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REDFISH BAY AND MORRIS & CUMMINGS CUT: INNOVATIONS IN BRIDGE CONSTRUCTION AND DURABILITY

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INTRODUCTION

The Redfish Bay and Morris & Cummings Cut Bridges are located in the Corpus Christi District on SH 361 between Aransas Pass and Port Aransas near the state ferry crossing. These bridges are situated along the Gulf Intracoastal Waterway, a very corrosive environment, on a heavily traveled stretch of highway that is one of two links to Mustang Island. If this route were closed to traffic, the detour would take travelers up to 67 additional miles to reach the city of Port Aransas. Therefore, when salt-water-induced deterioration necessitated replacement of these bridges, it was imperative to minimize the impact of bridge replacement on the traveling public and maximize the service life of the replacement structures.

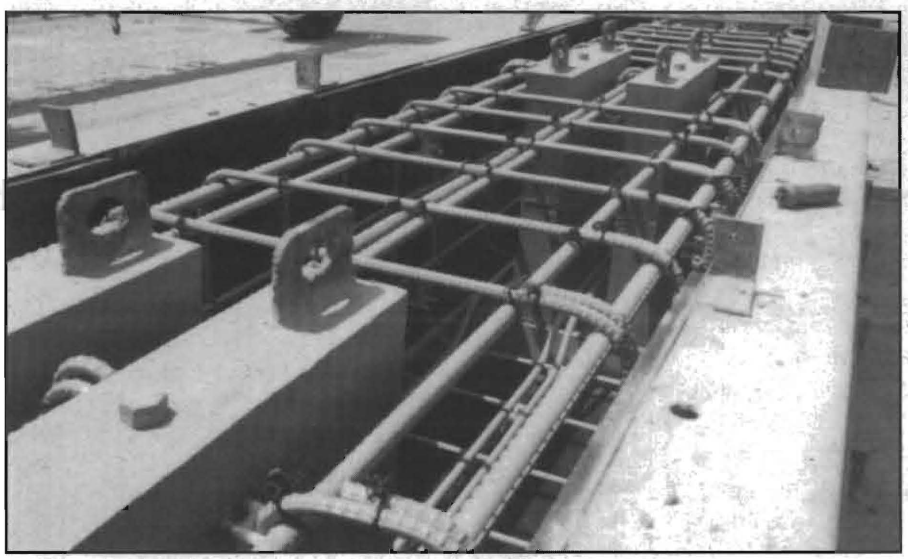

FIG. 1: Epoxy-coated reinforcing steel and slotted void forms coated with concrete set-retarding agent in precast bent cap forms.

CONSTRUCTION DETAILS

Both Redfish Bay and Morris & Cummings Cut Bridges were originally designed with cast-in-place bent caps on precast piles. The contractor, F&E Erection, requested to precast the bent caps to avoid the hardship of pouring concrete over water. They proposed a detail in which slots are cast in the precast caps that would then receive dowel bars protruding from the tops of the piles (Fig. 1). Each pile is cast encasing four 3-foot corrugated, galvanized steel sleeves opening at the top of the pile. The piles are driven with the aid of a steel frame that acts as a template to insure proper location. Because the piles must fit in a recess in the cap bottom, tolerances for pile location are critical.

After driving the piles, two #9 U-shaped dowel bars are epoxy grouted two feet into the top of the piles.

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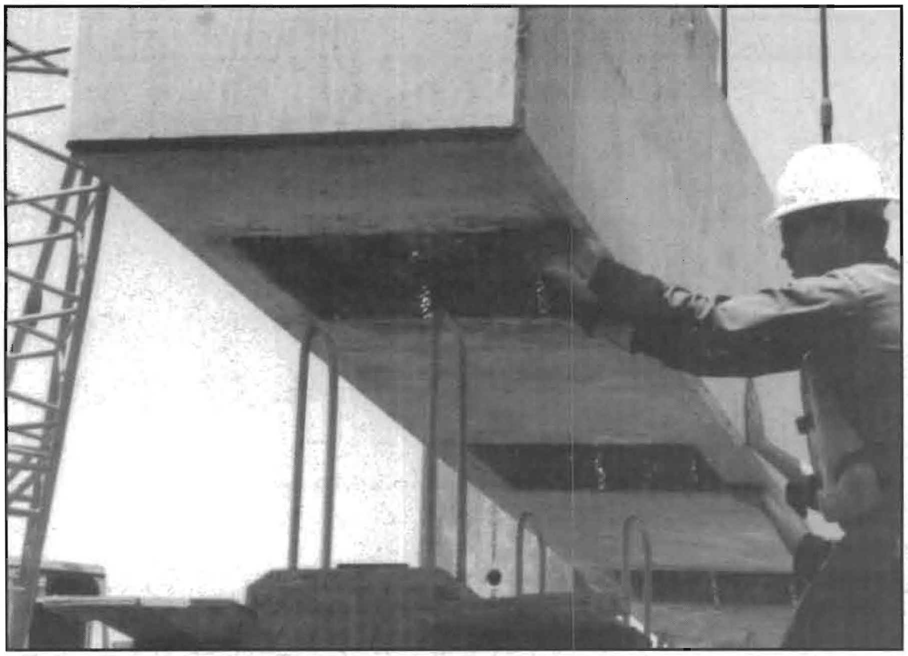

FIG. 2: Lowering precast bent cap onto precast and prestressed piles with u-shaped bars protruding from top of piles.

The steel sleeves are one foot longer than the depth of dowel embedment so that the top of the pile can be cut off to adjust for top of pile elevation. The precast cap is lowered onto the piles, with the U-shaped bars entering the slots in the cap (Fig. 2). Originally the caps were set down on shims on the piles, but due to slippage of the cap they were subsequently held up with friction collars at each exterior pile. After the cap is secured in place and top of cap elevations are verified (Fig. 3), the slotted voids in the cap are filled with concrete thus completing the cap to pile connection (Figs. 4 & 5). The concrete used here must meet all of the requirements of the bent cap concrete plus achieve an initial compressive strength, F'c of 4000 psi in 48 hours with shrinkage not to exceed 0.1 percent. The cement content was not less than eight sacks per cubic yard with a maximum 3/4 inch aggregate size. The accompanying photographs detail placement of a precast cap on piles with u-shaped bars in place and grouting the slotted voids in the cap.

The brackish coastal environment had exacted a heavy toll on the existing structures. Both Redfish Bay and Morris & Cummings Cut bridges were constructed in 1959 using "Concrete Slab and Girder Span" standards and class "A" concrete. Both bridges exhibited severe chloride-induced deterioration. This included cracking and spalling of the substructure and superstructure concrete members and partial sectional loss of reinforcing steel. The bridges had been repaired extensively. Many of the piles had been jacketed, and the bent caps and concrete girder stems had been patched over much of their area. In some places, the patches were already showing signs of cracking.

Severe exposure conditions dictate vigilant corrosion protection measures. Epoxy-coated conventional reinforcing steel and type II cement is being used throughout both replacement structures. An inorganic corrosion inhibitor containing calcium nitrite is being used in the piling, bent cap, and abutment concrete at a dosage rate of four gallons per cubic yard. This concrete additive should protect against up to about 13 pounds per cubic yard of chloride intrusion. The bent caps are precast which allow better quality control over field casting. Prestressed double T-beams were chosen for the superstructure because of their speed of construction. In addition, prestressed concrete members have exhibited excellent performance in corrosive environments. Under service loads, prestressed members are designed with an allowable tension stress in the precompressed tensile zone less than the stresses considered to cause flexural cracking in concrete. Therefore, very little flexural cracking is likely to occur to facilitate the permeation of chlorides. Class "C" concrete is used for the conventionally reinforced substructure members, class "H" concrete for the prestressed members and class "S" concrete for the bridge decks — all lower permeability mixes than the class "A" mix used for the original structures.

Costs

The cost of these corrosion protection measures is small compared

FIG. 3 Precast bent cap in place on top of piles. Note U-shaped bars in slotted voids with voids ready to be filled with concrete.

to the additional structure life anticipated from their use. Epoxy coating increases the cost of reinforcement by 25 to 50 percent. This equates to an increase in the cost of concrete in place of about three to four percent. The inorganic corrosion inhibitor used on this project, DCI, produced by the W. R. Grace Company, costs about seven dollars per gallon. This results in an increase in the cost of concrete in place of about five to six percent. Overall, the corrosion protection measures employed on this project have increased the bridge cost approximately five percent in exchange for an anticipated increase in structure life of about 50 percent, to an estimated 75 years.

Experimental Controls

Four research piles have to be driven within the limits of this project. The reinforcing steel in these piles will not be epoxy coated, and the inorganic corrosion inhibitor will not be used in two of these piles. These piles will be monitored as a control group to determine the effectiveness of the corrosion protection measures employed in the new structures under TxDOT Research Study 1300, ***Evaluation of Current Corrosion Protection Measures for Bridges.***

SUMMARY

Several innovative techniques were employed in the construction of the Redfish Bay and Morris & Cummings Cut Bridges. The project is currently about 50 percent complete and about four months ahead of schedule, due in large part to the use of precast bent caps. A "belts and suspenders" approach to corrosion protection with the use of epoxy-coated reinforcement, type II cement and inorganic corrosion inhibitor is anticipated to extend the life of the new structures well beyond that of similar structures lacking this added protection. Time will now be the true judge of the new structures resistance against the relentless onslaught of the sea.

FIG.4 : Filling slotted voids with concrete and vibrating into place.

FIG. 5: Completed interior bents. Note pile tops in background ready for precast bent cap placement.

CONGRATULATIONS, LLOYD!

Lloyd Wolf, P.E., coauthor of the preceding article, has received the 1994 M. D. (Mac) Shelby Award from the Center for Transportation Research at the University of Texas at Austin.

The award is given for excellence as a research project director for TxDOT. Mr. Wolf coordinated research efforts for the past four years for Project 1265, ***Structural Integrity of Epoxy-coated Reinforcement***.

NASA ROAD 1: CAN ITS STYLE OF ARTERIAL TRAFFIC MANAGEMENT WORK IN YOUR DISTRICT?

by **Janie Light**
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INTRODUCTION

Automobile manufacturers continue to make a concerted effort to build more fuel efficient and pollution-free automobiles, with a fair amount of success. This success can, to a large part, be directly attributed to the advent of the onboard computer that optimizes virtually all systems from the intake of combustion air to the exhaust of burnt hydrocarbons. Although their success is commendable, any reduction of fuel consumption and consequent reduction in environmental pollution is likely being offset by ever-increasing demands placed on the limited space within the right-of-way of our existing roadway networks.

In some of our major urban areas, this demand has reached staggering proportions, rendering the expansion of our networks ineffective. The fact that the acquisition of right-of-way within these areas has become increasingly expensive and difficult to obtain has been the stimulus for Texas Department of Transportation (TxDOT) to reconsider some of its previous solutions.

Economically, the proper management of the flow of traffic within these corridors emerges as the logical conclusion in providing immediate relief and gaining time to research the alternatives. For this reason, TxDOT is developing computerized traffic management systems for arterials, freeways, high occupancy vehicle lanes, and frontage roads. These four systems are designed to work with each other and can be used together to control corridors. Although the most obvious need for computerized traffic management systems is urban, arterial traffic management has rural applications as well.

This article discusses some of the features of TxDOT's Arterial Traffic Management (ATM) system, using the test case of NASA Road 1 in Houston as an example.

WHAT IS THE ATM SYSTEM?

The primary goal of the ATM system is to control individual intersections so they operate together enhancing the progression of vehicles along the controlled corridor. The ATM system includes the computer hardware, software, and control philosophy for an areawide traffic signal control system. It is designed to operate with any full-actuated NEMA controller. This feature allows the system to use traffic patterns that are dynamic enough to optimize the flow of traffic along an arterial corridor. The system is able to implement multiple traffic patterns and is intelligent enough to discern in *real time* when a change of pattern will enhance the through-put of vehicles.

