TECHNICAL QUARTERLY

"AN EXCHANGE OF IDEAS"

TQ8-2, JULY 1993 *EDITOR: Kathleen M. Jones*

NEW HOT MIX DESIGN PROCEDURE FOR COARSE MATRIX HIGH BINDER MIXTURES

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In recent years, considerable attention has been given to bituminous mixtures with a high percentage of coarse aggregates. Contrary to our conventional HMAC, which depends heavily on the fine and intermediate size aggregates to function, the new mixtures utilize the coarse aggregates for carrying the traffic loads. Stone matrix asphalt (SMA), introduced in the U. S. within the past three years, is such a mixture. The Texas Department of Transportation (TxDOT) has recently developed a new type of coarse matrix high binder (CMHB) mix design procedure that does not require additives or fibers. These mixtures should prove extremely rut resistant and will not segregate. Austin District (District 14) recently placed two sections of this new design on Spur 1825 in Pflugerville and on US 290 near Austin.

In CMHB mixtures, the aggregate gradation design allows contact between coarse stones. When stone-to-stone contact is achieved, the traffic load is transferred vertically through the stones to underlying pavement. Since coarse stones are the primary load carrying component of the mix, the dependency of the mix on quality and quantity of fine and intermediate size aggregates to prevent rutting is significantly reduced. In addition, the high concentration of coarse aggregates in CMHB mixtures allows use of more asphalt in the mix. The higher asphalt content and, more importantly, the thicker asphalt film on the rocks will improve the durability of the mix.

CMHB should not be mistaken for SMA or current gap-graded mixtures. Current conventional dense-graded hot mix design methods do not apply to the new CMHB type mixtures. Even for SMA mixtures, the design method which is used is deficient in characterizing the mixture properties and is based solely on empirical tests and experience of the users. The new CMHB mix design method, on the other hand, measures valid engineering properties of the mixture, rather than depending on material-specific empirical values.

The key component of a CMHB mix is the design of aggregate gradation. Since the entire success or failure of the mixture depends on achieving the optimum rock-to-rock contact, the design must be engineered to allow it. Optimum rock-to-rock contact means just enough coarse stone to cause contact without creating excess air voids. Too much coarse aggregates will

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The *Technical Quarterly* is dedicated to the free flow of ideas and information within the transportation community.

create excessive air voids, making mixture durability poor. Too few coarse aggregates creates unstable mixtures that will rut. Bituminous Section personnel of the Division of Materials and Tests (D-9) developed a design procedure which ensures rock-to-rock contact.

D-9 initially developed the CMHB design procedure for use with crumb rubber modified (CRM) hot mix and later refined it to include mixtures such as SMA. In fact, using the new mixture design procedure, a hot mix can be designed which will yield rock-to-rock contact without the use of fiber (required for SMA) or any other additive.

DEVELOPMENT OF CMHB DESIGN METHOD

The full details of CMHB design method are given in a new test procedure, "Test Method Tex-232-F." The design procedure uses the Texas gyratory compactor for molding the specimens and also requires the use of Static Creep Test (Test Method Tex-231-F).

For each set of aggregates, mixtures are prepared with several percentages of coarse aggregate concentration. All these mixtures are prepared at a constant asphalt content and compacted using TxDOT's standard procedure. After molding the specimens, relative density of each set is measured. The relative density is plotted versus the coarse aggregate content (percent retained on sieve size No. 10).

For example (Fig.1), as the percent retained on sieve size No. 10 increases, the density increases to the point where rock-to-rock contact is achieved. After that point, the density starts decreasing.

What takes place is that as coarse aggregate content increases, the film thickness increases and, at the same time, the amount of fine and intermediate size aggregates decreases. The fact is that fine and intermediate size aggregates generally cause the most resistance to compaction. Reducing the amount of fines while in-

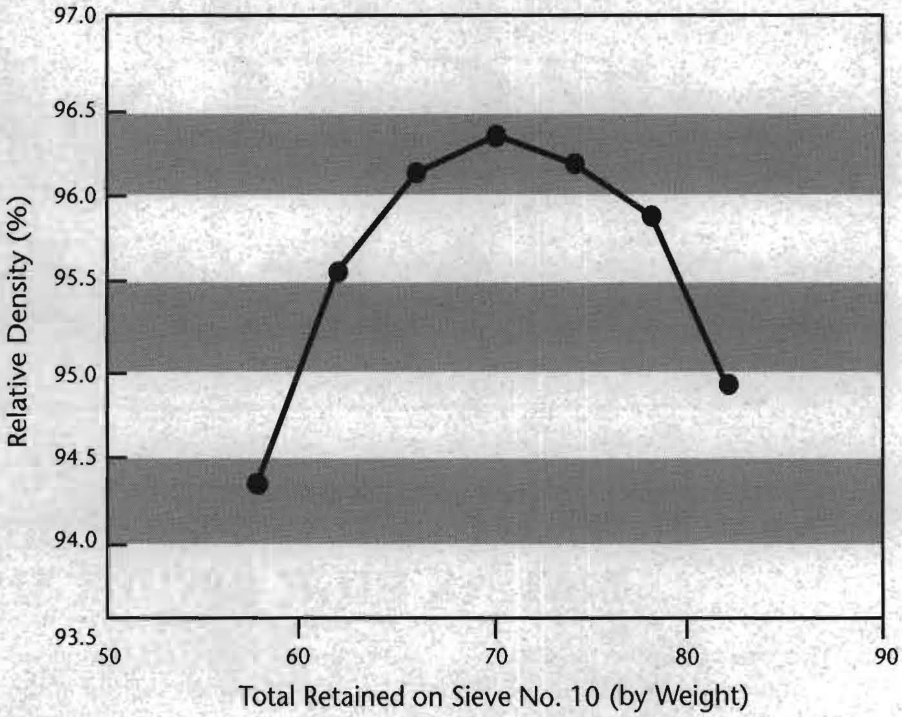

FIGURE 1. Example plot of relative density versus percent retained on sieve size No. 10 (by weight).

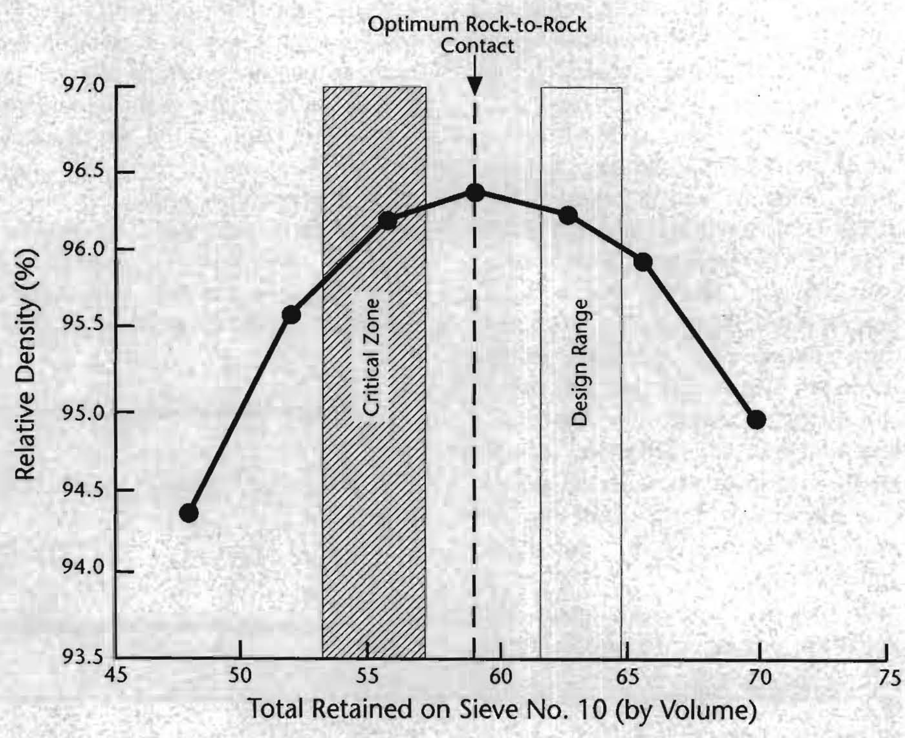

FIGURE 2: Relative density plot (by volume) showing critcal zone, optimum rock-to-rock contact zone and design range.

creasing the film thickness enables better compaction and increased density. When rock-to-rock contact is achieved, any increase in coarse aggregate contact will merely cause an increase in air voids. Therefore, the density will start dropping.

Two key points should be mentioned in regards to the relative density versus percent retained on sieve size No. 10 plot. As shown in Figure 2, the mixture is designed for 2.5% to 5.0 percent coarser than the optimum percentage of aggregate retained on sieve size No. 10 (by volume). This increase is necessary to ensure that the mix will not degrade during production to below the optimum. In addition, the area just before the optimum is a critically unstable area. This area is marked on Figure 2 and can be considered as the "critical zone." What takes place in the critical zone is that there is not enough coarse rock to make rock-to-rock contact and at the same time, enough fine aggregates are removed from the mix to cause instability. Mixtures in this area should be avoided at all costs.

This new design method offers lots of promise for the future of hot mix in Texas and elsewhere. The procedure can be used for SMA or CRM hot mix. The most important aspect is that the procedure can be used to design hot mix that requires no additives — just rocks and asphalt. This design procedure was used to design the mixture for two projects in the Austin District. The mix looks great and very uniform. Some people are calling CMHB "the nonsegregating mix" because it is impossible to make this mix segregate.

If you need more information on CMHB (coarse matrix, high binder) design, contact Maghsoud Tahmoressi of D-9 at Tex-An 241-3907 or (512) 467-3907.

STRUCTURAL FIELD WELDING: PREVIEWING THE NEW SPEC

by **Kathleen Jones**
Research and Development Section
Division of Transportation Planning

INTRODUCTION

The new specifications on structural welding have been finalized. The most significant change is the organization of Item 448, "Structural Field Welding." For example, requirements for welder qualification and certification will be stated at the beginning, rather than near the end. Since the new specifications will be published shortly, now is a good time to review why and how the welding specs developed and how they affect construction.

OVERVIEW

Producing good weldments is complicated; field conditions add to the problems. The Texas Department of Transportation (TxDOT) is unusual among state transportation agencies in that it actively promotes structural field welding. Many states shy away from large scale structural welding in the field, largely due to lack of experienced field welders and welding inspectors.

Today, TxDOT has specialized in-house structural field welding inspectors and a body of contractors experienced in welding to draw on mainly because of Percy V. Pennybacker. Around 1947, Mr. Pennybacker, then Bridge Engineer for the department, pushed welding for economic reasons (it is much less labor intensive than riveting or bolting splices) and ease of construction, particularly in fit-up.

