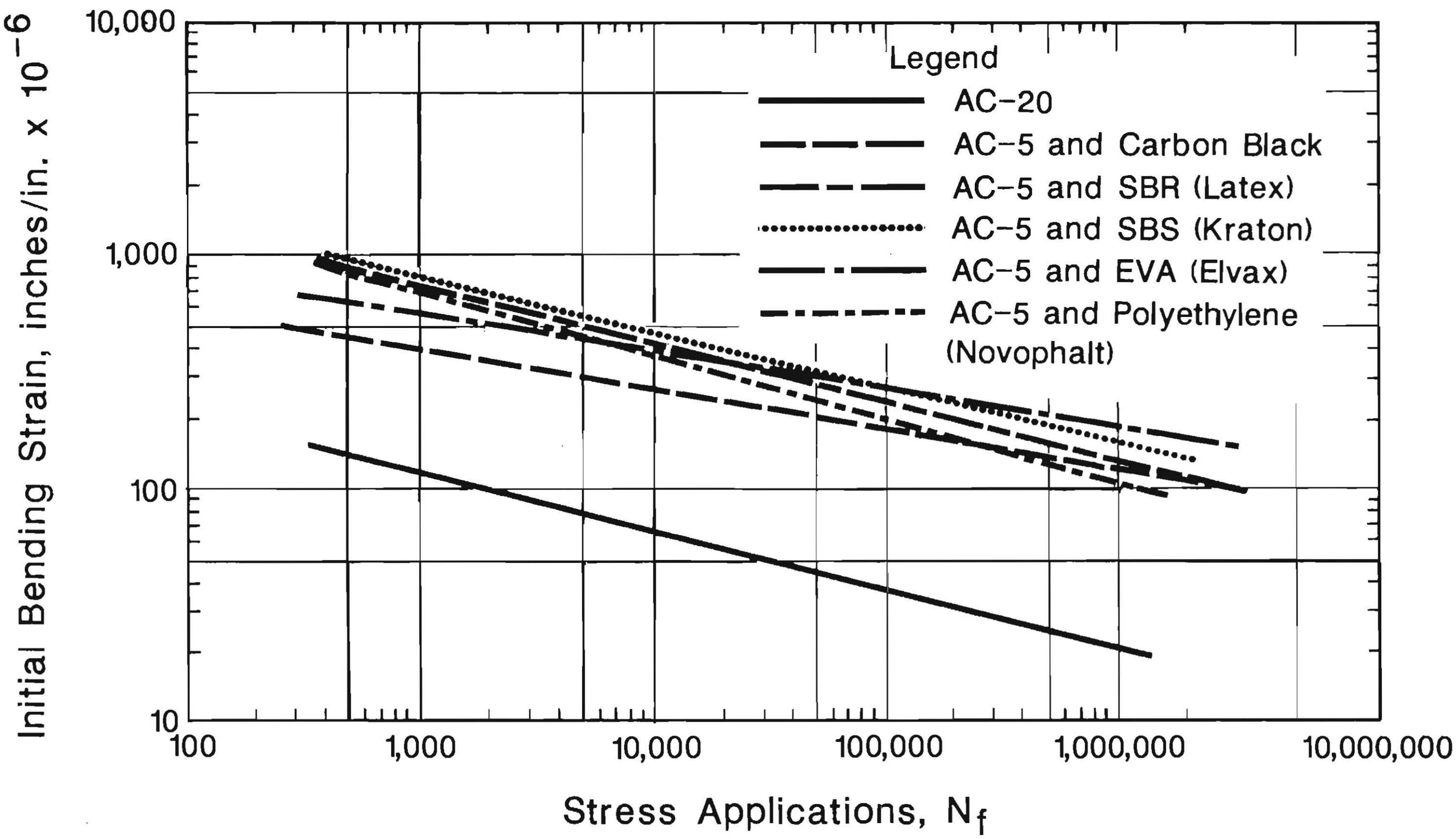


FIGURE 2: Controlled stress flexural beam fatigue results at 0°C (32°F).

whether the differences in extractability of the additives were specific to the asphalt used, or were due to other factors in the preparation and history of the asphalt concrete. Since conventional extraction methods do not remove all of an additive, data obtained for the quantity of extracted binder and for properties of the recovered binders should be used only with the realization that a substantial fraction of the additive may remain in the extracted aggregate.