Benefits

TxDOT's ATM system provides benefits to motorists, the environment, traffic operations personnel, and maintenance staff. Significant reductions in stopped delay, travel time, and the number of stops are all benefits an ATM system provides to motorists. These reductions, in turn, lower fuel consumption and vehicle emissions, preserving resources and controlling pollution. An ATM system provides surveillance of traffic conditions to help in incident management, as well, further reducing delays and preventing secondary accidents. The operator of multiple ATM system installations can manage these systems from one location, using one computer, and learning only one software package. Another advantage of TxDOT's nonproprietary ATM system is that intersection controllers are interchangeable. If one is damaged by lightning, for instance, instead of having to purchase a proprietary intersection controller to match the original brand, maintenance personnel can immediately install a TxDOT one.

HOW IT WORKS

The ATM System uses a distributed control concept. The *local control unit* (LCU) is located at each intersection and talks to the intersection control devices. The *system control unit* (SCU) is located on the project site and coordinates the operation of multiple LCUs on a real-time basis. The *manager* is usually located at a district office and provides remote monitoring and control capabilities. The manager software can be installed on multiple computers, providing control from several different locations (Fig. 1).

System Detectors

The ATM system determines the current traffic conditions from data it collects from up to 100 system detectors. These system detectors, mostly wire-loop-type, are located throughout the system. Their data is used to determine which pattern to implement.

The system detectors are very important for determining the current traffic conditions. If a system detector fails, a preprogrammed default value based on the time of the day and the day of the week is used as a backup in selecting patterns.

Patterns

A pattern is a set of variables that dictates the timing at each intersection. PASSER, a software program developed by the Texas Transportation Institute (TTI), calculates the signal timings required to accommodate a given traffic situation. The ATM System was designed with the idea of using PASSER II for pattern generation. However, any other analysis package may be used. The ATM System allows a total of 188 different patterns per subsystem.

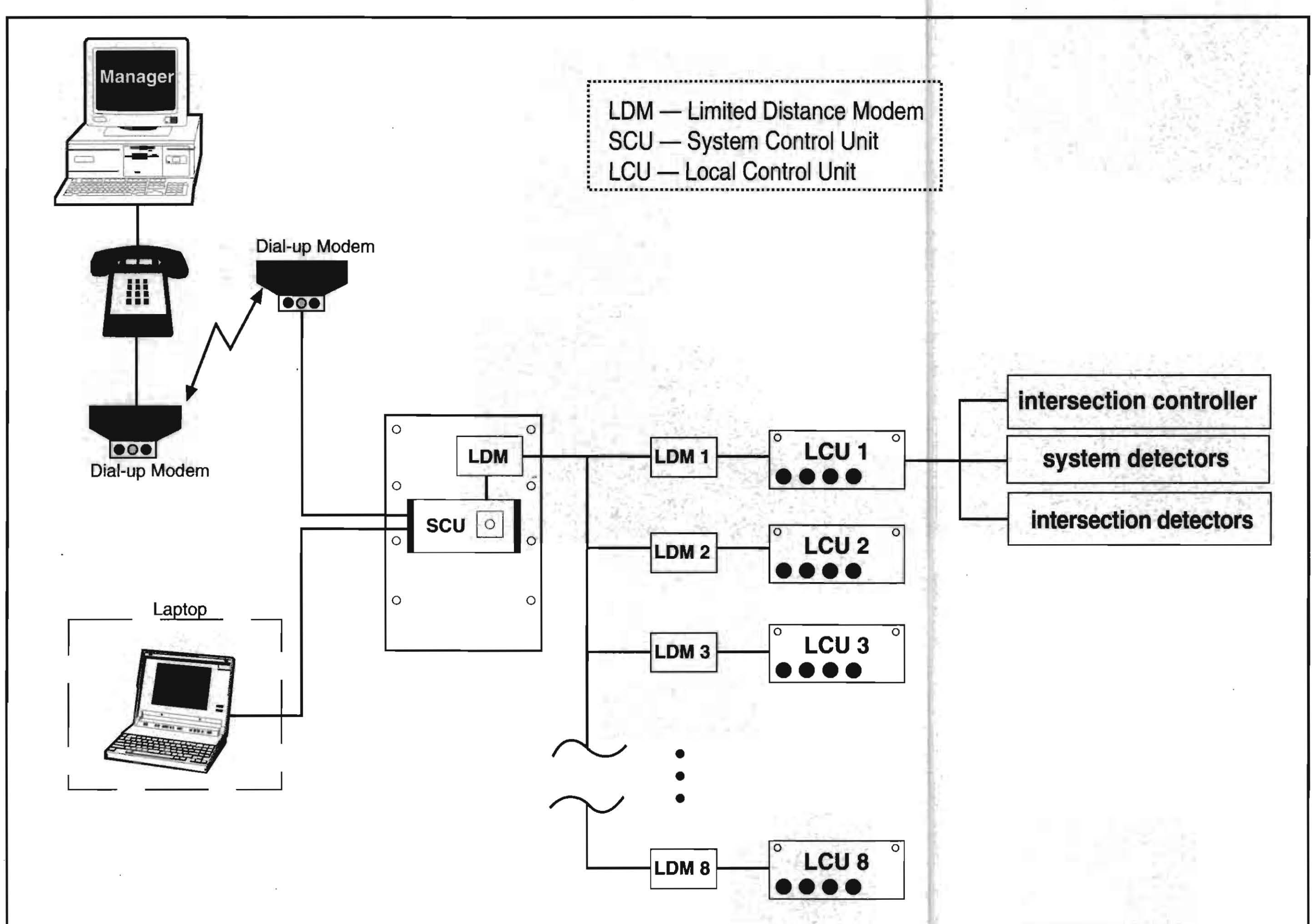

FIG. 1: ATM system block diagram. The manager computer(s), shown at left, is (are) located at the district office. Laptop computers may also be used to program or download information at the district office or at the field location as well.

Subsystems

The ATM System coordinates the operation of up to 64 individual intersections. These intersections may be grouped based on geometrical considerations or naturally occurring similarities in traffic flow conditions. Such a group of intersections is referred to as a subsystem and is the unit through which the ATM System achieves progressive traffic flow.

All intersections within a subsystem operate in the same way. Each subsystem can operate as an independent unit, and the operator defines which intersections are grouped into a subsystem. The ATM System allows the operator to define up to 5 subsystems.

Coordinating the operation of adjacent subsystems — called *subsystem locking* — enhances progression. Under certain conditions, adjacent subsystems implementing similar traffic patterns may lock onto a common pattern to extend the progression.

INTERSECTION CONTROL

The ATM system issues commands to the intersection controller (Fig. 2). By design, it cannot override the intersection controller's minimum green and clearance interval timings, which provides a fail-safe operation. Since it monitors the controller to verify the correct operation, the ATM System can detect when the controller does not respond to its commands. When this happens, a message is logged into a status report. A future version of the software will enable the ATM system to send in alarms to different day and night emergency telephone numbers. Operators on call can plug a laptop computer into a modem, determine the problem and, in many cases, resolve the problem remotely.

The ATM system can also detect other conditions, such as preemption operation or conflict flash operation. Once conflict flash operation is detected, the operator can command the ATM System to reset the conflict monitor without sending a technician to the intersection.

Subsystem Modes of Operation

The ATM System provides for the operation of intersections in a subsystem under three modes of operation.

- **traffic responsive mode**

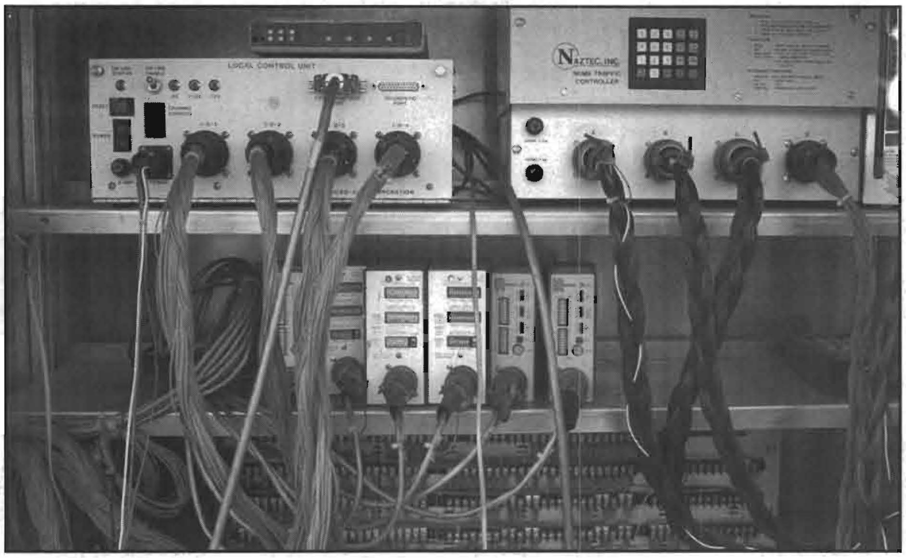

FIG. 2: Inside an intersection controller cabinet at NASA RD 1. The local control unit (upper left box) is the link between the other intersections in the corridor and the individual, nonproprietary intersection controller (upper right box).

FIG. 3: Janie Light demonstrates the NASA RD 1 Space Park intersection simulator at the traffic lab. Simulation of complex conditions with actual site traffic data is all-important. Timing plans may need to be adjusted before using them in the field.

- **time-of-day mode**
- **isolated mode**

The normal mode is traffic responsive mode where subsystem patterns are selected based on the current traffic conditions. When there are known surges of traffic, subsystem patterns can be selected based on the time of the day, called time-of-day mode. When traffic conditions allow the individual intersections to operate on their own, the signals may be removed from subsystem patterns and operated in isolated mode. Any intersection may be set to any of these three modes by an operator or by preprogramming a mode to activate at a specific time.

NASA ROAD 1

The NASA Road 1 site consists of eight signalized intersections. As reported by Doug Vanover of the Houston District, traffic congestion in this area is often heavy, with an annual average daily traffic (AADT) of 45,000 and PM peak hourly volumes reaching 3285 vehicles (one way, one hour, two lanes) at the Nassau Bay intersection. Clearly, a need exists for arterial traffic management.

The Traffic Management Section of the Traffic Operations Division (TRF) built simulations of each NASA RD 1 intersection controller cabinet, replicating the various different combinations of TxDOT local control units and nonproprietary intersection controllers (Fig. 3). The controllers power lighting arrays on their intersection's schematic board (top center of Fig. 3). These simulations, which use patterns generated from actual traffic count data from the NASA Road 1 site, give the Traffic Management staff a visual means of testing the behavior of patterns and timing sequences in the laboratory before loading the new programs into the system in Houston.

A study is planned to quantify reductions made by the ATM system to travel time, stop delay, and number of stops.

Other ATM Systems Coming On-line

The Houston District has several other corridors where ATM systems are coming on-line. State Highway 6 has a site that has been running under an ATM system since March of 1994. Westheimer (FM 1093) west of SH 6 and FM 1960 from SH 249 to IH 45 are in various stages of ATM implementation. The district is also designing other ATM systems.

HOW TO GET AN ATM SYSTEM

When a district decides that an arterial corridor warrants an ATM system, district traffic personnel should contact TRF's Traffic Management Section. Traffic Management personnel will work with the district to provide site design and installation (Fig.4).