Pennybacker was well aware that successful welding requires knowledge, experience and skill on the parts of both inspectors and welders. Therefore, between 1949 and 1952, he hired four specialist welding inspectors who were on call to the districts. During this period, he had one of these inspectors work with the Texas Transportation Institute (TTI) on the feasibility of using radiography for inspecting field welds. He worked with the contractors in developing welder qualifications and instituting a welder certification for the department. In 1956, he authored the department handbook, ***Construction of Welded Steel Bridges*** [Ref. 1]. The system of special welding inspectors, the certification program, inspection of field welds by radiography, and much of the information in his handbook are all in use today, though details have changed.

WHAT DETERMINES WELDING QUALITY

The quality of weldments depends on [Refs. 3, 4, 5, 6]:

- selection of an electrode type and size appropriate to the base metal and the type of joint,
- the manual dexterity and knowledge of the welder,
- correct fit-up to prevent distortion,
- applying preheating, when called for, to control heat-affected zones and cooling rates,
- correct input energy to the arc,
- correct sequencing of welding passes,
- maintaining interpass temperatures,
- achieving correct weld profile,
- proper grinding of the cooled weld, and
- applying postweld heat treatments when the material requires it.

If these factors are not met, weldments may be plagued with porosity, underweld cracking, hydrogen embrittlement, slag inclusions and other discontinuities, as well as low fatigue resistance, stress corrosion cracking, fracture, and other mechanical and chemical problems.

HOW TXDOT ENSURES SOUND WELDS

Welding is only feasible and economical when an agency can be sure that most of the weldments are sound and that the ones that aren't will be detected by inspection and corrected before the structure is placed in service. TxDOT's welded splices are good because:

- the specifications require welders to produce welds that must pass strength and ductility tests before welders are certified to weld load-carrying splices,
- the Division of Materials and Tests (D-9) provides a list of approved electrodes annually,
- good procedures have been worked out and documented over the years,
- the Division of Bridges an Structures has four field welding inspectors whose services are available to the districts.

This article will discuss these points in detail in the next sections.

WELDER CERTIFICATION

TxDOT welder certification is issued through the Division of Bridges and Structures (D-5) and signed by the Bridge Engineer. Without TxDOT certification, even an experienced welder cannot weld on a TxDOT structure, except for miscellaneous welds (as defined in 448.16 [Ref. 5]) that have no load-carrying capacity in the completed structure. Welders certification records are kept on file at D-5.

Passing the most stringent test allows a welder to make all types of weldments (groove and fillet welds on primary and secondary members, piling splices, rebar splices, and miscellaneous) in any welding position (Fig. 1). Passing the limited thickness test allows a welder to splice piling. Passing the rebar test means the welder is rated to weld rebar only. These tests are administered by commercial laboratories. Details of the actual tests are contained in "Construction Bulletin C-6" [Ref. 2]. Besides passing the most stringent test, new welders must demonstrate to a department welding inspector the knowledge and skill to produce sound welds before they are allow to weld load carrying members.

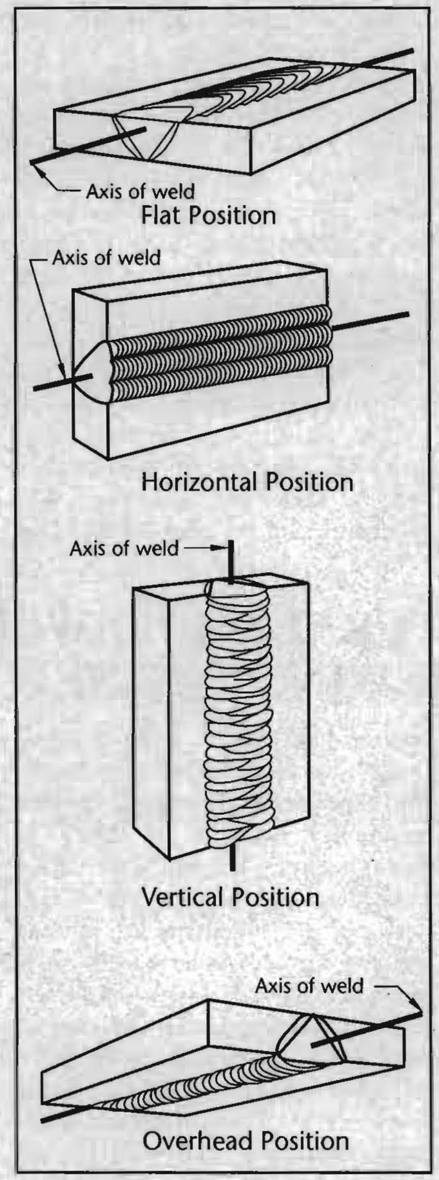

FIGURE 1: Positions of welding for groove welds [Ref. 5, p328].

Welders must identify their groove welds on the structure, and the welding report includes who made the weld so that a welder's performance can be tracked. No annual welding recertification is required, but a welder's TxDOT certification may be canceled by D-5 if the welder produces a significant number of bad welds.

APPROVED ELECTRODES

All final welding passes must be made with low hydrogen electrodes to reduce the chance of hydrogen embrittlement of the weldment. The type of electrode must be suited to the base metal. In joints involving base metals of different yield points, a low hydrogen electrode compatible with the lower strength metal can be used. D-9 tests different manufacturers' electrodes to see if they meet ANSI, American Welding Society (AWS), and AASHTO standards and publishes a list of approved electrodes annually. If a manufacturer's electrode does not appear on the approved list, it cannot be used on a TxDOT structure. Figure 2 is an example of one page only from this year's list.

PROCEDURE

Field Welding Processes

Manual shielded metal arc welding (SMAW) and flux-cored arc welding (FCAW) are virtually the only types of welding done in the field in Texas. SMAW is popular in the field because the rigs are inexpensive and portable. FCAW, because of the minerals and alloys in the flux, can deposit metal at a higher rate than SMAW. Although the American Welding Society considers FCAW to be more cost effective and to produce welds of better contour, it has not replaced the SMAW process in Texas.

Which ever process is used, the welding current, arc voltage, gas flow, mode of metal transfer and speed of travel must be regulated to produce complete fusion of base and weld metal without overlap, undercut, or excessive porosity.

Continued on page 11

WORKMANSHIP IS KEY TO SUCCESSFUL MICROSURFACING

INTRODUCTION

Paving season is in full swing. A lot of districts will be using microsurfacing, some for the first treatment for an existing pavement. Microsurfacing is a general term for a mixture of polymer-modified, asphalt emulsion, well-graded crushed aggregate, mineral filler (normally portland cement) and usually an emulsifying agent. Microsurfacing resembles a type II or type III standard slurry seal, but it breaks much faster. Microsurfacing has become increasingly popular in the last 5 years. Most of the time it performs very well, but there have been some notable failures. Current Texas Department of Transportation (TxDOT) microsurfacing specifications allow contractors to provide mix designs, as is the case in most DOTs.

PRELIMINARY FINDINGS

TxDOT has taken the lead among state DOTs in rationalizing test methods and construction specifications. Research Study 1289, ***Use of Microsurfacing in Highway Pavements,*** being performed at the Texas Transportation Institute (TTI) is already yielding some useful results. One fact that several TxDOT personnel have reported is that when TxDOT microsurfacing jobs fail, they fail because of poor workmanship, not because of material-related problems. In light of that fact, an excerpt from draft Research Report 1289, "Quality Assurance Plan for Microsurfacing," is given below.

Complete draft versions of both the "Usage Guidelines for Microsurfacing" and "Quality Assurance Plan for Microsurfacing" are available from ***TQ***: call the editor at (512) 465-7947, Tex-An 241-7947. Maghsoud Tahmoressi, P.E., Division of Materials and Tests (D-9), is the study's Technical Panel Chairman. He invites consideration and comment from district personnel, particularly on the draft "Quality Assurance Plan for Microsurfacing," during this construction season. His phone number is (512) 467-3907, Tex-An 241-3907.

WORKMANSHIP

Weather Limitations

The material shall be spread only when:

- the atmospheric temperature is at least 50°F and rising
- the weather is not rainy
- there is no forecast of temperatures below 32°F within 24 hours after mix placement or rain within 12 hours.

Surface Preparation

The area to be surfaced shall be thoroughly cleaned of all vegetation, animal carcasses, loose aggregate, soil, and other debris. Water used in prewetting the surface ahead of the spreader box shall be applied at a rate to dampen the entire surface without any free flowing water ahead of the spreader box.

Finished Surface

The finished microsurfacing shall have a uniform texture free from excessive scratch marks, tears or other surface irregularities. Excessive tear marks are:

- four marks more than 1/2 inch wide or wider and six inches or more in length per square yard
- any marks 1 inch wide or wider and four inches or more in length.

The mixture shall adhere fully to the underlying pavement within one hour after application. The mixture shall provide a uniform skid resistant surface with a skid number of 43 or greater as measured using ASTM E 274 at 40 miles per hour.

Opening to Traffic

The microsurfacing shall be ready for traffic to be applied within one hour after application. Traffic shall not significantly alter the surface.

Joints/Seams

The longitudinal and transverse joints shall be neat in appearance and uniform. No excessive buildup, uncovered areas or unsightly appearance will be permitted on longitudinal or transverse joints. Longitudinal joints shall be placed on lane lines when possible. Excessive overlap (greater than 2 inches) will not be permitted. There should be no more than a one-half-inch space between the pavement surface and a ten-foot straightedge placed on the longitudinal joint nor one-quarter inch for a transverse joint. The total number of joints shall be no more than one joint per lane mile based on the total mileage placed in the project.

Edges

The edges of the microsurfacing shall be uniform and neat along the roadway centerline, lane lines, shoulder or curb lines. The edge shall vary no more than plus or minus four inches from a 100-foot straightedge on a straight section or from a 100-foot arc of the design curve on a curved section.

Ruts

When required on the plans, before the final surface course is placed, preliminary microsurfacing material shall be required to fill ruts, utility cuts, depressions in the existing surface, etc. Each individual rut filling utilizing a rut-filling spreader box shall be crowned to compensate for traffic compaction. Maximum microsurfacing thickness applied as a rut-filling pass in a single lift shall not exceed 3/4 inch. Maximum microsurfacing placed a full width pass of a lane shall not exceed 1/2 inch in any location across the lane.

TABLE 1: Rut depths related to methods of filling.

IF THE RUTS ARE ...	THEN FILL ...	USING ...
less than 1/2 inch in depth and shallow or irregular	as directed by the engineer	a full-width scratch coat
1/2 inch to 3/4 inch in depth	by single pass	a rut-filling spreader box, no more than 6 feet in width
greater than 3/4 inch in depth	by multiple passes	a rut-filling spreader box, no more than 6 feet in width

At the end of construction, the transverse profile shall show no rutting in the wheel paths and no more than a 1/4-inch height above the desired profile.

POSTCONSTRUCTION CHECKS

At the present, no specific postconstruction checks have been defined. However, it is expected that postconstruction checks may include the some of these tests at some time in the future. The purpose of these checks will be to determine if the material meets the requirements of the specifications and if the treatment is expected to provide reasonable performance.

Some of the tests that are being considered include the following:

1. surface texture (sand patch or putty),
2. voids in the mixture,
3. cohesion, and
4. abrasion.