Evaluation of Fatigue Cracking Potential

The potential of asphalt concrete mixtures to crack due to cyclic fatigue was evaluated using a controlled-stress flexural fatigue test which provides a reasonably simple approach to simulate traffic-induced loads. Beams 3x3x15 inches were prepared using the Cox kneading compactor. The target air void contents were achieved for all mixtures except those containing carbon black. For these beams, it was much more difficult to compact the specimens to the 6 percent air void level. Even when twice the compactive effort was applied, the air void content could only be reduced to about 7 percent. This difference in compaction is largely due to the higher mass viscosity of the carbon-black-modified mixture.

Three beams were tested at each of three stress levels (low, intermediate and high). The logarithm of the strain induced during the 200th repetition of the applied stress level was plotted versus the logarithm of the number of load cycles to failure, N_f. The 32° F data are plotted in Figure 2. Each additive/AC-5 blend produced a mixture which has statistically superior fatigue properties compared to the control mixture using AC-20 asphalt as the binder. Statistical difference is defined as when either the intercept or slope are different. Fatigue results among mixtures containing polyethylene (Novophalt), SBS (Kraton), SBR (Ultrapave) and EVA (Elvax) were not significantly different. The 200th cycle strains were substantially different among the mixtures tested at 68° F. The general trend was a substantially more flexible response for AC-5 blends containing EVA, SBS (Kraton) and SBR (latex).

Creep/Permanent Deformation Testing

Asphalt concrete cylinders 8 inches high and 4 inches in diameter were fabricated using the standard California kneading compactor for the direct compression testing program. Every effort was made to keep the air voids in the cylinders between 6 and 7 percent. Also, care was taken that the air voids should be distributed equally in the cylinders to avoid a vertical density gradient.

All creep tests were performed on a Material Test System 810 closed-loop, feedback control hydraulic tester with a controlled-environment chamber. The creep tests were performed in accordance with the Alternate Procedure II described in the VESYS Users Manual (4). Tests on two specimens each at temperatures of 40° F, 70° F, and 100° F were performed. Permanent deformation properties were calculated from the incremental static loading and the creep compliance properties from the 1,000-second response curve for each specimen.

Figure 3 presents the results of creep compliance testing at 40° and 100° F for mixtures bound with blends of Texas Coastal AC-5 with additives and the AC-20 control mixture. Polyethylene in AC-5 exhibited compliance characteristics which were statistically the same as the AC-20 control. Although the resistance of the AC-5 to high temperature deformation is greatly improved by adding polyethylene, the low temperature compliance is also reduced giving it essentially the same fracture susceptibility as the AC-20 control.