CONCLUSION

Arterial traffic management systems cost significantly less than other types of improvements, such as building more lanes to increase capacity. The ATM system works with any brand of NEMA controller or with any combinations of brands. ATM systems are as valid for rural sites, such as around malls or small central business areas, as they are for major urban sites. Any arterial traffic can be efficiently managed with this system no matter where the arterial is located.

TxDOT's ATM system aids in the orderly movement of people and goods by controlling individual intersections such that they operate together to optimize the flow of vehicles through the controlled corridor.

For more details, contact Janie Light of the Traffic Management Section, Traffic Operations Division at (512) 416-3258.

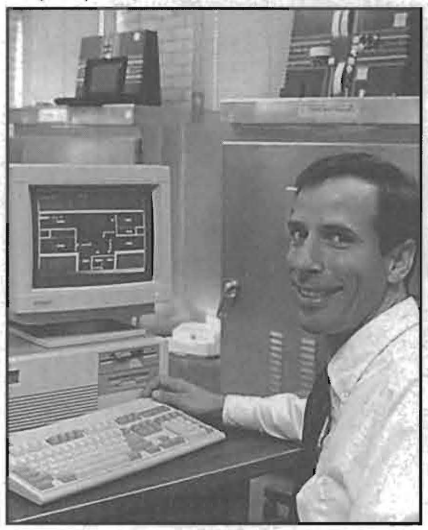

FIG. 4: Using the traffic lab's manager computer, Chris Harris reviews data on traffic flow through the simulated NASA RD1 corridor. The TRF Traffic Management staff are eager to help districts implement ATM systems.

The mentioning of brand names is strictly for informational purposes and does not imply endorsement or advertisement of a particular product by the Texas Department of Transportation.

METRICATION ANNOUNCEMENTS

"Opportunities for Improvement" is the theme for the metric booth, which will be part of the "Innovation Showcase," at the 1994 TxDOT Transportation Conference 17–19 October. Please stop by the booth and pick up a survey form, so that your ideas for improvement can be investigated. The video as well as other information provided at the booth will be distributed to each district and division after the Transportation Conference.

"Roadway Design In Metrics" is being taught through TxDOT during the months of August, September, October, and November 1994. This course covers the use of metric units in preparation of a set of plans. Contact your training administrator or Tom Rebstock, at (512) 483-3642, if you need additional information. Note that this class will be offered to consultants and local governments through the Local Technical Assistance Program at Texas A&M University. Contact Nelson Evans at (409) 845-4457 for additional information.

Have you received the July 1994 edition of the *Metrication Guide?* If you need to get a copy, please contact Lois Young, of the General Services Division, at (512) 465-7326.

AUTOMATION: PEN-BASED COMPUTERS FOR MAINTENANCE AND CONSTRUCTION INSPECTION FIELD DATA

by **Kelly West**
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INTRODUCTION

Crew chiefs from about 300 maintenance sections throughout the 24 TxDOT districts are required to manually record detailed maintenance activity data for every day of every job. Under similar requirements, highway construction inspectors tracking one $34 million project on about 3 miles of roadway monitored approximately 2,000 work items, generating paper records that filled five large file boxes. All of this paper work must eventually make its way into TxDOT's mainframe computer databases. Because this process is often time-consuming, is subject to numerous opportunities for error, and requires massive physical storage space, Texas Transportation Institute (TTI) researchers are coordinating with TxDOT's Construction and Maintenance Division (CMD) and selected districts to implement Pen Display Pad technology (Study 7-1991, Automating Data Collection at the Maintenance Section Level). This technology uses electronic clipboards or tablets to provide portable data entry for both maintenance crews and construction inspection personnel (Fig. 1).

FIG. 1: Bryan District Roadway Chief Reynolds McClure and TTI researcher Paul Chan discuss the pen-based, automated DAR.

THE AUTOMATED MAINTENANCE DAILY ACTIVITY REPORT (DAR)

The Problem with Paper

The maintenance "Daily Activity Report" (DAR, Form 1757) is made up of five major sections with a total of over twenty subsections. Information on the form ranges from highway number and reference markers for the job location, to employee names, work times, and signatures, to detailed equipment records and materials descriptions. The manually collected data passes from the crew chief's field notes, to the DAR form, and then to an office manager for review. Finally, it is key entered into four mainframe databases through the Single Entry Screen (SES). The databases include Maintenance Management Information System (MMIS), Equipment Operation System (EOS), Salary and Labor Distribution System (SLDS), and Material Supply Management System (MSMS). Clearly, this process requires excessive labor and time. Also, office personnel may have trouble deciphering handwritten data records kept in the field, introducing opportunity for transcription errors that are difficult to detect.

User Friendly Environment in the Field

Using the PenPal software development kit, TTI has designed a screen program — a computerized version — of the DAR for use with the GRiD Convertible 486 or PalmPad 386 pen-based computer. The PalmPad is 9x11x2 inches and weighs 3 lbs., and the Convertible is 11x9x2 inches and weighs 5 lbs. Both can easily be held in one hand, so entering data is as simple as filling out a paper form — especially since the electronic screen form retains a table format, helping the crew leader to quickly relate items to multiple data fields (Figs. 2–3).

The computer pen works like a mouse. To access different sections of the automated form, the crew leader has only to touch the screen in the appropriate data box. Then the pen tip is used to compose the data entry, either by touching fields from the alpha-numeric menu displayed at the bottom of the screen or by writing the information on the computer pad. Some data fields, such as crew and equipment lists, can be completed by simply touching the appropriate information displayed in an options list, also made available at the touch of the pen tip (Fig. 4).

The software also has built-in data verification. If a mistake is made, the computer will not accept the entry. For example, when entering the location of the job site, only certain reference marker numbers can be entered for certain highways; also, tasks, details, and function codes must match (Fig. 5). Crew chiefs can make corrections by simply drawing a line through the mistake and calling up the detailed option or function code list (of course, the option to hand write the information on the screen is always available).

Improving Speed and Accuracy of Data Transfer

After maintenance data is recorded in the pen-based screen program, it must be transferred to a PC in the area office and then to the mainframe for department-wide access to the crew and equipment information. To eliminate time-consuming transcription and typing, researchers working on Study 7-1991 are also developing two interface programs that will automatically execute the DAR data transfer. The first interface program will run on the maintenance section office PC with the following four features:

- **update** the equipment list and/or crew list, and download the updated list to the pen-based computer;
- **receive** DAR data from the pen-based computer;
- **view, edit, and print** DAR data; and
- **perform** a secondary level of data validation in addition to the first level performed through the pen-based computer out in the field.

Another interface program will also be developed on the mainframe computer. TTI researchers will work closely with TxDOT's Information Systems Division (ISD) at this crucial development stage. The program will have the following features:

- **receive** PC database file (dbf) of the DAR data from the maintenance

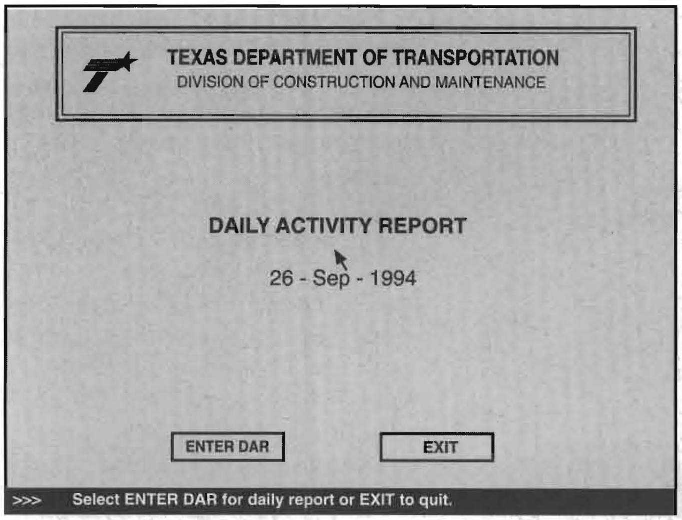

FIG 2: The first screen of the maintenance DAR.

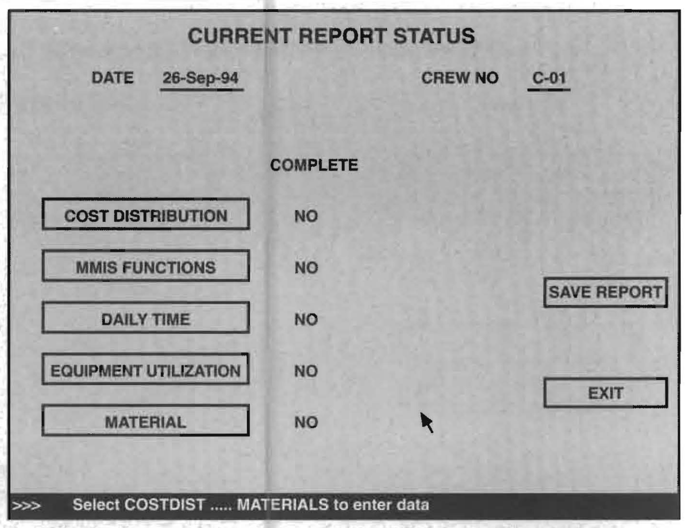

FIG. 3: Most of the screens are made up of easily understood choices. Selecting an item automatically takes you to the next appropriate screen.

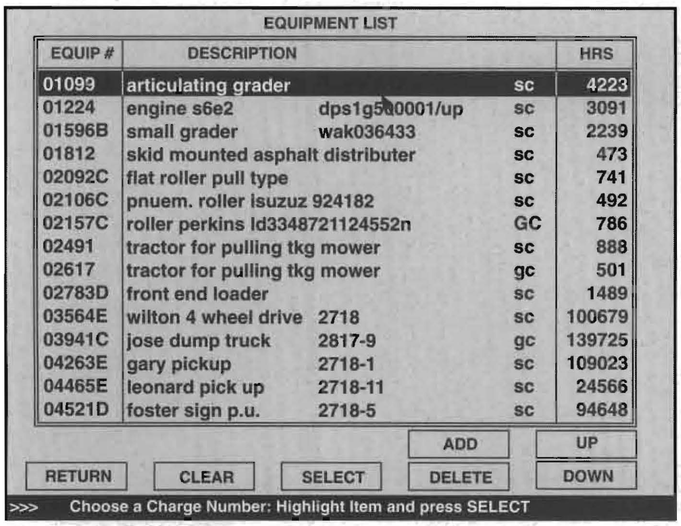

FIG. 4: Here the operator has selected "articulating grader." The next step is to touch the computer pen to the select box.

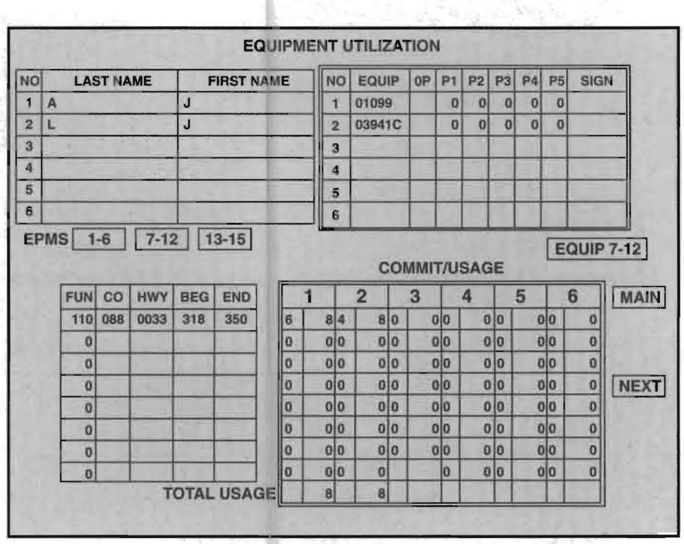

FIG. 5: The DAR software cross-checks items like function codes, tasks and details, and warns you if the entry does not match valid numbers for that particular job.

section;

- **convert** dbf to card file data format and match the data type and data format of each individual data field required in the Single Entry Screen (SES); and
- **carry out** final data validation in SES.