The workmanship checks and measurements during construction could also be used as postconstruction checks and measurements.

FORT WORTH DISTRICT GOES INTERACTIVE

by **Kathleen Jones**
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INTRODUCTION

Transportation professionals realized traffic congestion, air quality, and restricted right-of-way were problems long before the Intermodal Surface Transportation Efficiency Act (ISTEA) became law in December 1991. Traffic management through increasingly high-tech methods (ultimately yielding intelligent vehicle/highway systems) is seen as a good way to juggle the separate, often conflicting, concerns of mobility and environmental quality.

On May 6, 1993, Fort Worth District (District 2) achieved a long-awaited goal in Texas freeway traffic management. Two additional components of the traffic management system in IH 35W freeway corridors through Fort Worth became operational. Using software developed by the Systems Branch of the Division of Maintenance and Operation's Traffic Management Section (D-18TM), district personnel can now directly receive loop detector data from the roadway and remotely control devices such as lane control signals based on real-time information [Ref. 1]. With real-time data from the roadway, system operators can quickly pinpoint trouble. Then using computers, they activate changeable message signs and lane control signals to warn motorists far enough in advance of the problem to be of aid. System operators can also access color closed-circuit television cameras (CCTV) to confirm and monitor traffic incidents. How did District 2 get to this point and what does their system entail?

OVERVIEW OF DESIGN CONCEPTS

Some of the Texas Department of Transportation's (TxDOT) major urban districts have been planning and working on traffic management systems for their various freeway corridors since the mid-1970s. D-18TM has been developing the overall TxDOT goals and providing technical assistance to the districts. District 2's approach is for a modular design and staged implementation (tied to freeway reconstruction) using as much in-house design as possible. The use of in-house design resources produces a product that fits local conditions, is maintainable by TxDOT personnel, and is not proprietary.

When fully implemented, District 2's traffic management system will be capable of monitoring 260 miles of freeway operating conditions and will provide the means for implementing corrective actions in response to changing conditions on this network [Ref. 2, p. 5]. The goal of modular design and staged implementation is to get operational systems on the road quickly that are of immediate benefit to motorists, and not lose valuable time waiting for the "perfect" traffic management system to be created.

District 2's areawide plan involves three interrelated, integrated systems:

- Level 1 — the roadway itself — remote sensing or surveillance systems constantly monitor conditions by using inductive loop detectors on the mainlanes and ramps and by strategically placing closed-circuit TV camera (Fig. 1). The cameras can confirm potential problems, locate accidents or disabled vehicles and monitor the effectiveness of any corrective action taken. D-18TM's development of roadway equipment control software has been the key to making level 1 fully interactive with level 2.

FIGURE 2: Monitoring traffic at the new control center.

FIGURE 1: Closed-circuit TV camera in Fort Worth District.

- Level 2 — corridor control centers — offer interactive control of a specific corridor or corridors. They are usually located at a multilevel directional interchange. The Freeway Traffic Management workstation and related software, developed by D-18TM, is the heart of a corridor control center. With this software, using the Level 1 data, system operators have several options for dealing with freeway problems. They can regulate traffic volume entering the corridor at points by using ramp metering and by modifying the timing of frontage road traffic signals and can advise motorists of problems and alternate routes by using lane control signals, changeable message signs and travelers' advisory radio. District 2's courtesy patrol and incident management teams can also be dispatched to get traffic moving again. The first of the corridor control centers went on line May 6, 1993. Eight more are planned by 2004.
- Level 3 — proposed freeway traffic management center — when built, will serve to centralize and coordinate response measures, will provide an areawide communications link via fiber optics with all corridor control centers and other local systems, and will give oversight. An operator in this center will be able to collect data from any loop and to send commands to any element in the system. The hardware, software, and final concepts for this center are under consideration now, with design scheduled for 1995 [Refs. 3, 4].

ANTICIPATED BENEFITS

The total capital cost of the fully implemented system is projected to be about $53 million over twenty years (1985 dollars) [Ref. 4]. This cost is small compared to regular construction costs, estimated at several billion dollars over the next twenty years. Furthermore, the benefits to the highway user are substantial and immediate.

Based on experiences in other states, District 2 anticipates a savings of at least 156,000 vehicle hours of delay *a day,* 10 to 12 percent more vehicles moved per hour, and 30 percent fewer accidents [Ref. 2, p.5]. This kind freeway efficiency translates into substantial savings in fuel, reduction in air pollution, and an increase in available productive hours — exactly the measures ISTEA is requiring. The benefit-to-cost ratio of this project is estimated at 11 to 1.

WHAT'S IN OPERATION NOW

As of September 1993, the district will have the following system elements in operation (Table 1).

A COOPERATIVE EFFORT

In order to create this automated traffic management system quickly, District 2 established close working relationships with D-18 and other TxDOT districts as Houston and San Antonio that are working on similar systems. When specific expertise was lacking, the department authorized research projects like state-funded study 1950, "Design of Surveillance and Communication Systems." Other entities with an interest in traffic and incident management like the city of Fort Worth, the Federal Highway Administration, Houston Metropolitan Transit Authority, out-of-state transportation officials, and various equipment manufacturers and suppliers have contributed to the project. (See following article.)

Since the equipment installation for the traffic management system is tied to highway reconstruction, coordination and cooperation with district construction personnel and contractors is necessary for success. At the end of each reconstruction project, district section personnel debrief construction inspectors and contractor's personnel to determine how improvements can be made. The feedback from these sessions has been very valuable, allowing frequent reevaluation and improvement of the equipment specifications and installation methods.

CONCLUSIONS

The Fort Worth District's basic goals parallel TxDOT's vision: to create an automated traffic management system that is practical, maintainable, and capable of being upgraded without major modification of existing equipment. Although the staged, incremental installation has some drawbacks, it has allowed District 2 to get parts of the system up and running quickly, while spreading the cost of the whole system over a number of years and projects. At this time, district personnel are involved in all aspects of the system. They planned, designed, supervised construction, and are now operating and maintaining the equipment. D-18TM's roadway equipment control software package allows the integration of proprietary and nonproprietary elements into an efficient, interactive traffic management system.

TABLE 1: Total number of elements installed over 20 years compared to number installed by the end of FY 93 [Refs. 2, 3, 4].

NUMBER BY YEAR 2004	TOTAL TO BE INSTALLED BY SEPTEMBER 1993	ROADWAY ELEMENT
7000	1069	inductive loop detectors
207	0	ramps with new metering equipment and "wrong way" entry detection capabilities
95	0	computer-controlled traffic signals on frontage roads (need to be integrated with city of Fort Worth system)
45	10	changeable message signs
80	8	closed-circuit television surveillance cameras on fiber optic cable
640	123	lane control signals
6	0	highway advisory radio transmitters
9	1	corridor control centers

The new interactive network is already proving its usefulness. On 21 May 1993, at 5:15 a.m., a large truck hit the gore area of the IH 35W/IH 30 interchange spilling its cargo of cowhides forcing the closure of several lanes and ramps. The system standby operator was notified by the incident manager. He dialed into the system from his lap top computer and set up the changeable message signs to warn motorists of ramp and lane closures. District incident management personnel began removal and cleanup operations at approximately 5:30 a.m. [Ref. 3].

ISTEA mandates control of traffic congestion. Sophisticated traffic management systems are one of the better methods for reducing congestion. Future ***TQ*** articles will feature aspects of significant implementation of advanced systems in Houston, San Antonio and other TxDOT districts.

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TEXAS MOTORIST-AID CALL BOX TEST PROGRAM TO EXAMINE IMPACT ON EMERGENCY RESPONSE

Stranded motorists along highway sections in Tarrant, Hale, and Cameron Counties will be provided with more immediate access to emergency responders through a motorist-aid call box test program coordinated by the Advisory Commission on State Emergency Communications (ACSEC). "This program is truly a partnership between state, regional, and local government along with the telecommunications industry," said Mary A. Boyd, executive director of ACSEC.

The study will examine the impact of call boxes on emergency response time. Motorist-aid call boxes are wireless telecommunication devices located in bright yellow boxes identified with blue and white signs. The devices directly connect a caller to the appropriate emergency responding agency, including direct access to 911. The individual boxes are solar and battery powered. All test sites were selected based on traffic density and accident data. The test will last one year. The evaluation will focus on system usage, equipment function, and several environmental factors in order to determine the future of call box programs in Texas.

The Tarrant County motorist-aid call boxes are located along an 81/2-mile stretch of IH 30 between SH 360 in Arlington and east Loop 820 in Fort Worth. This test site will include 30 call boxes spaced at one-half mile intervals on opposite sides of the highway within motorists' line of sight. The Hale County call boxes are located along a 15-mile stretch of IH 27 between Abernathy and Hale Center, approximately 20 miles north of Lubbock. This site has 30 call boxes spaced at one-mile intervals. The Cameron County call boxes are located on a 10-mile section of SH 77/83 between San Benito and Brownsville. This site has 20 call boxes spaced at l-mile intervals. The Hale and Tarrant sites are sponsored by GTE-Government Information Services. The Cameron site is sponsored by Cubic Communications. The sponsorships include all installation, operation and maintenance of the systems.

The Texas Department of Transportation (TxDOT) approved the safety design of the call boxes and poles, assisted in the placement of the boxes in the right-of-way, and provided oversight during installation. "Call boxes with 911 services add one more feature to our safety network along the highways," said Arnold Oliver, Engineer-Director of TxDOT. "Safety is one of the first things we look at in all our work. This test program will help us evaluate call box use in other parts of the state."

Excerpted from a news release by Carey Spence, Public Education Coordinator for the Advisory Commission on State Emergency Communications, 1101 Capital of Texas Highway South, Suite B-100, Austin, TX 78746-6437.

A Tarrant County motorist-aid call box.

COMPUTERS IN THE ENGINEER'S WORKPLACE

by **Gary Beckner, P. E.**
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At the recent national ASCE convention, the involvement of computers in the engineering office was highlighted during two technical sessions. The desktop personal computer is replacing the mainframe for most computer analysis, especially with the dramatic drop in price of 486 class computers. The reliability of desktop computers was reported to be somewhat inconsistent in analysis results. This was said to be more prevalent with 8088 and 286 class PCs, and much less so with 386 and 486 class PCs. Similar patterns for Apple class computers seemed to hold.

Even the engineer's best friend, the spreadsheet, can be unreliable. So what's the problem with these modem tools of the trade?

The background of the software developers can be very important. Engineers familiar with the application need to be closely involved in the development of program coding. Computer programmers applying formulas and mathematical principals, but who are not engineers, are producing some software programs without an understanding of what the output means. The user must ask questions before he purchases a package.

How do engineering department managers get a handle on the numerical results coming from the computer? Engineers must realize that erroneous results are easy to get; by just improperly entering data and not following the program's input code format. It is also common for software programs to have code conflicts and errors that show up only for certain computation sequences. Frequently, code errors are left for the user to discover. Alternate checking of results should be mandatory at all levels of project design. Checking can be done by approximate hand methods, by changing computer hardware, and by running a different software program.