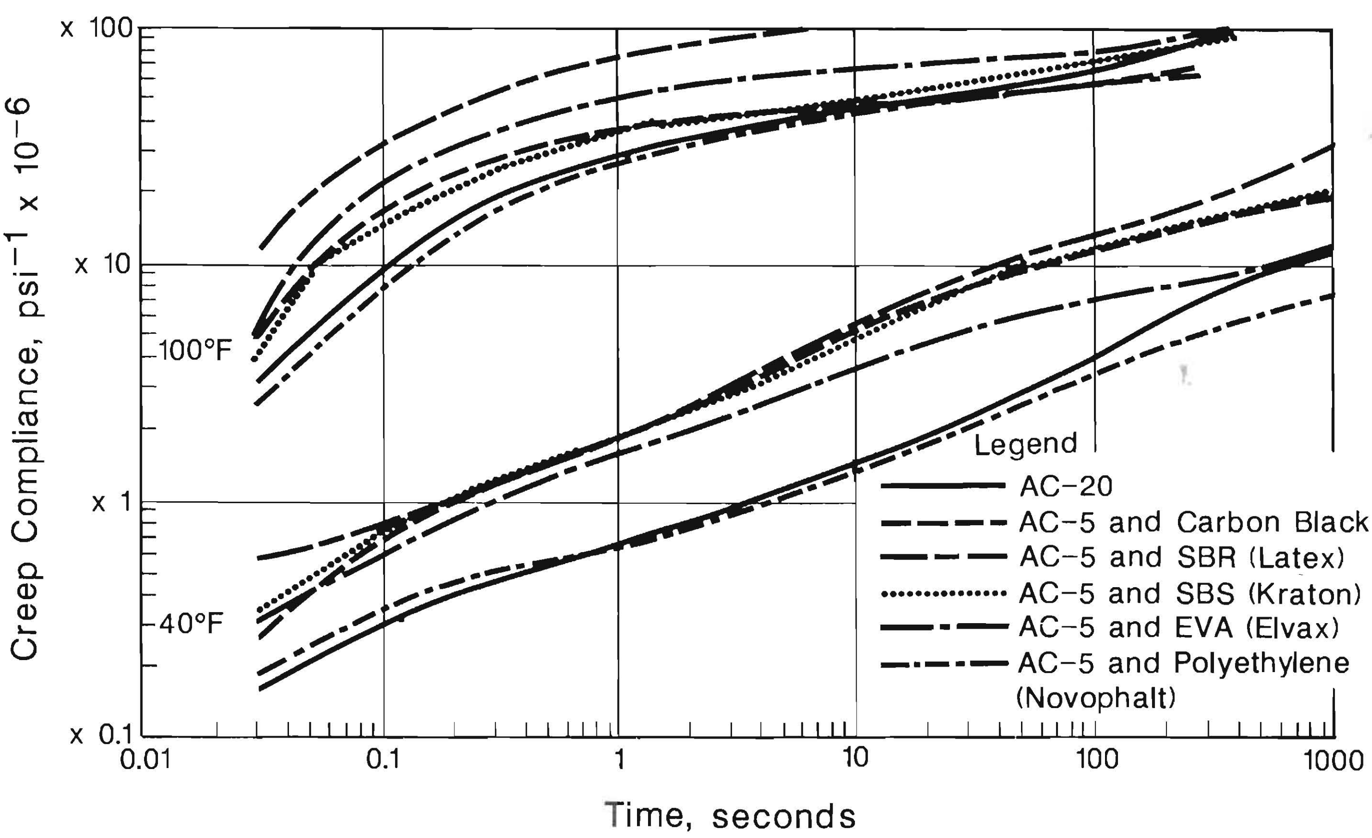
Blends of AC-5 with SBR (latex), EVA, SBR and carbon black all respond with a higher compliance than the AC-20 control at the low temperature. The more compliant nature of these blends indicates mixtures which are better suited to relieve stresses induced at lower temperatures and thus better resist low temperature cracking.

Based upon Figure 3, at the longer load durations, it may be stated that, generally, EVA (Elvax), SBS (Kraton), SBR (Ultrapave) and carbon black provide reduced mixture temperature susceptibility. This occurs because the compliances of the additive mixtures are significantly higher than the AC-20 control at 40° F and converge toward the AC-20 at the 100° F test temperature. The practical significance of this observation is that such a response is expected of additives which reduce rutting potential at higher temperatures and maintain a compliant (fracture resistant) nature at lower temperatures.

Approximate Costs for Additives

Costs of the additives examined herein are influenced by the cost of crude oil, as is the cost of asphalt cement. Currently, the price for the polymers ranges from 0.80 to 1.00 dollars per pound and for the carbon black, about 0.50 dollars per pound. This translates into a cost increase of about 4.00 to 9.00 dollars per ton of hot mixed asphalt concrete, depending on the dosage of the additive. Based on an in-place cost of 35.00 dollars per ton of hot mixed asphalt concrete, the additives would increase the paving cost by about 10 to 25 percent. In other words, assuming an average pavement life of 15 years, an additive would need to increase pavement life by 2 to 4 years to be cost effective or would need to decrease maintenance costs accordingly. Based on the laboratory test results reported herein, the polymer and microfiller additives studied can reasonably be expected to provide cost effective pavement performance.

FIGURE 3: Creep compliance curves at 4°C (40°F) and 38°C (100°F) for mixtures containing Texas coastal asphalts.



SUMMARY OF CONCLUSIONS

1. Traditional mixture design procedures, including the Marshall and Hveem methods, appear acceptable for determining optimum binder contents for additive-modified asphalt mixtures.

2. Although certain binder and mixture properties appeared to be sensitive to compatibility between the asphalt and the additives, overall, the mixture properties demonstrated an ability for each additive to alter mixture temperature susceptibility in a generally favorable manner.

3. Hveem stability of mixtures was not significantly altered by the additives. Although Hveem stability is quite sensitive to changes in binder quantity, it is not very sensitive to changes in rheological properties of the binder properties.