In the manual data transfer process, office managers must check and recheck to make sure information is correct. With the computer automatically checking the data entries and subsequent transfers every step of the way, the need for labor-intensive, time-consuming (and error-prone) data reentry is avoided, with an increase in both efficiency and accuracy. Researchers estimate an average time savings of two hours per day for each maintenance crew, allowing much more time for actual work activity. Figure 6 contrasts manual and automated data collection processes.

AUTOMATED CONSTRUCTION INSPECTOR'S REPORT (CIR)

The data management and collection process for construction projects is more involved than that of maintenance. For every construction project, the contract's specific work items (also called bid items), materials, quantities, and cost data are first entered into the mainframe's Contract Information System (CIS). Once downloaded to the area office PC, the area engineers and construction inspectors then use the information on computer-generated worksheets (CIS-35, "Quantity Update Worksheet," and CIS-37, "Contract Materials Summary") to monitor the project's daily and monthly progress for every work item. Construction inspectors

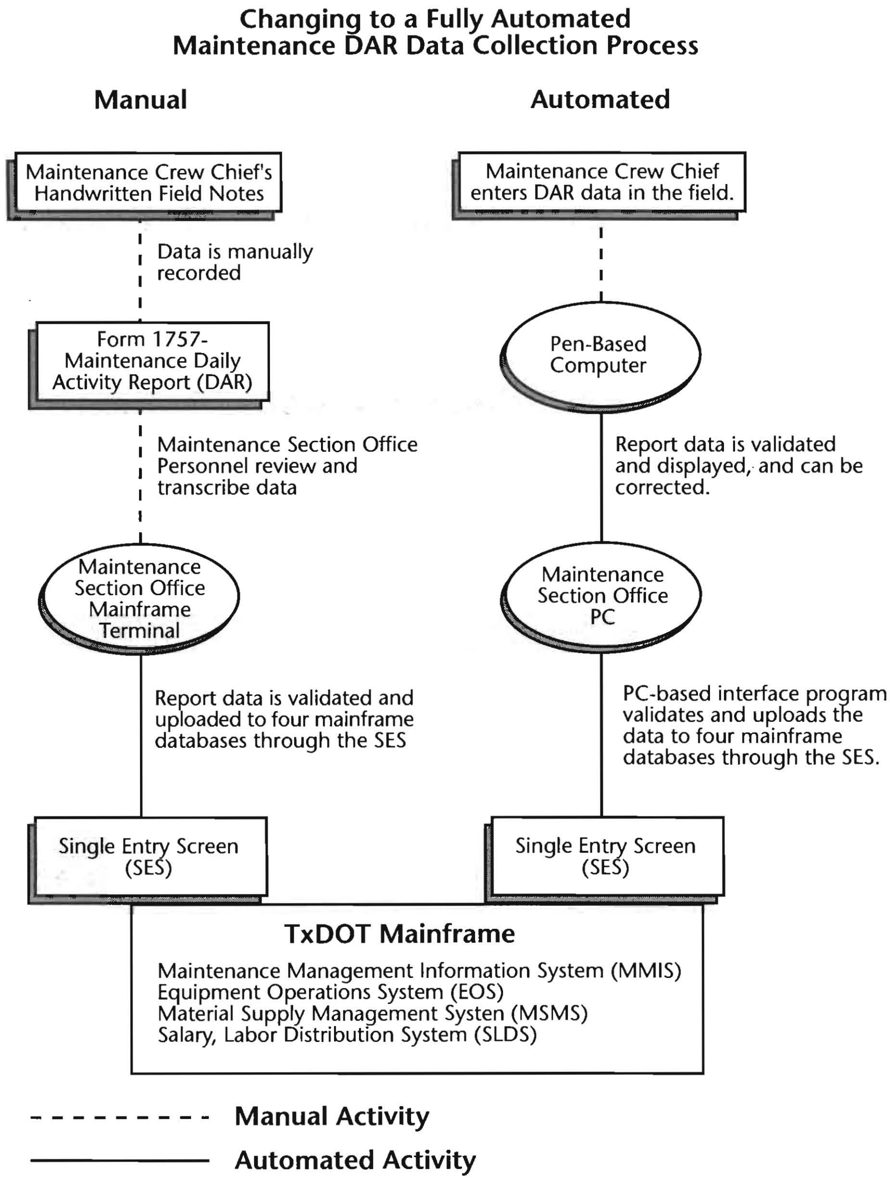

FIG. 6: Comparing the flow of manual and automated data collection processes.

hand record the daily and monthly data on three data collection forms: Form 1257, "Daily Work Report"; Form 1258, "Summary of Work Performed"; and Form 1259, "Daily Summary of Materials Received and Used." The field data on these forms is then transferred back to the mainframe CIS database through roughly the same process as the maintenance activity data. However, fulfilling careful field inspection to ensure accurate payment to the contractor can sometimes mean up to ten pages of hand-recorded measurements, calculations, dates, and pay quantity totals for each work item — all of which must be entered into the computer. According to Dawn Scheel, TxDOT Field Engineer and project director for the CIR portion of Study 7-1991, "Using computers in the field will probably reduce the inspector's paperwork by half and free-up their time so they can more effectively monitor the actual construction activities of the project — rather than sitting in the trailer filling out forms to document project history."

Two Forms in One Program

For the construction inspector's "Daily Work Report," the "Summary of Work Performed," and part of the "Daily Summary of Materials Received and Used," the research team is using the same pen-based computer and modifying Michigan DOT's automated INSPECTOR'S DAILY REPORT (IDR) to fit TxDOT needs (Fig. 7). The new automated TxDOT CONSTRUCTION INSPECTION REPORT (CIR) will combine the 1257 and 1258 forms into one screen program, where data recorded on the DAILY WORK REPORT screens will automatically validate and calculate materials used for the SUMMARY OF WORK PERFORMED. The inspector can then easily deduct this amount from the materials on hand.

For example, when paying for one work item (in this case, riprap) when the project has a large quantity (19.8 cubic yards) of material, the inspector simply calls up the BID ITEM LIST screen (Fig . 8), touches the "riprap" line, and automatically gets a WORK ITEM INFORMATION screen (Fig. 9). This screen shows the work item number, description, and plan quantity. When the inspector fills in the pay quantity of riprap completed that day, say 3.54 cubic yards, the program automatically computes the amount of material (in this case, coarse aggregate) that will be placed for that day's riprap activity. Because the program already knows the placement factor for the amount of coarse aggregate is .65 cy/cy and the quantity for that day as 3.54 cy, it automatically gives the estimate of 2.30 cy of coarse aggregate used for that day. This information can be called up by simply touching the box labeled "MATERIALS" at the bottom of the WORK ITEM INFORMATION screen. The ensuing MATERIALS screen (Fig. 10) shows the newly calculated and validated materials status for the work item. Inspectors do have the option of changing the placement factor if necessary, and the CIR also has the option of a sketch function to document the work item measurements and calculations done on construction sites.

Two-Way Data Transfer

Since construction inspection data requires two-way data transfer and individualized project information for each new contract, the interface program requirements will be more demanding. One interface program must *download* the CIS BID ITEM LIST and the ITEM MATERIAL INFORMATION LIST (CIS 35 and 37)to the pen-based computer, so the screen program is tailored to the individual contract bid quantities and can perform accurate data calculation and validation on each project. Following the collection of the field data, two more interface programs will *upload* the new material quantities and work item status to the area office PC and then to the mainframe.

IMPLEMENTATION PLAN

Abilene, Atlanta, and San Angelo District representatives evaluated a preliminary version of the maintenance DAR screen program. Maintenance supervisors and crew chiefs responded favorably to the new technology and made useful suggestions for making the interface more user friendly. Researchers are incorporating the suggested modifications, and the final DAR screen program is close to complete.

Through fiscal year 1995, the TTI project team will continue to develop the maintenance interface programs necessary to complete a fully automated data collection and transfer system. Installation, training, and field testing of the Pen Display Pad's maintenance DAR is scheduled to begin in November 1994. Six maintenance sections from three districts will actually use the technology (along with paper forms) for six months. Instructional manuals will

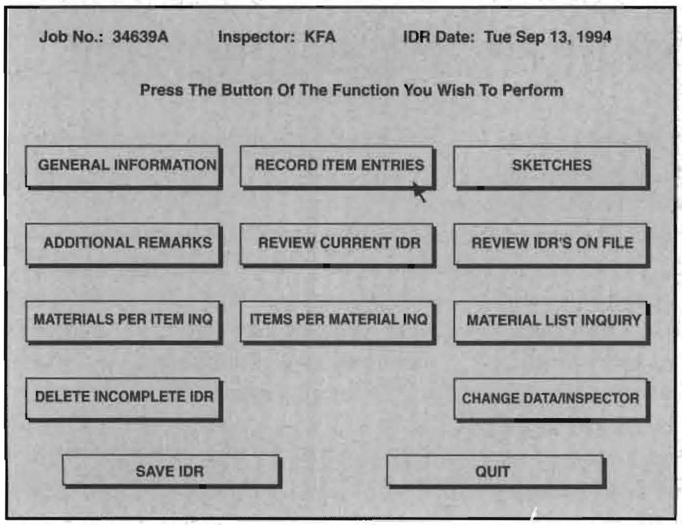

FIG. 7: The INSPECTOR'S DAILY REPORT menu of the automated CONSTRUCTION INSPECTION REPORT.

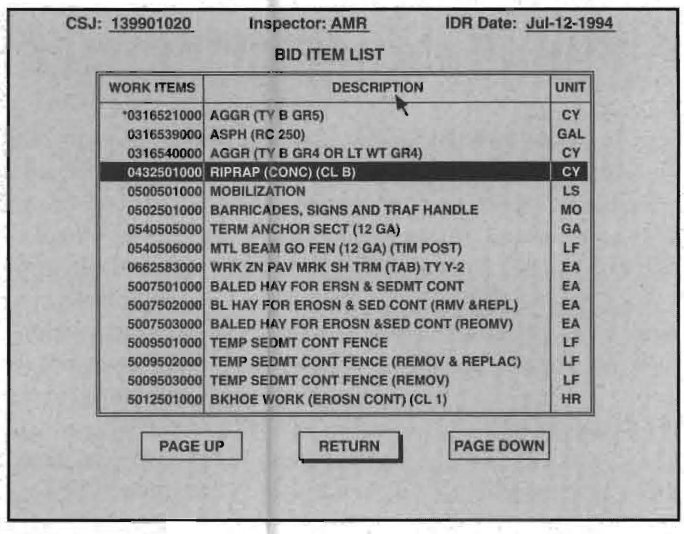

FIG. 8: The BID ITEM LIST. The inspector has selected the "riprap" item. The software will now bring up the WORK ITEM INFORMATION screen.

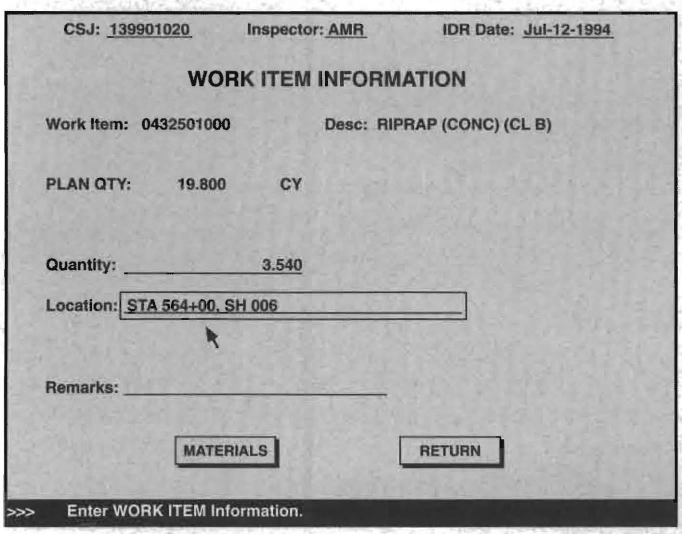

FIG. 9: The WORK ITEM INFORMATION screen. The inspector fills in the desired quantity, and the software computes the amount of material that will be place for that day.