Of a more crucial aspect, a proper computer model has to be correctly set up. Engineers who create a model and its nodes or links, must understand how the model will behave and especially understand the failure modes. Formulas need to be run and reviewed for several conditions if a program is created in-house, even for input data abuse conditions. Complicated formula routines in a common spreadsheet should be verified by calculator and hand checked. Intended limits of in-house programs should be clear to the user.

A growing concern shared by software developers, educators, and engineering managers in our profession is the competence of the person performing the data input. Frequently, the data is input by an engineer who is right out of school and who has little engineering experience. This would appear to be good project economy, but only until output errors in the project's design appear. Managers must know what is happening and the implications thereof of data input. There is no substitute for experienced model builders guiding the inexperienced computer operator. Understanding the behavior of a model and its failure modes are essential to proper use of the computer. This only comes from experience and knowledge in the application of engineering principals in the design project. Looking at the output and identifying obvious errors and inconsistent patterns is a mark of an experienced engineer. Additionally, the young engineer is probably going to have to look out for himself to avoid becoming "trapped" behind the computer for project after project. The young engineer does not learn the profession and become a viable engineer this way. It is essential for managers to broaden the experience of young engineers, or they are really depriving the next generation of designers the essential tools to continue the profession.

Source: Olympia-Tacoma Section ***ASCE Newsletter*** (December 1992). As seen in ***The Northwest Technology Transfer Center Bulletin*** (Winter 92/93): 6. Reprinted by permission of the author.

Structural Welding … *continued from page 4*

Texas Department of Transportation

Approved Electrodes and Flux-Electrode Combinations
for Fabrication of Bridge Structures
April 2, 1993

Expiration Date: March 31, 1994

AWS 5.1 SHIELDED METAL ARC — COVERED CARBON STEEL ARC WELDING ELECTRODES

Classification	Producer	Product	
E6010	Alloy Rods	Mild Steel AP100	(a)
	Hobart	Hobart 60 AP	(a)
	Lincoln	Fleetweld 5P	(a)
		Fleetweld 5P+	(a)
	L-Tec	L-Tec 6010	(a)
E6011	Hobart	Hobart 335A	(a)
		Hobart 335C	(a)
	Lincoln	Fleetwood 35	(a)
		Fleetwood 35LS	(a)
E7015	*No Submittals*		
E7016	Lincoln	Jet-LH 7016	
E7018	Alloy Rods	Atom Arc 7018	
	Hobart	Hobart 418	
		Hobart 718	
		Hobart 718C	
		Hobart 718MC	
	Lincoln	Jet-LH 78 MR	
		Jetweld LH-70	
		Jetweld LH-73	
		Jetweld LH-75 MR	
	L-Tec	L-Tec 7018	
	McKay	7018 XLM	
E7018-1	Alloy Rods	Atom Arc 7018-1	
	L-Tec	L-Tec 7018-1	
E7028	Hobart	Hobart 728	
	Lincoln	Jetweld LH-3800	

FIGURE 2: Page 1, "TxDOT Approved Electrodes and Flux Electrode Combinations for Fabrication of Bridge Structures." Published by the Division of Materials and Tests, 124 East 11th St., Austin, TX 78701-2483.

Fit-up

Assembly and fit-up are carefully considered in specification 448. Inspectors should keep an eye out that enough allowance has been made for shrinkage during fit-up. Joints must never be restrained on both sides at once. All butt splices must be made before welding secondaries such as diaphragms and sway bracing.

Preheating

Preheating is necessary in many cases (Table 1) to control cooling rates and prevent cracking. Highly restrained joints often need higher preheat than the minimums listed in Table 1. Preheat temperature is measured on the side opposite the application of heat about 3 inches away from the joint.

Passes

Large structural welds cannot be made in one pass. To minimize shrinkage and distortion in beam and girder splices, TxDOT 448 specifies alternating, symmetric passes (Fig. 3).

The welds must alternate from side to side to prevent heat from building up in one flange edge. Passes are arranged between top and bottom flange to maintain balance. Some splices will require more or fewer passes than shown. More than fifty years of experimentation and field experience has proven this procedure safe and effective.

Place passes one, two, and three in the top flange, followed by four, five and six in the bottom flange. Passes one and four are always made in the overhead position and are gouged out and replaced before welding on the web. Always weld the web "uphill." Start at the bottom of the upper third and move toward the top flange. Repeat this step with the middle and bottom thirds. This method creates a more unified, narrower width of heat-affected zone than starting at the bottom flange and welding up to the top flange.

TABLE 1: Minimum preheat and interpass temperatures [Ref. 4].

THICKNESS OF THICKEST PART AT POINT OF WELD	FCAW OR MANUAL SMAW WITH LOW HYDROGEN ELECTRODES
Up to 3/4 inch, inclusive	50° F
Over 3/4 inch to 1-1/2 inch, inclusive	70° F
Over 1-1/2 inch to 2-1/2 inch, inclusive	150° F
Over 2-1/2 inch	225° F

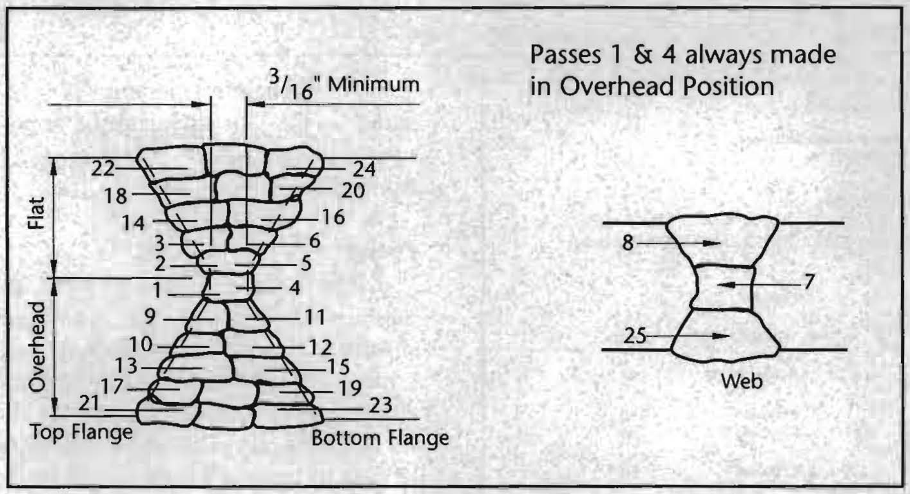

FIGURE 3: SMAW splicing procedure for 50,000 psi yield strength material [Ref.4].

Maintain sufficient interpass temperature to prevent cracking and remove slag before depositing the next layer. The maximum thickness of weld layers is controlled by welding process, by whether the weld is groove or fillet, and welding position.

D-5'S SPECIALIZED TEAM

Welding inspection requires a detailed knowledge of welding processes and metallurgy. Actual experience as a field welder is also valuable. Because experienced welding inspectors are hard to come by and because sound welding is so critical to the proper function of a bridge, D-5 has a team of four welding inspectors who are certified welders. D-5's special welding inspection is a service to the districts, not a contract requirement. Districts should call to schedule a welding inspector before the job begins since it is important that the welding inspector check that:

- welder certifications are valid,
- proper equipment and materials are used,
- the contractor is following the approved bracing and erection process, and
- proper fit up is obtained.

To schedule a field welding inspector, contact the D-5 Construction Section a week or two prior to the work.

Overview of Inspector's Duties

The welding inspector's first item of business is to check the welders' TxDOT certification to see that the welder is properly certified to perform the type welding required. The welding inspector may work closely with the welder if the welder is new to TxDOT. An advantage to using D-5's welding inspectors is that these inspectors are familiar with contractors' welders all over the state and generally know who is new or whose work needs frequent checking while in progress.

The welding inspector usually samples the fit-up of joints to see that they are within tolerance. The inspector checks that the low hydrogen electrodes are an approved type, have been dried for the necessary time before use, are undamaged, and that they are used or redried within

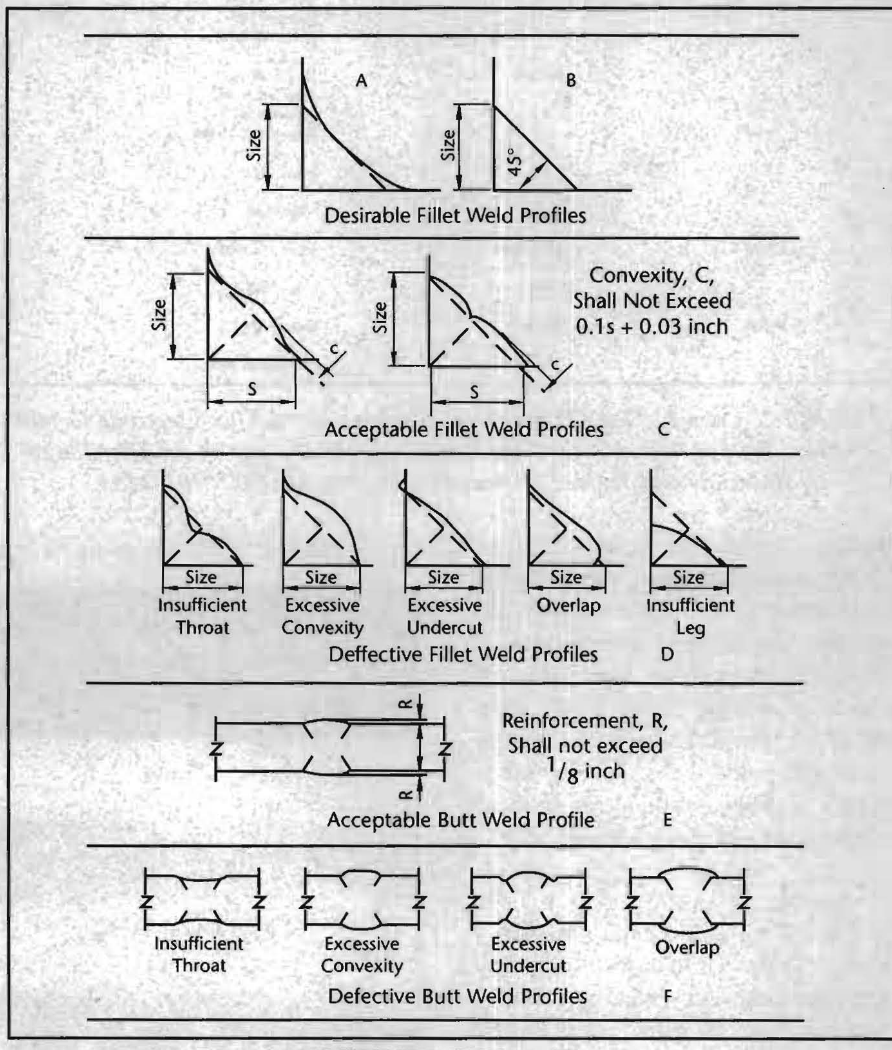

FIGURE 4: Weld profiles.

the specified time for each type of electrode.