4. The additives increased Marshall stability of mixtures when added to AC-5 or AR-1000 but not up to that of mixtures containing AC-20 or AR-4000, respectively, with no additive. This should not discourage the use of these additives with asphalts softer than the usual paving grade, particularly where low temperature cracking is a concern.

5. At low temperatures (less than 32° F), the additives had little effect on consistency of the asphalt cements. This was reflected in the diametral resilient moduli (stiffness) of the mixtures. Resilient moduli of AC-5 (or AR-1000) mixtures above 60° F were generally increased by the additives, but not up to that of the AC-20 (or AR-4000) mixtures without additives. Although the load spreading ability of asphalt concrete containing a soft asphalt is increased when these additives are employed, the pavement thickness should not be reduced.

6. Indirect tension test results showed that, at the lower temperatures and higher loading rates, the additives increased mixture tensile strength over that of the control mixtures. Strain (deformation) at failure was generally increased by the additives. At the higher temperatures and lower loading rates, the additives did not appreciably affect the mixture tensile properties.

7. The additives had little effect on moisture susceptibility of the mixtures made using the materials included in this study.

8. Flexural fatigue responses of mixtures containing AC-5 plus an additive at 68° F and particularly at 32° F were superior to the control mixture which contained AC-20 with no additive.

9. Creep/permanent deformation testing showed that, at high temperatures, all the additives except latex produced equal or better performance than the AC-20 control mixture. At low temperatures, all the additives in AC-5 except polyethylene produced equal or better creep compliance than the AC-20 control mixture.

10. Standard asphalt extraction methods to determine binder content of paving mixtures are unsuitable when polymers or carbon black are used as these materials are insoluble or only partly soluble in standard solvents.

11. Each additive proved to be successful to some degree in improving properties on at least one end of the performance spectrum; however, no additive proved to be a cure-all. There is a need, therefore, to develop an additive selection procedure based on conditions of traffic, pavement structure and climate. To rank the additives according to relative capabilities is a difficult task, as sensitivity to the base asphalt played a significant role. In general, the most effective additives in reducing rutting were EVA, polyethylene and SBS for the Texaco asphalts. For the San Joaquin Valley asphalt, carbon black, polyethylene, and EVA performed most effectively and without significant difference. In terms of reduction of flexural fatigue cracking, the most successful additives were, in order, EVA, SBS, SBR (latex) and polyethylene which demonstrated essentially equal performance.

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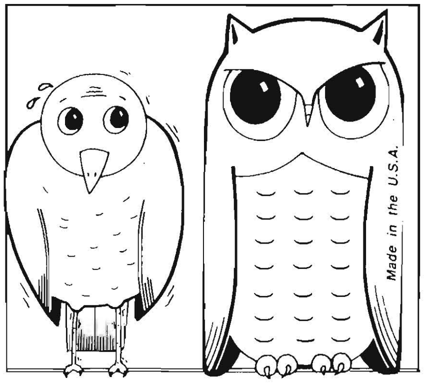
2. Button, J. W. and Little, D. N., ***Asphalt Additives for Increased Pavement Flexibility,*** Research Report 471-2F, Texas Transportation Institute, Texas A&M University, November 1986.

3. Lottman, R. P., ***"Laboratory Test Method for Predicting Moisture-Induced Damage to Asphalt Concrete,"*** Transportation Research Record 843, Transportation Research Board, National Research Council, Washington, D.C., 1982.

4. Kenis, W. J., ***Predictive Design Procedures, VESYS Users Manual,*** Report No. FHWA-RD-77-154, January 1978.



Wise Way to Control Pigeons

When New Hartford, New York officials were besieged with complaints from motorists about aerial pigeon pollution from the bridge over Genesee Street, they contacted the New York DOT for a possible solution. It seems that the birds were fond of nesting and perching on the bridge.

As it is a DOT bridge, the regional maintenance employees came up with an idea that paid dividends and solved the problem. Rather than use chemicals or other deterrents that have proved ineffective, they provided some plastic owls, natural enemies of pigeons, and placed them along the lower edge of the bridge.

Initially, about 75 percent of the offending pigeons left for safer places, and by placing the owls in strategic locations under the bridge, it is expected the rest may get the message. The plastic owls are used for crow hunting and can be obtained from sporting goods stores.

Rebuilding New York Transportation Newsletter, July 1986.