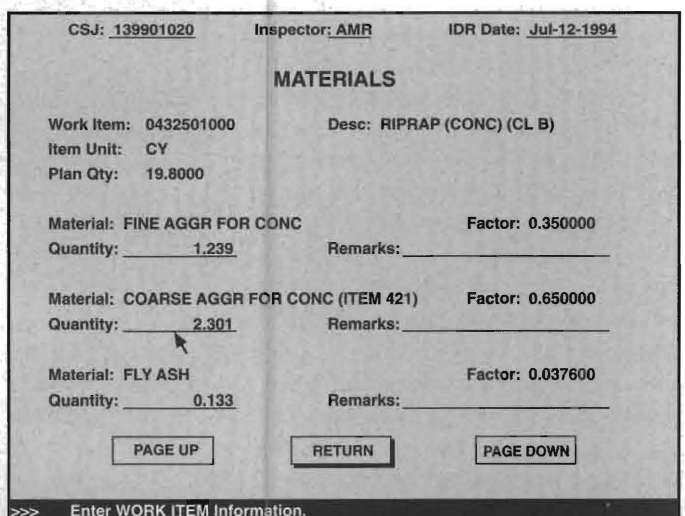

FIG. 10: The MATERIALS screen shows the validated materials calculation for the work item.

be provided as part of the training. Comparing the computer and manual processes, researchers will then perform an analysis of cost-effectiveness.

Work on the CIR screen and interface programs will also continue, and construction inspectors from selected districts will participate in a demonstration/evaluation of the first version. According to Dawn Scheel, this system will serve TxDOT well while waiting for the completion of a state-of-the-art, completely automated Construction Management System being developed under an AASHTO project, jointly funded by 13 states.

Both the maintenance DAR and the CIR will be on display in demonstration booths at the 1994 Transportation Conference (formerly Short Course). Presentations on study 7-1991's automated CIR and AASHTO's pending Construction Management System will also be given at the Transportation Conference during Wednesday morning sessions. For more information about the Maintenance DAR, contact Joey Matesic, (512) 416-3218; for the CIR, contact Dawn Scheel, (512) 416-2472.

EDITOR'S NOTE

CMD's pen-based computer programs for maintenance and construction inspection are being featured in Session 15, "Field Operations," 1994 Transportation Conference. If you can't attend the session, watch the videotape. You can get a copy on loan from the Research and Technology Transfer Library. Call Librarian Dana Herring at (512) 465-7644 after 1 December 1994 to order.

TEXAS HIGH-STRENGTH CONCRETE BRIDGE PROJECT

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INTRODUCTION

High-strength concrete is one of the most significant new materials available to federal, state, and local highway agencies to rehabilitate the nation's crumbling infrastructure. High-strength concrete, as defined in this article, has a specified design strength of 55.2 megapascals (8,000 pounds per square inch) or greater. With its improved impermeability, durability, and accelerated strength gain over normal-strength concrete, high-strength concrete should enhance performance and be an ideal material to assist with the widespread problem of deteriorating bridge structures.

In addition to its better long-term performance, the use of high-strength concrete allows either longer spans with fewer support locations or fewer beams for a given span length. This results in savings due to reduced fabrication, transportation, and erection costs, as well as reduced substructure requirements because of the lighter superstructure. The net result should be comparable, if not decreased, costs relative to conventional construction.

This article describes the design and construction details for Louetta Road Overpass, two adjacent bridges on State Highway 249 in Houston, Texas. These structures showcase the use of high-strength concrete and are the first bridges in the United States to fully use high-strength concrete in all aspects of design and construction. Several innovations make these structures unique in the use of high-strength concrete. They are also the first in the United States to use 15.24-millimeter (0.6-inch-) diameter, prestressed strands in a pretensioned concrete application and on a 50-mm (1.97-in) grid spacing.

Continued on page 14

OTHER HIGH-STRENGTH CONCRETE BRIDGES*

1980	Red River Cable-Stayed Bridge Guangxi, China	60 MPa (8,700 lbf/in^2)
1985	East Huntington Cable-Stayed Bridge East Huntington, W. Va	55 MPa (8,000 lbf/in^2)
1986	Annacis Cable-Stayed Bridge Vancouver, British Columbia, Canada	55 MPa (8,000 lbf/in^2)
1989	Joigny Bridge Joigny, France	60 MPa (8,700 lbf/in^2)
1990	Braker Lane Bridge Austin, Texas	66 MPa (9,600 lbf/in^2)
1990	Liangshui River Bridge Beijing-Tianjin Highway, China	60 MPa (8,700 lbf/in^2)
1993	Normandie Bridge Normandie, France	60 MPa (8,700 lbf/in^2)
1993	Portneuf Bridge Quebec, Canada	60 MPa (8,700 lbf/in^2)

* Several other bridges have used some high-strength concrete, however, these are the only commonly known high-strength concrete bridges.

SAFER SIGNPOST INSTALLATION WITH NEW DISTRICT-DESIGNED TOOL

The current standard statewide installation of sign posts anchors uses a system called POZ-LOK. Workers typically use a ball peen or a claw hammer to drive retaining wedges into the POZ-LOK stub to secure the signpost in position. Jim L. Keck, Maintenance Technician IV, a signman in the Wichita Falls District, believes this technique is not only dangerous, but ineffective as well. Installing the system with a hammer requires the worker's hands, knees, and face to be very close to the hammer's point of impact, and glancing blows are common due to the shape of the POZ-LOK wedge and to its low-to-the-ground position.

Mr. Keck fabricated a combination wedge driver/tamp bar as an alternative tool to install the POZ-LOK signpost anchor system (Fig. 1). The wedge driver/tamp bar allows the worker to stand upright with hands and face away from dangerous glancing blows and flying steel pieces (Fig. 2). Also, the contour of the wedge-driver head secures it to the post and allows the worker to use a larger force to drive the wedge into its proper position (Fig. 3). To finish the job, the worker uses the opposite end of the wedge driver/tamp bar to pack the loosened soil, thereby providing a more permanent, plumb signpost installation.

Contributed by Rodger Clements, P.E., Director of Operations in the Wichita Falls District.

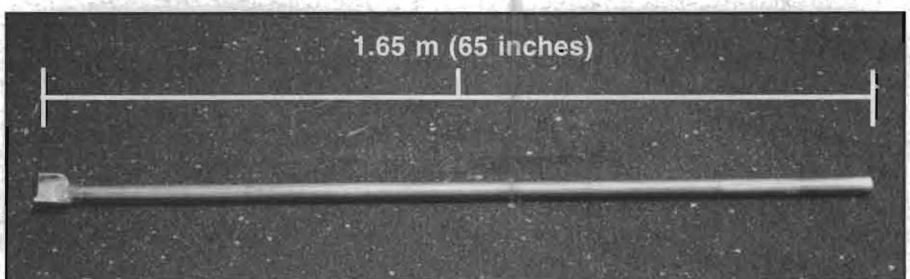

FIG. 1: The 1.65 m (65 inch) wedge driver/tamp bar can be fabricated easily in a district shop.

FIG. 2: The bar allows a worker to stand while driving in the POZ-LOK wedge.

FIG. 3: The wedge driver head fits securely against the post.

A number of differences exist between the Louetta bridges and the Braker Lane Bridge, built in Austin, Texas, in 1990. The Braker Lane Bridge is a conventional prestressed concrete beam bridge except that its I-shaped beams have a design strength of 66.2 MPa (9,600 lbf/in^2). Actual concrete strengths ranged from 75.8 MPa (11,000 lbf/in^2) to 96.5 MPa (14,000 lbf/in^2) at 28 days.

The Louetta Road Overpass structures, which were let to contract in February 1994, are simple-span, pretensioned concrete beams with composite precast/ cast-in-place concrete decks using construction materials that incorporate the latest technology. All components of these structures are being built with high strength concrete. The beams are pretensioned concrete U-beams — a recent, Texas Department of Transportation (TxDOT) development in which aesthetics was combined with the usual safety, economy, and durability concerns to form the primary driving forces for design. Rather than using typical prestressed concrete design strengths in the traditional 34.5- to 41.4- MPa (5,000- to 6,000-lbf/in^2) range, the beams in these structures fully use concrete strengths in the 69- to 89.6-MPa (10,000- to 13,000-lbf/in^2) range.

The high-strength beams combine with a high-strength concrete deck in one of the structures to obtain a totally high strength concrete superstructure. The superstructures are supported on high-strength concrete, post-tensioned pier segments — another new application for conventional bridge construction. This culminates in the first bridge structures in the United States to fully use high-strength concrete in combination with aesthetics and economy in a total package that adds up to long-term high-performance at costs that are anticipated to be competitive with conventional structures. It is expected that information developed from this project will assist in the design of high-performance, economical structures throughout the country in the near future and for years to come.

THE COOPERATIVE AGREEMENT

In July 1993, a cooperative agreement was initiated between the Federal Highway Administration (FHWA) and TxDOT, in conjunction with the Center for Transportation Research (CTR) at The University of Texas at Austin, to conduct research in the design and construction of extra-high-strength concrete bridges. The agreement involves the Louetta Road Overpass with specified design strengths in the 69- to 89.6MPa (10,000- to 13,000-lbf/in^2) range for pretensioned beams and 69 MPa (10,000 lbf/in^2) for post-tensioned substructures. This research project is the first phase of a larger, overall effort to design and construct bridges with specified strengths in the 103.4- to 117.2MPa (15,000- to 17,000-lbf/in^2) range. The emphasis is to collect data on all aspects of high-strength-concrete bridge construction to lay the groundwork for designing and constructing extra-high-strength concrete bridges with minimum variation from conventional bridge-building techniques. A cooperative agreement is also anticipated between FHWA and TxDOT to develop and present technology transfer materials in conjunction with the Louetta Road Overpass design and construction effort.

LOUETTA STRUCTURES

The existing S.H. 249 is a four-lane, at-grade, asphalt-surfaced road that is classified as a major rural/ urban arterial. After reconstruction, the thoroughfare, known as the Aggie Freeway, will be a controlled access, six- to eight-lane, divided freeway with access ramps to and from frontage roads and with a number of mainline overpasses, including Louetta Road. The 1992 average daily traffic count for S.H. 249 was 32,700 vehicles, of which 5.8 percent — approximately 1,900 vehicles — were trucks. A minimum average daily traffic count of 144,200 vehicles is projected for the year 2022, again with 5.8 percent — 8,400 vehicles — projected to be trucks. The construction phasing allows the project to proceed with minimum inconvenience to motorists.

The sequence of work was modified to allow construction of the Louetta Road Overpass structures at the beginning of this project. Construction is, therefore, anticipated to start in the spring of 1994 and to be completed in the fall of 1994. According to the current plan, the structures will be opened to traffic in 1995.

Figure 1 shows a plan view of the Louetta structures. Each three-span unit consists of a 37-m (121.5-ft) span, a 41.3-m (135.5-ft) span, and a 40.8-m (134-ft) span, each with a varying roadway width. These lengths are longer than the maximum spans used in typical U-beam bridges, which have wide beam spacings that limit the span lengths to approximately 35.1 m (115 ft).