When welding is in progress, an experienced welding inspector can tell by the sound of an arc whether it is too hot or too cold. The inspector keeps tabs on preheating as well.

Contour of the finished joint is very important (Fig. 4). Both overlap and undercut should be caught by visual inspection. No overlap of the weld is allowed. The amount of undercut allowed in the base metal is controlled by whether the undercut is transverse or parallel to the primary stress. During visual inspection, the inspector also looks for surface evidence of porosity, shrinkage cracking, slag inclusions, and removal of adjacent base metal.

Radiography

All flange splices and specified portions of the web splices are radiographed as well as visually inspected. Radiography is not practical for fillet welds. The actual radiographs of welds are made by independent laboratories at the expense of the contractor. One of the D-5 Bridge Construction Inspectors interprets the radiographs. If the inspector finds significant defects, that weld is rejected (Fig. 5). After repairs are made, the weld is radiographed again. All radiographs become the property of the department.

Maintenance and Rehab Welding

The D-5 special welding inspectors are available for maintenance and rehabilitation welding jobs as well as new construction. Consulting them can save a district money: they can usually tell if a beam can be heat-straightened in the field, instead of removed and replaced. They also can make recommendations on what are the most cost-effective measures in other cases concerning steel. Calling the special inspectors out before the contract is let is a good idea.

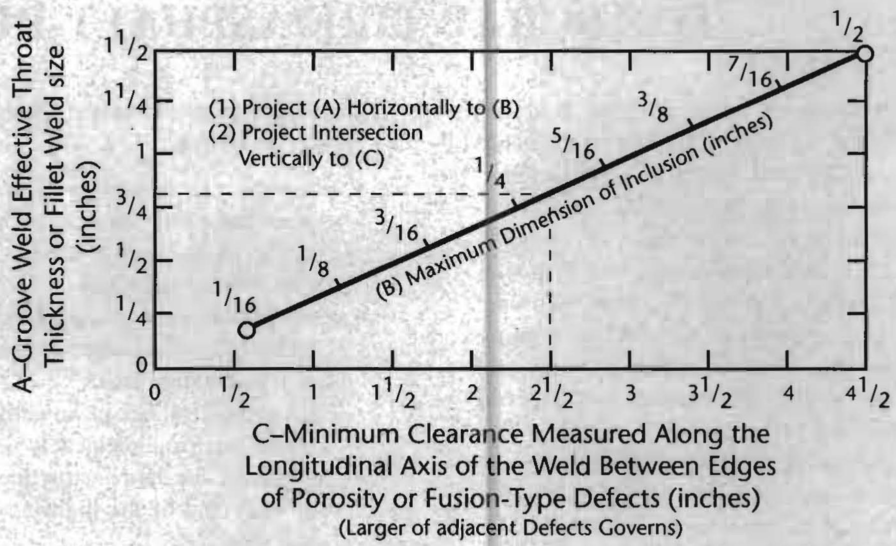

FIGURE 5: Standards for allowable inclusions [Ref. 4].

CONCLUSIONS

As Mr. Pennybacker stated in 1956, "Our practice in designing steel bridges and in supervising their construction is based on the fact that 1) welded designs properly made and properly constructed are both sound and economical but 2) without competent supervision and inspection, welding cannot be considered safe." [Ref. 1] This statement is still true today. By adhering to TxDOT specification 448, safe welds can be produced routinely. The Division of Bridges and Structures also provides a team of special welding inspectors who are available to the districts for new construction inspection or for maintenance and rehabilitation jobs involving welding.

SPECIAL THANKS TO:

- Randy Cox, P.E. and Charles Stone, P.E. of the D-5 Construction Section for suggesting this article and for providing technical material and assistance.
- Marvin Heleman, one of the four original D-5 special welding inspectors hired by Mr. Pennybacker, for his information on the history of welding in TxDOT. Mr. Heleman is currently an Engineering Technician with D-5.

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6. Charlotte, ed. ***Welding Handbook: Fundamentals of Welding,*** Vol. 1, 7th ed. Miami: AWS, 1976.

THE SCRAP TIRE/ASPHALT-RUBBER ISSUE

Disposal of scrap tires is a national issue. It is no longer debatable whether it is really a major problem or not. Forty-four states have drafted, introduced, regulated, or enacted laws to control scrap tire disposal. Congress has legislated on the issue. A combination of forces coming from the asphalt-rubber industry and environmental interests has focused on the state highway agencies and the hot-mix asphalt (HMA) industry as a solution to the problem. In other words — use scrap tires in HMA pavements!

PERTINENT LEGISLATION

The big push for the use of asphalt rubber in pavements comes from Section 1038 of the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA). While this section in the ISTEA is about three and a half pages long, the three major points of concern to the industry are:

1. It removes the experimental classification from asphalt rubber. In other words, asphalt rubber may be approved the same as any other paving material, and patented application is eligible for approval for federal aid work under the same conditions as a non-patented process.
2. It requires research on the health, the environmental impacts, recyclability, and performance of asphalt-rubber by the Federal Highway Administration (FHWA) and the Environmental Protection Agency (EPA) in cooperation with the states.
3. It sets minimum use requirements for asphalt-rubber beginning in 1994. It requires that five percent of the federal aid tonnage in 1994 be asphalt-rubber, increasing five percent per year to 20 percent in 1997. A key point in the legislation, not often publicized, is that the minimum use requirements can be set aside or revised under certain conditions:
   - when the use of asphalt-rubber poses threats to human health or to the environment — greater than conventional HMA
   - when asphalt-rubber cannot be recycled to the same degree as conventional HMA
   - when asphalt-rubber pavements do not perform adequately as a material for the construction or surfacing of the highways and roads.

The Secretary of Transportation is to consider the results of the research mentioned in making any determination to set aside the minimum use requirements. The minimum use requirements may also be reduced if there is insufficient quality of scrap tires available in the state to meet the requirements because of other recycling or reprocessing uses.

CURRENT ACTIVITIES

It does not appear that any definitive research results will be available from FHWA and EPA before the minimum use requirements become effective in 1994. The law requires that the federal agencies report to Congress on the results of the research by July 1993. Any report to Congress by this date will only be a compilation of existing information.

The existing reports do not answer the question of environment, health, recyclability, or performance. It is expected the research contracts will be awarded by the FHWA and EPA early in 1993 to develop new information. With this timing, it is unlikely that there will be anything persuasive one way or the other by the end of 1993.

The National Asphalt Pavement Association (NAPA) developed a worker exposure testing protocol and sent it to the American Association of State Highway Transportation Officials (AASHTO), FHWA, EPA, and the Occupational Safety and Health Administration (OSHA) for comment. Worker exposure testing was done on an asphalt-rubber project in California using the protocol, but the results are not yet in.

[The Texas Department of Transportation has two research projects active, begun in September 1992, "Short-Term Guidelines to Improve Asphalt/Rubber Pavements (TTI 1332)" and "Recycling Second Generation Asphalt/Rubber Pavements (TTI 1333)," both with the Texas Transportation Institute (TTI). Guidelines and feasible methods of use should be in draft form by November 1994.]

There is no provision in the law that delays the minimum use requirement until the research is completed. However, if the data indicates problems, then a strong case could be made for such a provision.

AASHTO RESOLUTION

AASHTO, at its October 4, 1992, meeting, passed a resolution urging the U.S. Department of Transportation to provide more flexibility in meeting the minimum use requirements of the ISTEA. They requested that the USDOT, in its rule making, permit all highway-related applications be included in the minimum use requirements. In the event that the USDOT is unable to allow this flexibility, the resolution also provides that AASHTO will seek an amendment to Section 1038 of ISTEA to permit all potential transportation-related applications be included in the minimum use requirements.

*Source: **Nuggets and Nibbles*** 12 (Winter 1993), Cornell Local Roads Program, citing in part an article by Richard D. Morgan, Vice President of the National Asphalt Association, *in **ASPHALT*** 6(Winter 92-93*)*, Asphalt Institute.

OUR DANGEROUS SUN

(AND WHAT YOU CAN DO ABOUT IT)

DO YOU STAND A HIGH RISK OF CONTRACTING SKIN CANCER?

You are on the road every day. You're constantly exposed to the rays of the sun. Road maintenance and construction is hot, hard work. You're tempted to take your shirt off and throw your hat in the back of the truck. Beware: Experts warn that today's rays can develop into life-threatening skin cancer.

In fact, of all malignancies in the United States, one-third are skin cancers, says dermatologist Darrell S. Rigel, M.D., New York University Medical Center. People don't realize that tans and burns don't turn into cancer overnight, Dr. Rigel says. There's generally a 10 to 20 year delay. Today's statistics show what people were doing in the '60s, '70s and early '80s, he explains.

Says Derek Cripps, M.D., a University of Wisconsin Medical School professor of dermatology: "Your skin is like a bank account with a memory — it never forgets sunlight to which it's been exposed. Unless you protect your skin, there will come a time when it can no longer accept any more sun damage, leading to wrinkling, cracking and probably cancer."

GAMBLING WITH MELANOMA

Melanoma is the nightmare of all skin cancers. The New York University Medical Center has uncovered six factors that increase the odds of developing melanoma.

Determine your risk: Circle the factors that apply to you:

- Blond or red hair.
- Marked freckling on your upper back.
- Small, rough, red bumps on your skin from sun exposure.
- Family history of melanoma.
- Three blistering sunburns during your teenage years.
- Three or more summers of outdoor work as a teenager.

Understand your risk: If you circled one or two factors, your risk of melanoma is 3.5 times greater than your risk if you hadn't circled any. If you circled three or more, your risk is 20 to 25 times greater.

IF YOU MUST BE IN THE SUN, TAKE EXTREME PRECAUTIONS

There's no such thing as a safe tan, according to the American Academy of Dermatology. Never seek a tan by sunbathing or using tanning lamps, the Skin Cancer Foundation warns. But sometimes you just have to be in the sun. When you do, experts advise:

Avoid tanning binges. Melanoma tends to hit people who try to tan quickly.

Choose a sunscreen with a sun protection factor (SPF) of at least 15. People with light complexions should choose at least SPF 20. Blonds and redheads, at least a 30.

Block UVA and UVB (two types of ultraviolet light linked to cancer). Broad-spectrum sunscreens, such as those containing benzophenes (oxybenzone), cinnamates and salicylates, can provide protection against both UVA and UVB.

Apply sunscreen liberally, at least 15 minutes before you go out. For continued protection reapply every two hours if you're perspiring. Also reapply sunscreen immediately after swimming.

Protect lips and eyes. Use a lip balm that contains sunscreen. Wear sunglasses that filter out both UVA and UVB radiation.

BEST CURE: PREVENTION

If you take a few precautions there's no reason to hide inside.

Always use sunblock with an SPF (sun protection factor) of at least 15 to protect your skin.

Avoid long exposure. Don't expose your skin to the sun any longer than necessary. Wear long-sleeved shirts, pants, and a brimmed hat. Sit in the shade for the greatest natural protection.