SAFE EPOXY HANDLING

There are some precautions that should be taken in handling the resin, curing agent, and modifiers when mixing and applying epoxy systems. Distributors warn of hazards that might be associated with their products and the user should heed them.

Epoxy resin itself is only slightly toxic. There is little or no danger in inhalation of vapor or fumes over brief periods, but one should not expose oneself to them for long periods. The amine curing agents and the resin are skin sensitizing agents. Repeated exposure to them can cause serious irritation, rash, and skin burn.

Epoxy should be prepared in a well-ventilated area away from heat, sparks, and open flames. In enclosed areas or where ventilation is poor, an approved air mask and adequate safety precautions to prevent fire or explosion should be used. Protective gloves, clothing, and goggles should be used when mixing or pouring grout.

Areas of the body that contact the resin or the curing agent should be washed immediately with soap and water. A solvent should not be used because it will carry the epoxy into the skin. If the eyes are affected they should be flushed with lots of clean water and a physician should be consulted immediately.

There are not extreme hazards accompanying the use of epoxy, but judicious care and precautions can prevent injuries that might otherwise occur.

PUBLICATIONS OF INTEREST

Implementation Manual for the Rapid Repair of Wet Asphaltic Concrete, FHWA/TX-86/51+359-3F, David Cherem-Sacal, David A. Price, Brian Osterndorf, Alvin H. Meyer, and David W. Fowler. Austin:University of Texas Press, October 1985.

Maintenance Activities Accomplished by Contract, Clifford C. McMullen, NCHRP Synthesis of Highway Practice 125. Washington, D.C.:Transportation Research Board, July 1986.

Manual on Countermeasures for Sign Vandalism, FHWA-IP-86-7, D. Perkins, McLean, Virginia:Federal Highway Administration, September 1986.

Mix Proportioning of Concrete Containing Fly Ash for Highway Applications, FHWA/TX-87/4+364-4F, P. M. Carrasquillo, P. J. Tikalsky, and R. L. Carrasquillo. Austin:University of Texas Press, May 1986.

Statistically Based Acceptance Procedures, Quality Assurance, and Construction Management, Elizabeth W. Kaplan, gen. ed., Transportation Research Record 1056. Washington, D.C.:Transportation Research Board, 1986.

Conference on Highway Applications of Microcomputers
November 16-18, 1987
Austin, Texas

Oriented toward representatives of state and local agencies, the 1987 Conference on Highway Applications of Microcomputers will present the most current and effective microcomputer technology used in traffic engineering, road and street maintenance and construction, planning and management. Participants will learn successful microcomputer applications, where to obtain the technology and how best to implement it to suit individual needs.

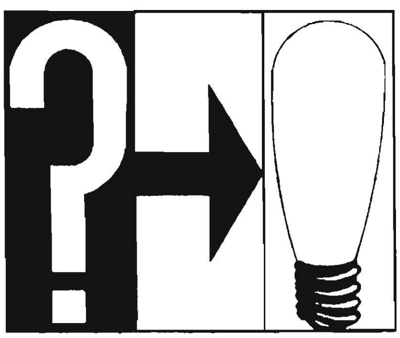
Conference topics will include: pavements, bridges, traffic, expert systems, planning, design, maintenance and safety. Products used in these areas will be exhibited for the participants' use. Field trips to centers of microcomputer use in the Austin area are also planned.

The conference is co-sponsored by the Federal Highway Administration, Texas State Department of Highways and Public Transportation, the Pan-American Highway Congress, The Texas A&M University System, The University of Texas System, Inter-American Development Bank and the International Road Federation. A two-day seminar following the conference will provide representatives from other Western Hemisphere countries with in-depth information and training regarding automation aids suitable to their particular needs.

The $100 registration fee covers conference materials, refreshments, a luncheon and a reception. For more information, call the Public Works Training Division at 409/845-2913.

A novel use of computer-aided design (CAD) to reduce automobile accidents is reported by the Traffic Engineering Div. of the Minneapolis Public Works Dept. A new CAD system is producing schematics of accidents at intersections designated as high-risk areas by the Minneapolis Top Accident Control Target (TACT) program. Says Dave Bruckelmyer, public works engineering aide, the CAD system helps clarify accident statistics, provides data for analysis of why accidents occurred, and produces schematics to facilitate redesign of intersections.
Government Product News, 24, 8 (August 1985):24.

ATTENTION SDHPT INNOVATORS



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.

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