Thus, the Louetta bridges are an ideal application for high-strength

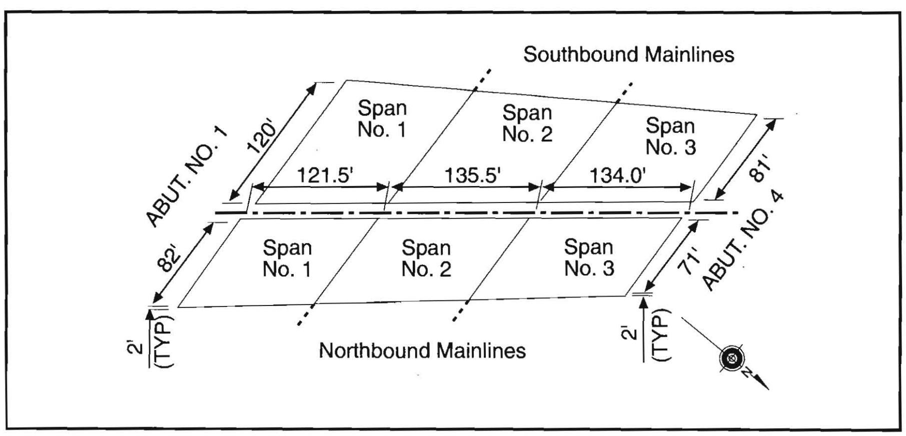

FIG. 1: Plan view of Louetta Road Overpass.

TABLE 1: Average beam spacings and concrete strengths.

CATEGORY	UNIT	SOUTHBOUND	NORTHBOUND
Average Beam Spacing - Span #1	ft	15.8	13.0
Average Beam Spacing - Span #2	ft	13.7	12.4
Average Beam Spacing - Span #3	ft	11.7	11.7
f'ci ~U-Beams [3 designs]	psi	6,900 to 8,800	6,900 to 8,800
f'c ~ U-Beams [3 designs]	psi	9,800 to 13,100	9,800 to 13,100
f'c ~ Post-Tensioned Piers	psi	10,000	10,000

1 ft = 0.3048 m
1 psi (lbf/in^2) = 6.89 kPa

concrete. The longer span lengths combine with wider spacing of the U-beams to provide a more structurally efficient, aesthetic, streamlined appearance than could be achieved with typical design concrete strengths of less than 55.2 MPa (8,000 lbf/in^2). Six U-beams span the southbound lanes, and five U-beams span the more narrow northbound lanes. The average beam spacings vary from 3.57 to 4.82 m (11.7 to 15.8 ft), as shown in table 1. This results in clear spacings of 1.13 to 2.38 m (3.7 to 7.8 ft) between beams.

Also shown in table 1 are the specified design concrete strengths. The U-beams are designed for three concrete mixes, with design release strengths from 47.6 to 60.7 MPa (6,900 to 8,800 lbf/in^2) and with specified 56-day design strengths from 67.6 to 90.3 MPa (9,800 to 13,100 lbf/in^2). The post-tensioned concrete pier segments are designed for 69-MPa (10,000-lbf/in^2), specified 28-day strength. The design strengths for the U-beams were specified at 56 days, the project standard for high-strength concrete. The standard is 56 days, compared to the 28-day standard for normal strength concrete, to account for the appreciable strength gain with time that occurs in high-strength concrete after 28 days. The post-tensioned concrete segments, however, were specified at 28 days because preliminary results from the 69-MPa (10,000-lbf/in^2) mix designs indicated the strength could be achieved in 28 days.

THE U-BEAM

The Louetta structures were designed using a new beam shape recently developed by TxDOT. Dubbed the "U-beam," this beam is a pretensioned concrete, open-top, trapezoidal shaped beam that was developed as an economical, aesthetic alternative to I-shaped beams. Structures designed with U-beams typically require only one-half to two-thirds as many beams as structures designed with I-beams.

A reduction in both number of beams per span and number of visual horizontal breaklines per beam contributes to the streamlined appearance of the U-beam bridge. This can be seen in figure 2, which shows that seven American Association of State Highway and Transportation Officials (AASHTO) Type IV beams — 1.37-m- (54-in-) deep prestressed concrete I-beams — on a typical 17.1-m- (56-ft-) wide roadway can be replaced with four 1.37-m (54-in) U-beams, called U54 beams. The Louetta bridges, designed with high-strength concrete U54 beams, will have a similar decrease in the number of beams.

The U-beam was developed in metric dimensions, anticipating the requirement that all federally funded construction projects be specified in metric (SI) units, effective September 1996. Figure 3 shows the cross-sectional dimensions and pretensioned strand locations for the U54 beam. This beam is 1,372 mm (54 in) in depth, thus allowing its use as an alternative to the 1372-mm (54-in) AASHTO Type IV beam, the most common I-beam used in Texas bridge construction. The 2440-mm (8.01-ft) overall top flange width includes two 400-mm- (15.75-in-) wide compression flanges. Two or

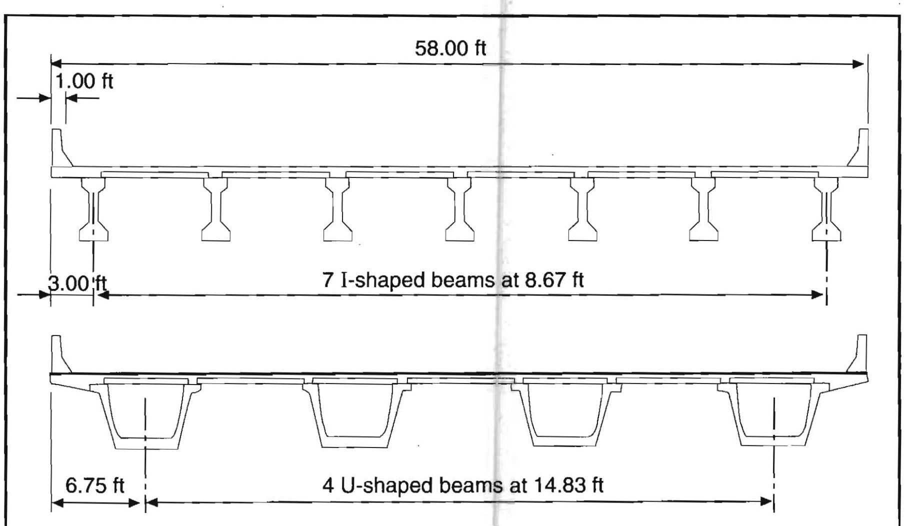

FIG. 2: Comparison of Texas standard 16.6 m (56 ft) wide roadway cross-section, with AASHTO type IV beams, and with U54 beams.

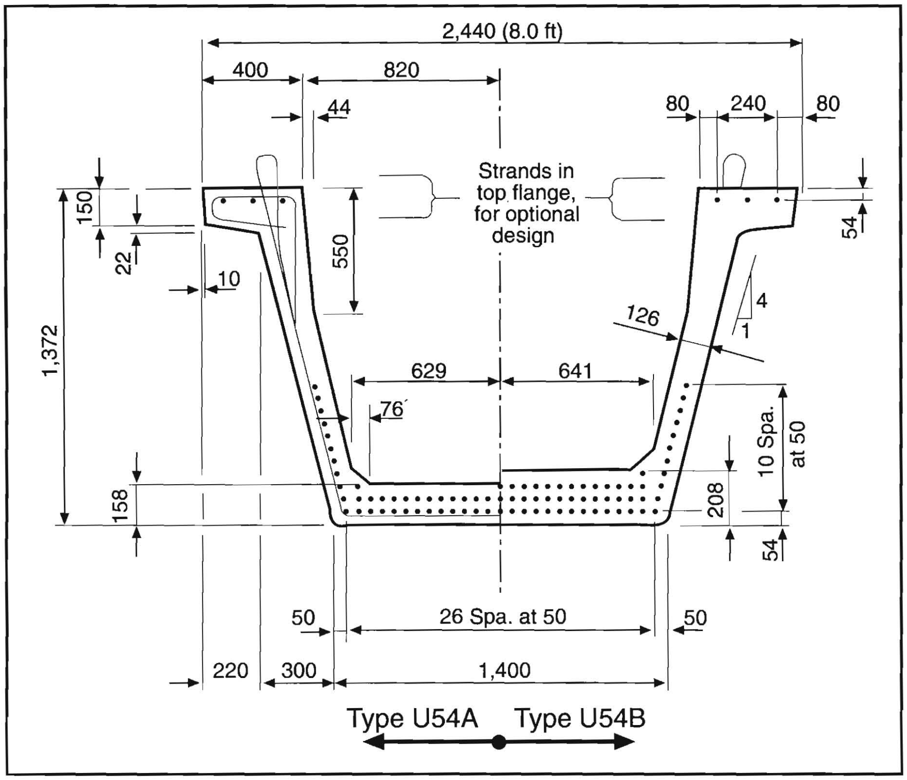

FIG. 3: Cross-section and prestressed strand patterns of U54 beams. (Note: Dimensions are shown in millimeters: 1mm = 0.0394 in.)

three layers of prestressed strands, with a maximum of 27 strands per row, can fit in the 1400-mm- (5-ft-) wide bottom flange, as shown in figure 3. A single strand per row may be placed in each of the 126-mm- (5-in-) wide webs.

HIGH-STRENGTH CONCRETE

The economical use of high-strength concrete depends on a local supply of acceptable aggregate, as well as on other considerations, such as quality of available cement, admixture compatibility, and availability of mineral admixtures. Because this structure is in a no-freeze area, it was not necessary to use air entrainment, which normally carries a sacrifice in strength.

One of the most important considerations for this project was the understanding of the role of the aggregate on the performance of the concrete. Optimization of the physical characteristics of the aggregate resulted in lower mixing water demand while retaining adequate workability, higher strengths, higher modulus of elasticity, and higher flexural strengths. For the same materials and mix proportions, the aggregate resulted in up to 24.1-MPa (3,500-lbf/in^2) strength difference and up to 20 percent difference in modulus of elasticity. Of great importance to optimizing the flexural strength of the concrete were the surface characteristics, size, and composition of the aggregate, as well as the amount used in the concrete.

The strength-gain characteristics of the concrete were greatly influenced by the type and dosage rate of retarding admixture, as well as by the compatibility between the retarding admixture and the high-range water-reducing admixture. Critical to the performance of the concrete was also the time of addition of each admixture, as well as the minimum allowable mixing-water content of the concrete. Cement content was found to be ineffective above about 294.84 to 317.52 kilograms (650 to 700 pounds) of cement per 0.765 cubic meter (one cubic yard). Instead, the use of a high-quality ASTM Class C fly ash was found to be necessary to obtain adequate workability, placeability, and concrete strength at early ages. Fly ash contents of up to 40-percent replacement of the cement were evaluated.

USE OF 15.24-MM- (0.6-IN-) DIAMETER STRAND

To take full advantage of high-strength concrete, a higher prestress force is required than can typically be achieved with the use of 12.7-mm- (0.5-in-) diameter prestressing strand. Therefore, the Louetta Road Overpass beams have 15.24-mm- (0.6-in-) diameter prestressed strands. Also, the strands are on the same 50-mm (1.97-in) grid spacing as used for standard 12.7 mm- (0.5-in-) diameter strands to maximize the effect of the larger strand and to allow the use of existing hardware at the precast plants. This grid spacing results in a clear spacing between strands that is less than currently allowed in AASHTO standard specifications. Although FHWA has a moratorium on the use of 15.24-mm- (0.6-in-) diameter strands for pretensioned applications a special approval was requested and received from FHWA based on results from tests conducted on this project indicating no problems with the strand configuration.