Check with your doctor or pharmacist to make sure you're not taking a medication that could make your skin more sensitive. You might also ask about hypoallergenic products.

Stay out of the midday sun. To reduce your skin's UV exposure by 50 percent, avoid direct sunshine during the two hours around high noon, according to the U.S. Department of Public Health.

Examine your skin monthly. Pay particular attention to changes in size, color, shape or thickness of moles, birthmarks or other irregularities. Report these and any unusual symptoms to your physician: a growth that begins to itch, hurt, crust, scab, erode or bleed.

*Excerpted by Oregon's T^2 Center from **ROAD BUSINESS**, 7 (June 1992), produced by U. S. DOT, FHWA.*

TIP

To promote interest in routine safety meetings, have employees take turns selecting and presenting safety topics. Once a year, have employees vote on the most interesting or useful presentation — and give the winner a small gift or an award certificate.

Source: Patricia Booth, County of El Dorado, 360 Fair Lane, Placerville, CA 95667, as seen in ***Communications Briefings*** 11(Oct. 1992):1.

THE BENEFITS OF U. S./MEXICAN INTERMODALISM

by **Robert Harrison**
Associate Director
Center for Transportation Research
The University of Texas at Austin

INTRODUCTION

The U.S. border with Mexico is in the spotlight. Federal, state and trade agencies on both sides of the border are expressing interest in economic and environmental concerns accompanying the growth in trade. Clearly, much border infrastructure is inadequate for projected traffic levels, but highway investments alone cannot solve the challenges facing the United States and Mexico with regard to the movement of freight and passengers. Simple forecasting of traffic patterns in this complex international economic situation could yield drastically wrong answers. New methods of planning are needed to ensure proper funding of an efficient mix of transportation modes.

Several Texas universities have been working in cooperation with the Texas Department of Transportation (TxDOT) to solve border transportation problems for more than a decade. Their efforts have resulted in such things as the "Border Base," a socio-economic database devoted to the border regions [Ref. 1]. In general, the smaller universities have tackled specifics of forecasting future traffic, while the larger universities are working on issues related to integrating statewide and border multimodal planning [Ref. 2]. Six studies are currently active (Table 1).

This article summarizes some of the insights gained and outlines the benefits of U.S. intermodalism with Mexico in light of recent and on going research.

SIGNIFICANT CHANGES IN US/ MEXICAN TRADE

U. S./Mexico tariffs fell from 80 percent to 12 percent after the GATT (General Agreement on Trade and Tariffs) agreement of 1986. Trade between the U.S. and Mexico doubled between 1987, when it was $34 billion, and 1990, when it reached $62 billion. Forecasts for 1992 suggest that the trade will total over $76 billion [Ref. 2]. Mexico is now the third largest U.S. export market after Canada and Japan, and this trading partnership is likely to increase significantly over the next decade. In the proposed North American Free Trade Agreement (NAFTA), various forecasts have been made of the changes in annual gross domestic product (GDP) over the next five years. Of the three nations, Mexico is predicted to have the most significant change in GDP, with a growth of between four and six percent between 1992 and 1995 [Ref. 3]. This change in GDP will stimulate trade and it is likely that freight traffic will continue to flow strongly over the next five years, with or without a NAFTA agreement.

TABLE 1: Active border studies for TxDOT.

STUDY NUMBER	TITLE	PERFORMING AGENCY
1312	Truck Traffic in Laredo, Texas — A Case Study of Issues and Remedies	CTR
1317	The Impact of a U.S./Mexico Free Trade Agreement on the Texas Highway Network	TTI
1319	Multimodal Planning and the U.S./Mexico Free Trade Agreement	CTR
1976	Texas/Mexico Toll Bridge Study	CTR
2034	Measurement of the Impact of International Truck Traffic on the Texas Roadway Network	TTI
2036	Border Crossing Automatic Traffic Recorder Counts	TxDOT

FREIGHT PATTERNS

How does this freight move? Trade to Mexico from the U.S. in 1990 constituted about 21 million tons by surface transport and 12 million by maritime vessels, with a very modest (but valuable) tonnage by air (Fig. 1). Tonnage to the U.S. from Mexico is dominated by petroleum products, at over 47 million tons and transported by vessel. A small but positive amount flows by air, while about 20 million tons travel by surface modes [Ref. 4]. Much of this surface transportation is funneled through four key gateways between the two nations. These are San Diego in California, Nogales in Arizona, and El Paso and Laredo in Texas. Trade in terms of rail and trucks has been growing strongly in recent years. In 1991, over 120,000 loaded rail cars passed through Laredo to Mexico, while truck traffic has grown most strongly at El Paso and Laredo (Fig. 2). The traffic to Laredo is now around 600,000 loaded trucks per year while that for El Paso is about 500,000, mostly associated with maquila trade.

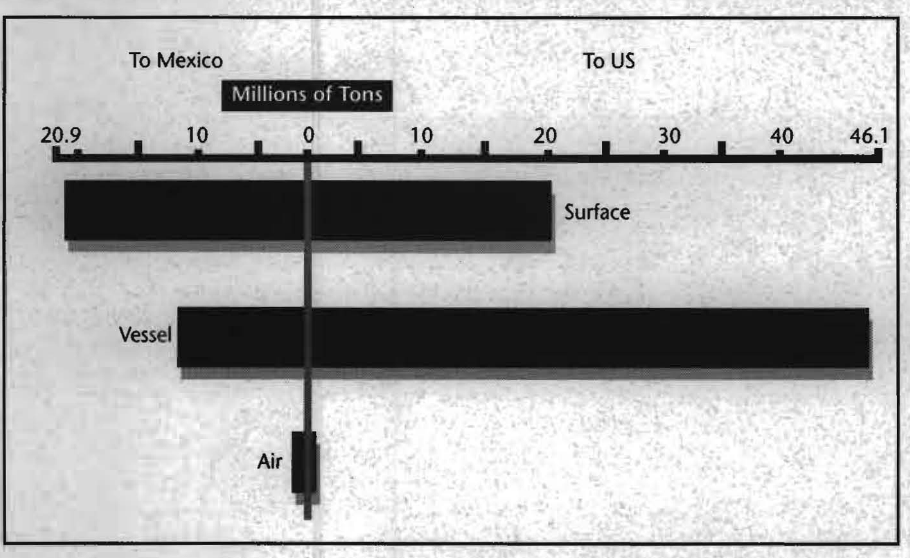

FIGURE 1: Modal tonnage by direction, 1989 [Ref. 5]

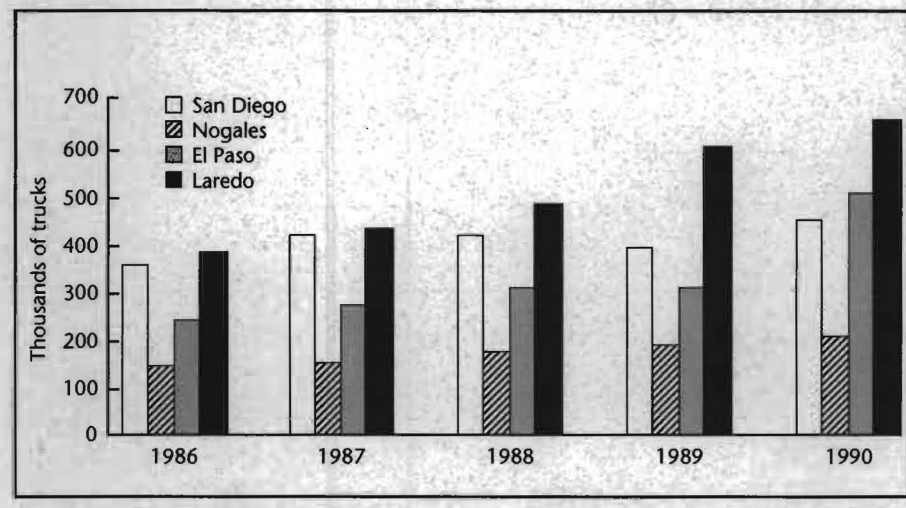

FIGURE 2: Trucks processed at southwest border [Ref. 10].

Over 80 percent of the vehicle miles of travel of maquila production is by truck, and trucks dominate the surface transportation flows. However, this has severe costs given the current processing of trucks at both U.S. and Mexico Customs points and the need to cross the Rio Grande over designated bridges. Mexican railways (FNM) lack the appropriate support to complement the U.S. railroads, and this has inhibited intermodal competition. As currently constituted, the border is a barrier to efficiency in terms of congestion, air pollution, handling costs, and highway damage caused by the passage of heavy trucks.

The central planning question is simple. Will traffic persist in growing and how will it be carried? First, trade is likely to grow with or without NAFTA, since tariffs are already low. However, it is also true that NAFTA would stimulate the recent growth in trade. One key projection, produced for the Border Trade Alliance, suggests that total trade between the U.S. and Mexico could reach $125 billion by 1995, $225 billion by the year 2,000 and $430 billion by the year 2010 [Ref. 5]. Economic forecasting is notoriously difficult but even if these projections are only half right, such massive increases in trade will cause additional serious constraints to efficiency if changes are not made to the way goods are transported.

TRADE STRESSES

Trade is putting enormous stresses on border infrastructure, and these are seen most critically at the key gateways where freight is processed between the two nations. Railroads have recently streamlined their processing and in any event, do not share track with other users. In other words, if problems occur in processing loaded rail cars, it is the railroads themselves that suffer. Their rail systems become saturated and congested, and they then absorb the full costs. However, the same is not true of truck traffic. It is not just a case of simply transferring traffic from one side of the border to the other with the same equipment. Complex arrangements (Fig. 3) are currently made in order to clear customs and meet other fiscal requirements, and a complicated system of drayage has resulted in high numbers of loaded and unloaded vehicles traversing border cities. This complex system has caused the following series of social, economic, and engineering problems:

- Street damage. Heavy trucks running over inadequately strengthened pavements have caused rapid deterioration, interfere with the passage of other vehicles and created serious problems for city street maintenance and rehabilitation budgets (Fig. 4). Heavy vehicles have damaged large sections of city streets, and these deteriorated streets then cause damage to vehicles in a vicious circle of spiraling costs [Ref. 6].
- Safety and pollution. Large numbers of trucks, often with old and inefficient tractive units, create problems with respect to the safety of both highway users and pedestrians, and cause increased pollution through exhaust emissions. Truck pollution and congestion are closely related.