A 42-percent increase in prestress results from using the 15.24-mm- (0.6-in-) diameter strand. This increase in prestress force allowed full use of concrete strengths greater than 69 MPa (10,000 lbf/in^2) in the U-beam designs. The benefit of this combination quickly became apparent in designing the U-beams for the Louetta structures. The interior beams in the 37-m (121.5-ft) span of the northbound mainlanes were the only beams that could be designed with 12.7-mm- (0.5-in-) diameter prestressed strands. All other beams required 15.24-mm- (0.6-in-) diameter strands in combination with the high-strength concrete to meet design criteria.

Use of the larger 195.5 kN (43,950 pounds force) per strand on a 50-mm (1.97-in) grid spacing raised concerns about stress concentrations and possible concrete splitting in the end regions of the beams and about development length requirements. To get field data and to verify adequate performance, two full-scale U-beam specimens were cast in September 1993. The beams were instrumented with mechanical gauge points on the outside surfaces of the webs along the beam length to measure concrete strains at release of prestress. No end splitting due to prestress force was seen, and preliminary results from strain measurements indicate adequate transfer length. The release was gradual (multistrand release), as required by TxDOT for bridge projects.

Also of concern is the development length of 15.24-mm- (0.6-in-) diameter strand. Two rectangular beams, 355.6 mm (14 in) wide and 1,066.8 mm (42 in) deep, were cast in December 1993. Each was pretensioned with one layer of six 15.24-mm- (0.6-in-) diameter strands on a 50.8-mm (2-in) grid spacing at 50.8 mm (2 in) up from the bottom fiber. These beams will be tested to failure at the CTR laboratory to obtain development length measurements.

BEAM DESIGN

The beam designs have different concrete design parameters due to the use of high-strength concrete. The allowable tension coefficients were increased from 7.5 to 10 for release and from 6 to 8 for final to be consistent with previous experimental studies of high-strength concrete. Modulus of rupture tests conducted on the mix designs used in the field tests indicate an allowable tension coefficient at release of 9.6.

The modulus of elasticity used in design was 41,370 MPa (6 million lbf/in^2) at seven days. An average modulus of elasticity of 45,507 MPa (6.6 million lbf/in^2) at seven days was obtained in the field tests.

CONCRETE MIX PROPORTIONING

When proportioning high-strength concrete, emphasis must be placed on the interaction among the components used in making the concrete, as well as the quality and characteristics of each component. Materials selection should be based on the following four considerations:

- Contribution to the workability, placeability, and finishability of the fresh concrete.
- Effect on the mixing-water demand of the fresh concrete for adequate workability.
- Effect on the mortar-aggregate tensile bond strength within the hardened concrete.
- Contribution of the material to any special specification or performance requirements of the concrete, such as durability, modulus of elasticity, or flexural strength.

The special requirements for the Louetta U-beams include a high modulus of elasticity, 41,370 MPa (6 million lbf/in^2) minimum at early ages to control deflections, as well as a 33-percent higher flexural strength, as indicated using the modulus-of-rupture test. This increased demand on the flexural capacity of the concrete was needed to prevent cracking at release. Other specifications include concrete compressive strengths up to 60.7 MPa (8,800 lbf/in^2) at release, which is typically 18 to 24 hours after casting and up to 90.3 MPa (13,100 lbf/in^2) at 56 days.

The concrete is also required to have excellent workability to allow placement from one web of the U-beam. The concrete must flow across a 1400-mm- (4.59-ft-) wide bottom flange without segregation, passing two layers of strands in a 158-mm (6.22-in) depth or three layers of strands in a 208-mm (8.19-in) depth, and then flow into the bottom portion of the far web, at which time concrete is placed in the far web to fill the entire cross-section.

No silica fume was used in any of the mixes in this study.

A field trial batch program was conducted to evaluate eight of the mixes that had been developed in the laboratory. The results from the trial batch program are detailed below. No accelerated curing was used in the field tests.

In summary, use of high-strength concrete depends greatly on the optimization and engineering of the concrete and its components. For high-strength concrete construction, compressive strength, flexural strength, modulus of elasticity, creep, and shrinkage need to be predictable performance characteristics of the concrete. It is evident that future advancements in construction are go-

TABLE 2: Louetta U-beam concrete characteristics.

FRESH CONCRETE	
Slump after high-range water reducer (HRWR):	177.8 to 241.3 mm (7.0 to 9.5 in)
Concrete temperature:	35.6° to 38.9° C (96° to 102° F)
Unit weight:	66.77 to 69.67 kg/m^3 (147.2 to 153.6 lb/ft^3[pcf])
HARDENED CONCRETE	
Compressive strength at 40 hours:	56.677 to 66.054 MPa (8,220 to 9,580 lbf/ft^3 [pcf])
Compressive strength at 56 days:	90.118 to 110.32 MPa (13,070 to 16,000 lbf/in^2)
Modulus of elasticity at 7 days:	41,370 to 48,270 MPa (6 to 7 million lbf/in^2)

ing to be highly dependent on advancements in concrete technology.

PIER DESIGN

The Louetta substructures at interior bent locations are designed as individual post-tensioned piers, as shown in figure 4. The hollow core column segments are 0.99 m (3.25 ft) square and have 228.6-mm (9-in) daps at the corners. The two transverse walls are 101.6 mm (4 in) thick. The two longitudinal walls are 190.5 mm (7.5 in) thick, with each containing three 34.93-mm- (1.375-in-) diameter post-tensioned bars. The post-tensioned bars are designed for a wobble coefficient of 0.0, an anchorage set of 1.59 mm (0.0625 in), a maximum average bar stress after anchoring of 70-percent guaranteed ultimate tensile strength, and allowable final concrete stress coefficients of 3 for tension and 0.4 for compression.

This innovative substructure was selected for several reasons. First, the bridges are classified as highly visible, and therefore, an aesthetic substructure as well as superstructure was required. The individual piers, devoid of the conventional connecting cap, are perceived by many as more aesthetic. Second, relatively thin walled, hollow post-tensioned concrete pier segments were required to

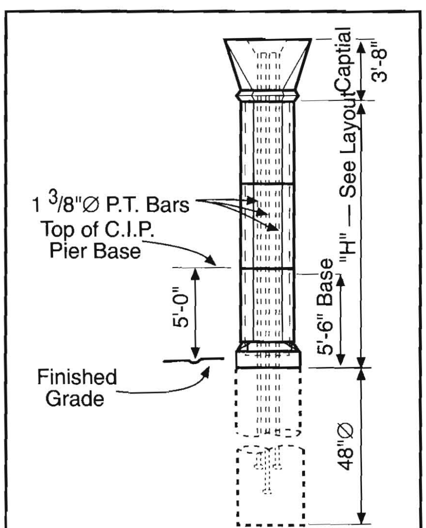

FIG. 4: Typical post-tensioned pier at interior bent locations.

fully use the high concrete strength in design and to also have a practical and economical construction method. In addition, the use of precast hollow pier segments allows the introduction of architectural creativity in future designs. Third, the time savings inherent with precast concrete construction should result in a reduction in costs. Immediately upon completion of the pier construction, the U-beams may be erected and deck construction begun. This saves a significant amount of construction time since the substructure does not require the usual seven-day minimum to obtain design concrete strengths.

DECK DESIGN

Figure 5 shows a typical partial transverse section of the southbound mainlanes of the Louetta Road Overpass The cast-in-place reinforced concrete in the deck was specified as 55.16-MPa (8,000-lbf/in^2) concrete on the southbound mainlanes and as the Texas standard 27.6-MPa (4,000-lbf/in^2) concrete on the northbound mainlanes. Both structures have 55.2-MPa (8,000-lbf/in^2) prestressed concrete panels specified, although permanent metal deck forms are allowed as an option. The 55.2-MPa (8,000-lbf/in^2) concrete on the southbound mainlanes was specified so that observations could be made to determine whether the increased cost and complexities of placing and curing the higher strength concrete are justified by an increase in long-term performance.

The deck was designed for main reinforcement perpendicular to traffic, the standard method used in Texas. The transverse No. 5 bars at 152.4-mm (6-in) spacings were doubled on the overhang. This allowed a 2.29-m (7.5-ft) overhang from centerline of outside U-beam to edge of slab, compared to the 2.06-m (6.75-ft) overhang used in standard U-beam bridge design. The wider overhangs contribute to a more aesthetic overall appearance.

A perspective of the completed southbound mainlanes is shown in figure 6.

QUALITY CONTROL/QUALITY ASSURANCE PROGRAM

Most important to the successful completion of a high-strength concrete project is the establishment of a comprehensive Quality Control/Quality Assurance (QC/QA) program. Furthermore, if the QC/QA program is to work as intended, it must be developed with the full cooperation and approval of all the parties involved in the construction process, including FHWA, the state DOT, and the general contractor and its subcontractors, such as the testing laboratory and the concrete supplier.

Developing and implementing the QC/QA program will be a dynamic process requiring continuous updating through regularly scheduled meetings to accommodate test results and findings during actual construction. The QC/QA program should cover all aspects of the concreting process at the construction site — from materials selection to concrete production, curing, testing, placement, troubleshooting, and performance evaluation. This program should include some of the more traditional aspects of quality control, such as frequency of testing, sampling, size of test specimens, testing machines, sample preparation, and others, as well as strict, fresh concrete temperature controls, limits on temperature rise due to cementitious hydration, vibration, surface temperature at time of form work removal, etc.

Key elements to the QC/QA program are the awareness of the parties involved of the purpose of each of the elements of the QC/QA program and their commitment to communicate and cooperate in the resolution of any concerns. The Louetta project will be an opportunity for all individual parties to contribute to the overall QC/QA plan and ensure the success of this challenging and unique bridge project.

TECHNOLOGY TRANSFER EFFORTS

Efforts are underway to document all aspects of the Louetta Road Overpass high-strength concrete project. Videotapes and slides have been taken of the two castings of research beams done at the precast plant and are planned for the preconstruction and subsequent meetings, the U-beam and pier segment fabrication, the bridge construction, and any loading or monitoring of the completed structures.

The videotapes with script will be edited into a 10- to 15-minute production that documents the entire project. The slides are being used in presentations at various technical conferences and meetings around the country.

Ongoing efforts include development of brochures on the initial and final phases of this high-strength concrete project and development of two or three multiday workshops on high-strength concrete to be held around the country, including one planned for Houston during bridge construction.

CONCLUSION

The Louetta Road Overpass structures are the first in the United States to fully use high-strength concrete in all aspects of design and construction. They are also the first in the United States to use 15.24mm- (0.6-in-) diameter strands in a pretensioned concrete application and on a 50-mm (1.97-in) grid spacing. This project lays the groundwork for designing and constructing extra-high-strength concrete bridges with minimum variation from conventional bridge-building techniques.

The benefits of high-strength concrete to the transportation system are being identified, documented, and verified in this project. Methods for optimizing all aspects of design and construction are being developed, and specifications and construction documents for future high-strength concrete projects are being formulated. Results from this project should assist the engineering and construction professions in consistently producing high-strength, high-performance, prestressed concrete bridges and to do so at competitive costs.