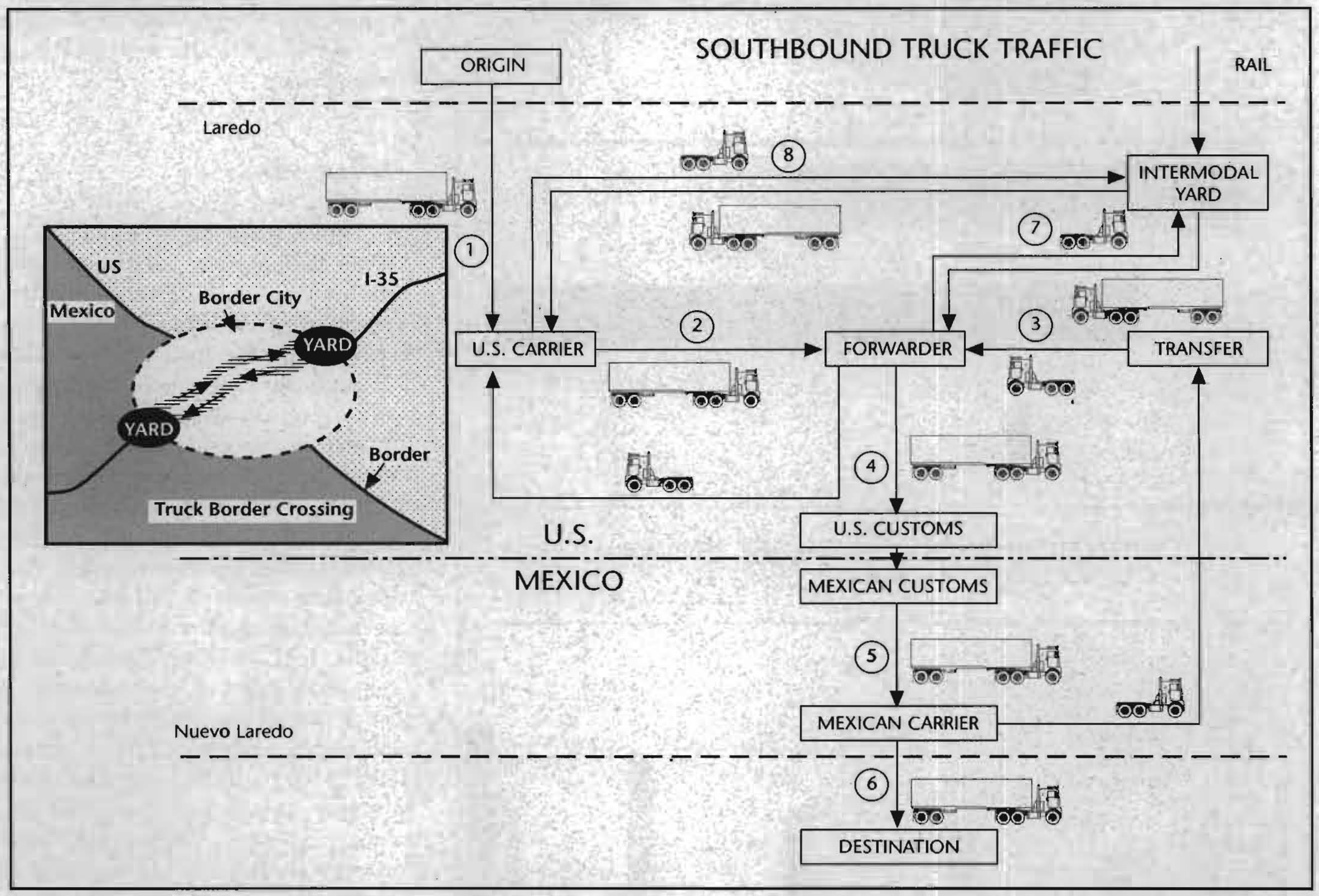

FIGURE 3: Complex arrangements — an example of crossing patterns for southbound truck traffic in Laredo [Ref. 7].

- **Customs.** Customs arrangements plus immigration controls and drug enforcement procedures all have inhibited efficient border transfers. Moreover, customs stations are frequently inadequately staffed and are not able to rapidly process the volumes of traffic wishing to cross the border. This is being closely examined in the harmonization subcommittees under the proposed NAFTA.
- **New bridges.** A number of new bridges have either been recently completed or are proposed, yet they all remain as projects rather than part of a coherent planning process in South Texas aimed at allowing transport to efficiently flow in the next century.
- **City planning.** Many border cities have old street systems and are now moving into newer systems involving inner and outer loops. With these new loops comes added potential for new crossings into Mexico, with large surface areas researched for the transfer of goods through customs and immigration processes. However, this potential has resulted in great competition for both crossing permits and financing sources. This competition has manifested itself in a variety of ways, but po-

FIGURE 4: Congestion in Nogales. Scenes like this are found at every border crossing.

litical lobbying and pressure is now evident in South Texas. Political lobbying is not a desirable mechanism for planning efficient, coherent infrastructure.

- **Cost recovery**. If new facilities are to be provided, then they should be funded primarily from those that benefit — namely the rail companies for rail bridges, and truckers for highway bridges. In Laredo, there has been a constant and significant growth in truck traffic and this should provide the basis of the user cost mechanism.
- **Revenue generation**. Obtaining taxation for such schemes as highway improvements through a new mechanism is always extremely unpopular. However, on the border there is one distinct advantage. In order to cross into either Mexico or the United States, a fee is paid to the bridge authority. In Laredo, for example, the tolls taken on the bridges first reimburse the bonds for the construction of the bridges and their maintenance, and then the surplus funds are used by the city of Laredo for general expenditures. For Laredo, this surplus amounts to over $3 million annually, while in El Paso it exceeds $10 million [Ref. 7]. An element of these general expenditures is city street investment, and in 1991, 16 percent or $1.8 million was used for Laredo street reconstruction. Therefore, bridge tolls could be increased to raise the revenue required to provide an effective truck street system.

TYPES OF INTERMODALISM

Intermodalism can take many forms. The oldest intermodal facility is the port, where ships transfer cargo to a variety of surface and river modes. Airports are also good examples of passenger intermodal facilities. Intermodalism in the context of Texas/Mexico trade focuses on two key modes, namely trucks and rail, although water transport may become more important if we follow Japan's lead. The Japanese are constructing a modern mechanized container port in Topolobampo, Mexico.

U. S. Rail Intermodalism

Intermodalism has been the driving force of modernization and profitability of the U.S. Class 1 railroads in the last decade [Ref. 9]. In year-to-year changes, there continues to be strong growth in vans and containers on U.S. rail intermodal routes. This growth in intermodal traffic has demanded greater efficiency throughout the industry and has enabled rail services for the first time to rival the efficient service provided by truckers in door-to-door service.

Rail intermodalism is characterized by large, efficient intermodal yards where cranes lift trailers and containers onto flatcars, usually in less than a minute (Fig. 5). Sometimes two containers are placed on each other in specially constructed articulated chassis and these "double stacks" (Fig. 6) have become an even more profitable way of hauling bulk transport. Indeed, many maritime shippers now unload at the East Coast, use double stacks to move to the West Coast, and then reload onto container ships for the Pacific Rim rather than go through the Panama Canal.

Can the lessons learned from U.S. rail intermodalism be transformed into improving the traffic between U.S. and Mexico? To answer this question, it is

FIGURE 5: An intermodal yard crane lifts a semitrailer onto a flatcar.

FIGURE 6: A double-stacked container train bound for Mexico City.

constructive to break intermodal activities into those at the border and those deep within continental Mexico.

Border Intermodal Yards

Two key intermodal yards serve the U.S./Mexico border. Southern Pacific operates one in El Paso serving the maquiladora industry, while Union Pacific has constructed a $12 million facility 12 miles north of Laredo, near IH-35. At the latter site, more than 1,000 containers and trailers can be stored, and there is the capacity for two intermodal trains to be loaded and unloaded simultaneously (Fig. 7). From this yard, three double stack trains are run weekly to Mexico City, and there is a growing use of the facility by truck/rail partnerships such as J.B. Hunt on Chicago corridor.

These border intermodal yards have been tremendously successful, far exceeding the predicted traffic volumes first made by the railroads when they were evaluated at feasibility level. Indeed, Union Pacific is enhancing its capacity at Laredo because demand has grown so strongly. Therefore, it can be claimed that intermodal terminals at the border are helping, but there remain problems: truck traffic still has to cross the border cities in order to get to the U.S. intermodal terminals. However, using the new bridges being planned across the Rio Grande, intermodal traffic may possibly come to the border from Mexico on truck to be transferred to rail, or arrive at the border on rail from the U.S. to be switched to truck at the border for delivery within the northern industrial sector of Mexico. Border yards will likely continue to play an important role in alleviating congestion at the border.

Continental Intermodalism

Mexican continental intermodalism, however, remains a real challenge. The Mexican government must continue to either invest, or find private investors willing to commit funds to other modes. In particular, the degree to which intermodalism can be successful in Mexico depends on four factors:

FIGURE 7: Union Pacific's intermodal facility near Laredo.

- the success of the current highway infrastructure investment program;
- the modernization of FNM;
- the development of ports and port handling; and
- the emergence of an intermodal planning process where investments can be channeled into appropriate areas to encourage efficient intermodal activities.

U.S and Mexico railroads face very difficult challenges if they are to solve many of the problems individually. First, they themselves have congestion at border crossings. Moreover, although it is investing significantly in control and infrastructure, FNM has problems with terminals and motive power requirements, together with control and communications. These latter are critical in terms of location of containers and vans so that they can be tracked and collected efficiently. However, railroads seem to have taken the first step of solving problems cooperatively. U.S. and Mexican railroads are working to expedite customs facilities and U.S. railroads are helping by providing terminal knowledge and motive power. Moreover, they are providing run-through trains, and Southern Pacific is helping FNM develop its ferropuertos sites.

CONCLUSIONS

Current concerns about future trade growth between U.S. and Mexico are related to the belief that the numbers of trucks generated by the growth will be extremely damaging to the network of roads along the border. Intermodalism offers a different solution and suggests that movements using Mexican ports and Mexican rail systems which link with U. S. rail systems, together with truck movements out of Mexico and onto U. S. rail intermodal terminals at the border, will reduce in the truck traffic volumes currently predicted from historic bridge crossing data.

To be successful, intermodalism needs a coherent planning process and significant infrastructure investment. In the short to medium term, maquiladoras and new production centers will shift south to find a new labor force, and Mexican trucking can not support substantial rapid trade growth in the next five years. FNM needs to develop a network of intermodal yards within its system, emphasize the shipment of container export traffic growth, adopt a new marketing attitude, and reduce its labor force so that it can be cost competitive. This, then, will enable it to form important strategic alliances with truckers of all sizes to complement the system of distribution within Mexico.

Continental intermodalism seems to be a promising alternative to reliance simply on highways and trucks. Without an intermodal system, people on both sides of the border face higher transport costs, increased highway wear and increased air pollution. Research suggests several recommendations for intermodal planning. These are:

- develop a planning process that stimulates true intermodalism based on unsubsidized, economic cost data.
- develop cross border international infrastructure planning so that highway, rail, pipeline and other modes are seen as a *system*, and not as simple projects competing for certain limited resources.
- the truck size and weight regulations in both countries need to be strictly enforced to preserve the enormous amount of investment made by both countries in their highway infrastructure.
- additional truck routes through border cities should be made to improve efficiency and lower costs and the investments should be recovered through a toll increase at bridges.
- customs should be streamlined and relocated away from central business districts and larger areas, preferably on new bridge sites.

Transportation engineers, industrialists (both large and small), and highway agencies should have an interest in stimulating the growth of U.S./Mexican intermodalism. The desire to stimulate Mexican trade and its economy will result in a greater need for efficient freight movements. Long distance travel for freight, which can be complementary in nature between modes, will become efficient and result in more money being available for urban transportation systems. Moreover, the system will then complement that evolving in the United States, to make one complete continental system to the benefit of both nations.

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EUROPEAN PAVEMENT INSPECTION TOUR

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INTRODUTION

Seven engineers [from Michigan Department of Transportation] returned from a 12-day tour of Europe on October 22, 1992. The purpose of the trip was to gain insight into European pavement design and construction practices for possible application in the United States.

Funding levels for transportation in Germany are higher than in the United States. Gas prices are about 1.5 marks/liter, which includes a tax of about 0.6 marks, or about 40 percent of the fuel price. Equivalent cost in the U. S. would be $4.00/ gallon, with a $1.60/gallon gas tax. A vehicle tax based on engine size is paid on a yearly basis. These funds are spent for both highway and railroad construction.

Truck axle load characteristics in Germany are much different than in the U. S. Single axle loads are allowed to be 25.3 kips and will be increased to 28.6 kips in 1993. [Note: the measurements used in this article have been converted from the metric system.] Single, super tires (inflated to 125 psi) are permitted on the single axle. The new axle weights will be uniform throughout the European Community.

Vehicular volume on their freeways is normally 40,000 to 60,000 per day with 25 to 40 percent being trucks. This volume of truck traffic, use of super tires, and relatively high single-axle loads permitted there requires the pavement design thickness to be greater than that in the U. S.

AUSTRIA

Design

An unusual feature of the Austrian design is that three layers of asphalt and subbase are placed for a new roadway. After completion, these three layers carry traffic for five to seven years to allow settlement to occur. The ruts and bumps created in the asphalt are then milled, weak spots in the subbase revealed by traffic are replaced, and a concrete pavement is placed on top of these layers. There are no problems with the concrete bonding to the asphalt subbase layer because the five to seven years of traffic wears the surface to an irregular, open pattern. This procedure is used to accommodate the mountainous terrain which requires widespread use of embankments on the sides of the mountains to accommodate the roadway.

The concrete pavement consists of a two-layer monolithic (wet-on-wet) construction. That is, fresh concrete of the top layer is placed on the fresh concrete of the bottom layer in one continuous operation. This pavement is typically 8.7 inches total thickness, 7.1 inch (the bottom layer) is made from their standard concrete and the top 1.6 inch consists of a premium concrete with an exposed aggregate surface treatment. Transverse joints are spaced at 16.4-foot intervals, and the concrete pavement is not reinforced. Dowel bars in transverse joints are variably spaced, with a closer dowel bar spacing used in the wheel paths.

The exposed aggregate treatment used in Austria since 1989 is a patented process, and is performed only on the traveled roadway, with a burlap drag treatment used on the shoulder. Because of the random pattern of the exposed coarse aggregate, tire noise level generated by traveling vehicles is decreased. The friction characteristics are comparable to a transverse tined surface due to the aggregate surface roughness and high resistance to polishing.

The process of exposing the aggregate consists of spraying a retarder on the top surface immediately after finishing, then covering immediately with 2-mil plastic sheeting. The joints are saw cut through the plastic sheeting within 24 hours. The plastic sheeting is removed within 24 to 72 hours and the retarded concrete surface is dry wire brushed to remove the surface mortar and expose the coarse aggregate particles.

Materials

Concrete — The top layer of premium concrete normally contains 759 lb of cement/cu yd with a water/cement ratio of less than 0.40. It is superplasticized and contains about 4 percent entrained air. Compressive strength from the top cores tested at 28 days is typically about 8700 psi. The bottom layer, consisting of their standard concrete, contains 590 lb of cement/cu yd. The water/cement ratio is 0.42 and a retarder is normally used. Entrained air of 5 percent is used for this bottom layer, and 28-day compressive strength from testing the second layer cores is typically about 5075 psi. The mix is very stiff, with essentially zero slump.

Coarse Aggregate — Coarse aggregate in the top layer is a basalt consisting of sizes from 0.16 to 0.32 in. The bottom layer coarse aggregate is typically a high quality natural gravel. Both top and bottom layer coarse aggregates have high resistance to freeze-thaw damage.

Exposed Aggregate Surface Treatment — The retarder that is used in the exposed aggregate process can be either a sugar-based admixture (red color tint), which provides about 0.04 inches of exposed aggregate when completed, or a citric acid chemical-based admixture (green color tint), which provides about 0.08 inches of exposed aggregate. These retarders are color-tinted in order to visually check for uniform application rates. The citric acid chemical-based retarder also acts as a curing compound; however, the sugar-based does not.

Sample Analysis — A thin wafer of pavement section and a sample of the coarse aggregate contained in the top layer of the pavement were brought back from Austria for a petrographic examination. It appears that sources for the high quality coarse aggregate required in both the top and bottom layers are available in the state of Michigan for use in a trial pavement.

Construction

The Austrian construction methods are similar to those employed in Michigan. The major difference was the paving operation. A short paver was used for both the bottom an top layers of concrete pavement. These pavers ran in tandem with concrete being delivered to the second paver by a conveyor. Line and grade control were established for each paver. The first paver had a dowel bar inserter, mounted on a beam, which allowed variable spacing of the dowel bars. Both pavers contained an auger and a screed. The process is not labor or equipment intensive.

GERMANY

Design

The current concrete pavement design in Germany consists of a 10.2-inch concrete pavement without steel reinforcement. The pavement is constructed in two layers, wet on wet, using a burlap drag surface finish. This is placed over 5.9-inch lean concrete base. These two sections of concrete are placed over a 11.4 to 19.3 inch thick layer of granular material that is not frost susceptible. Climate and soil conditions dictate the thickness that will be used. This layer serves as structural support for the pavement and is drainable.

A 16.4-foot transverse joint spacing is used with variably spaced, plastic-coated dowel bars. The dowel bars are spaced closer together in the wheel paths. The lane ties are epoxy coated in the middle one-third of the bar only, and three to four ties are inserted in each slab. Transverse and longitudinal joints are saw cut in the concrete pavement, and are either saw cut or vibrated into the lean concrete base. Joints that occur in the lean concrete base will have a joint directly above them in the concrete pavement. Elastomeric seals are used for both the longitudinal and transverse joints.

It is anticipated that the bond between the concrete pavement and the lean concrete base will last about five years. Initially, the debonding starts at the joint and works its way toward the center of the slab. Subsurface drainage is required because this bond of the pavement to the base is not permanent. This entails an enclosed drainage system (using edge drains and sewers) in order to evacuate the water from the subbase.

Traffic lanes are 12.3 feet wide and the edges of the concrete pavement extend 1.6 feet beyond the traffic lane edge in order to provide good edge support for the wheel loads. Shoulders are paved with the full-depth concrete sections (pavement and lean concrete base) and are 8.2 feet wide. The lean concrete base extends beyond the shoulder 1.6 feet and provides good edge support.

The transverse and longitudinal joint operations are similar to Michigan's. The main difference is that the transverse joints are cut approximately one-third of the pavement depth, and a plastic cord is inserted to keep the saw cut clean. The notch for the elastomeric seal is then made. Elastomeric joint seals are used for the longitudinal joints as well. It was interesting to note that expansion joints are used only at bridges. It is the German's belief that there is enough concrete shrinkage in their 16.4 foot long slabs to accommodate the expansion that occurs in the summer months.

Materials

Concrete — The top layer of the concrete pavement contains 574 to 590 lb of cement/cu yd with a water/cement ratio of 0.4 to 0.45 and an air content of about 5 percent. The compressive strength at 28 days, measured using a 7.8-inch cube is typically about 5075 psi. The bottom layer of the concrete pavement has a mix design similar to the top. The lean concrete base mix design has a water/cement ratio of about 0.8 and an air content of 5 percent. The compressive strength of this lean concrete base, based on using a 7.8-inch cube, is about 2175 psi.

Coarse Aggregate — In the concrete pavement, the top layer coarse aggregate consists of crushed basalt and high quality natural gravel. The bottom layer coarse aggregate consists of high quality, natural gravel or recycled concrete. In the lean concrete base, natural gravel or recycled concrete is used.

Frost Inhibiting Layer — The granular material that is used for this layer is different than that used in Michigan because not more than about 15 percent is permitted to pass the No. 100 sieve. The intent of this layer is to provide structural support and allow water in the subbase to escape. This is accomplished by allowing very few fines in the granular material.

Edge Drains — The edge drains that were being placed were smooth-lined corrugated plastic pipe with an inner diameter of 4.7 inches. These drains are slotted and the slots are placed facing up in the trench. The drains were not wrapped with a geotextile fabric even though crushed rock was being placed in the trench for backfill.

Sample Analysis — Samples of aggregate used for the top layer of the concrete pavement and samples of crushed concrete used for the bottom layer of the concrete pavement were brought back from Germany for a petrographic analysis. The results of this analysis indicate that similar sources of the coarse aggregate are available here for use in trial sections.

Construction

The lean concrete base is placed with a typical concrete paver. Longitudinal and transverse joints are cut or vibrated into the lean concrete base when wet. The lean concrete base is paved outside the concrete pavement width. This provides a level, solid base for the paver, which results in a smoother concrete pavement surface and a better ride. The lean concrete base is mixed in a typical concrete plant, and no special equipment is required for its construction.

The two-layer, monolithic (wet-on-wet) concrete pavement is slightly different from typical Michigan concrete paving. The German paver has two augers and two screeds. The paver resembles two pavers in one. Concrete is dumped in front of the paver for the first auger and screed. Approximately two-thirds of the pavement thickness (bottom layer) is placed in this operation. A dowel bar and lane tie inserter then installs the bars in the fresh concrete before the second auger and screed places the top layer of pavement. Concrete for the second auger and screed is delivered by a conveyor after dowel bar and lane tie insertion.

In Germany, the contractor is responsible for line and grade of the pavement, the concrete mix design, and quality control testing. A four-year warranty from the contractor is required. No cracks in the pavement is the condition required by this warranty and a portion of the contract price withheld by the owner until the end required by this warrant to cover repair cost is of the warranty period.

TRIAL PROJECT

A trial section using a combination of German and Austrian designs has been selected for a 1993 demonstration project by the Michigan Department of Transportation. The trial section is on northbound IH 75 and will be approximately one mile long located between IH 94 and IH 375 in downtown Detroit. The entire project is 2.1 miles long and includes replacing both the northbound and southbound concrete pavements. [Michigan DOT] conventional concrete pavement design will be used on the remaining portion of the project to serve as a control section. The selection of this section was, in part, based on review of the weather data of Munich, Germany as compared to that of the Detroit City Airport. The average high and low temperatures of these two cities compare very closely.

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