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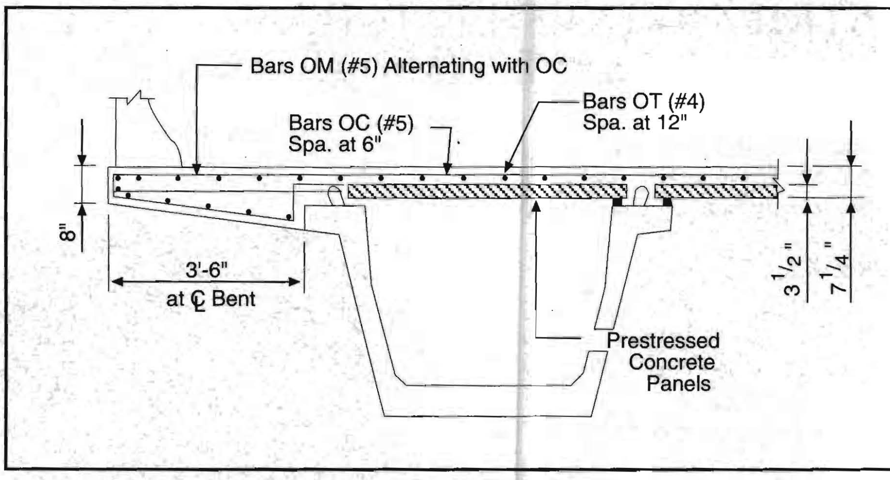

FIG. 5: Typical cross section of the southbound Louetta Road structure, showing deck reinforcement.

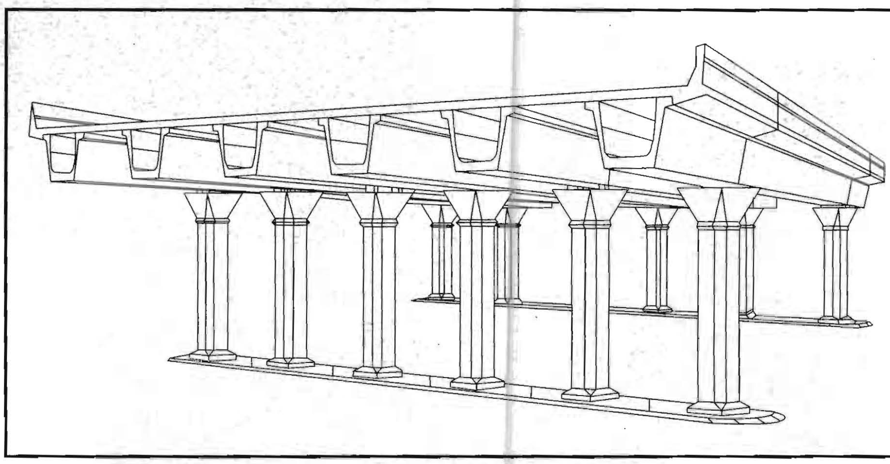

FIG. 6: Perspective of the completed southbound lanes.

EDITOR'S NOTE

TxDOT's high-strength concrete research study, Project 580, is featured in Session 15, "Field Operations," of the 1994 Transportation Conference 17–19 October, as well as at the Research and Technology Transfer Office's information booth. If you don't get a chance to attend Session 15, get a videotape copy of it on loan from the RTT library. Call Librarian Dana Herring after 1 December 1994 to order it.

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STRIPING FRESH PATCHES WITH PERMANENT TAPE CAN SAVE TIME AND INCREASE SAFETY

by **Kathleen Jones**
Research and Technology Transfer Office
Texas Department of Transportation

BACKGROUND

Would Type A foil-backed permanent pavement marking tape (TxDOT material specification D-9-8240) stick to a fresh road patch? That's what Austin District's Taylor Maintenance staff wanted to know. If the tape could be placed on fresh premix, the benefits would be two-fold. Since a permanent stripe would be on the patch before the patching crew left the job, motorists would have the guidance of standard pavement markings, and the district would save money by not having to send a striping crew out later. Interested in how its product behaved on fresh, granular material, the 3-M Company donated a quantity of its Type A tape and the use of a tape dispenser cart. 3-M also donated several preformed railroad crossing markings.

PERMANENT TAPE

To find out how the tape behaved, district forces placed three approximately 500-foot sections on FM 619 near Byersville on 24 February 1994 (Fig. 1). The average annual daily traffic (AADT) on the section is 440 vehicles. The patch in the first test section was about two-weeks old when Taylor Maintenance personnel placed the tape. The second patch was one-day old, and the third was fresh when the crew placed the tape. In places, the tape ran across the fine feathered edge of the patches. At AADTs lower than 1200, Type A tape is expected to last for about four years.

The crew measured from the edge line and used a marked chain to establish the roadway centerline. They were able to maintain a sufficiently straight course through both curved and tangent sections of the patches using the tape dispenser cart. The cart can hold two 90-yard rolls of tape side-by-side. The width between the rolls can be up to 12 inches. There are separate cutting bars for each roll so one lane can be dashed for passing, while the other remains solid. The cart is necessary for double lines in order to keep them parallel.

The crew used a portable leaf blower to clear the roadway of fines and debris immediately ahead of the tape cart. No primer was used on the day-old and fresh patches. The manufacturer recommends the use of primer on older patches and over other stripes containing glass beads. The crew started laying the tape when the temperature reached 45°F and rising. The tape was rolled with

FIG. 1: Applying permanent tape stripe to a fresh premix patch on FM 619.

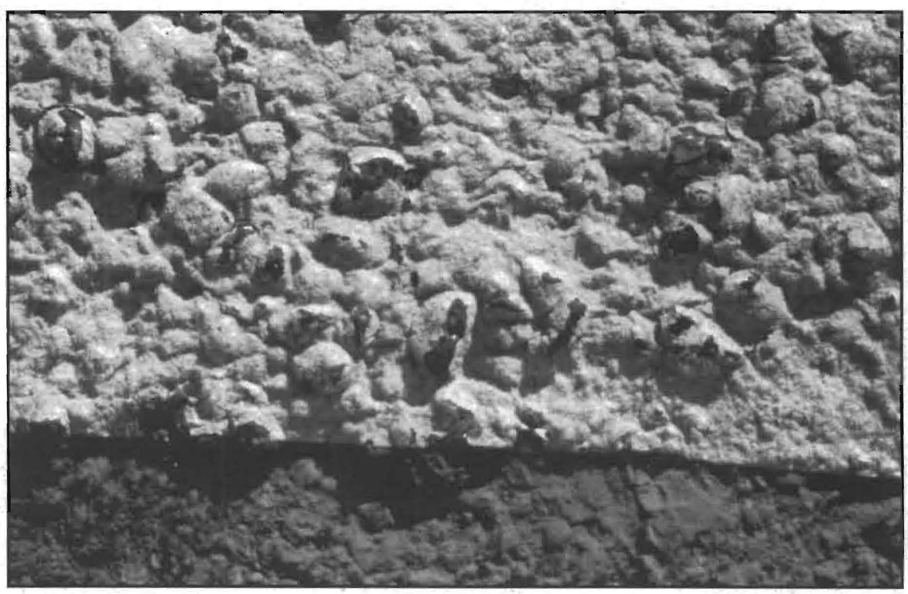

FIG. 2: Although gravel has punched through the tape in places, the retroreflectivity is still well above minimum

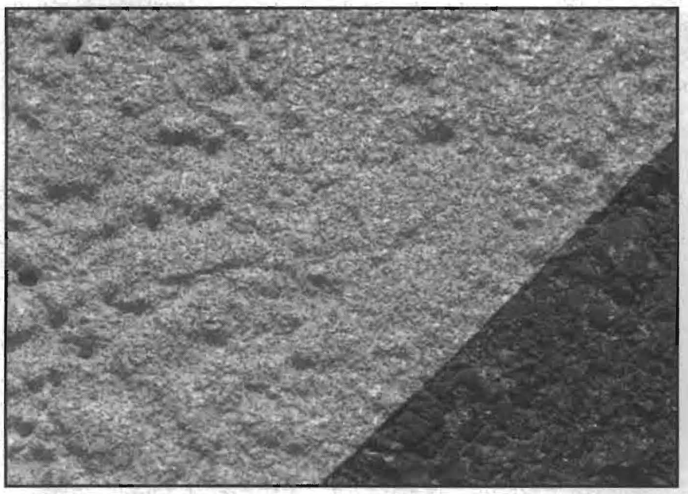

FIG. 3: Close-up of tape on day-old patch after application.

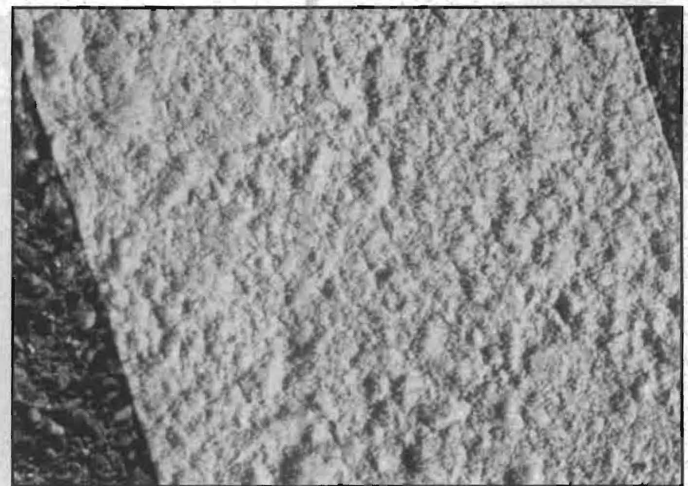

FIG. 4: Close-up of tape on day-old patch after six months.

a pneumatic roller after application.

The Traffic Operations Division (TRF) and Materials and Tests Division (MAT) staff evaluated the tape at six months after placement. Although everyone expected the tape to rip off the areas where it crossed the finely feathered edge of the patch (so much so that Taylor Maintenance Supervisor Paul Michalk had the crew cut out a ten-foot section immediately and had it replaced with paint), it did not. Traffic appeared to have pressed the tape more firmly to the roadway. The loose gravel punctured the tape in the feathered edge areas, but did not reduce its effectiveness (Fig. 2).

Art Barrow, P.E., Coatings and Traffic materials Director, MAT, tested the tape material's retroreflectivity with a Mirolux unit on 2 September 1994 (the six-month evaluation point). Yellow stripes must show at least 100 millicandelas per m^2 per lux (the per area amount of light given back divided by units of light put in) after 15 months to be acceptable. The average for the tape placed on the two-week-old patch was 460 millicandelas (Figs. 3 & 4). The average for the one-day-old and the fresh patches was 600. The difference between the retroreflectivity of the two-week-old patch and the other patches may be because the older surface, being harder, subjected the glass beads to more direct wear from traffic.

PREFORMED MARKINGS

The first preformed railroad marking took a district three-person crew 45 minutes to install. The second one took only 20 minutes. The markings were placed over old painted markings on FM 1331 near Circleville. The AADT in this area is 1000. At the six-month evaluation, the average Mirolux readings for the west side marking were 520 millicandelas in the wheel path and 730 millicandelas outside the wheel path. The east side readings were 630 for the wheel path and 700 outside the wheel path. The minimum required for white markings is 150 millicandelas after 15 months.

Visually the markings appear dirty white by day but are exceptionally bright at night.

CONCLUSIONS

This particular Type A tape worked well on fresh premix patches. Mr. Michalk said he would use it again for immediate patch striping, since the extra cost (a 4-inch wide roll cost about 27 cents a lineal foot) is offset by not having to send out a separate striping crew later.

The preformed railroad markings performed well, also. In their case, the fact that they last longer and are much quicker to apply (which also limits worker exposure to traffic) offsets the initial expense.

ATSSA "HOW II" WORK ZONE CONFERENCE A SUCCESS

by **Kathleen Jones**
Research and Technology Transfer Office
Texas Department of Transportation

INTRODUCTION

B. F. Templeton, P.E., Executive Director for Field Operations, Texas Department of Transportation (TxDOT), gave the beginning and ending keynote addresses at the American Traffic Safety Services Association "How II" Work Zone Conference held 19–21 April 1994 in Houston, Texas, in cooperation with TxDOT. The main theme was partnering. The traffic control contractor on a job and the state inspectors have the common goal of moving people in an orderly fashion through a construction site. A good traffic control plan, teamwork, and effective two-way communication are necessary elements in achieving that goal.

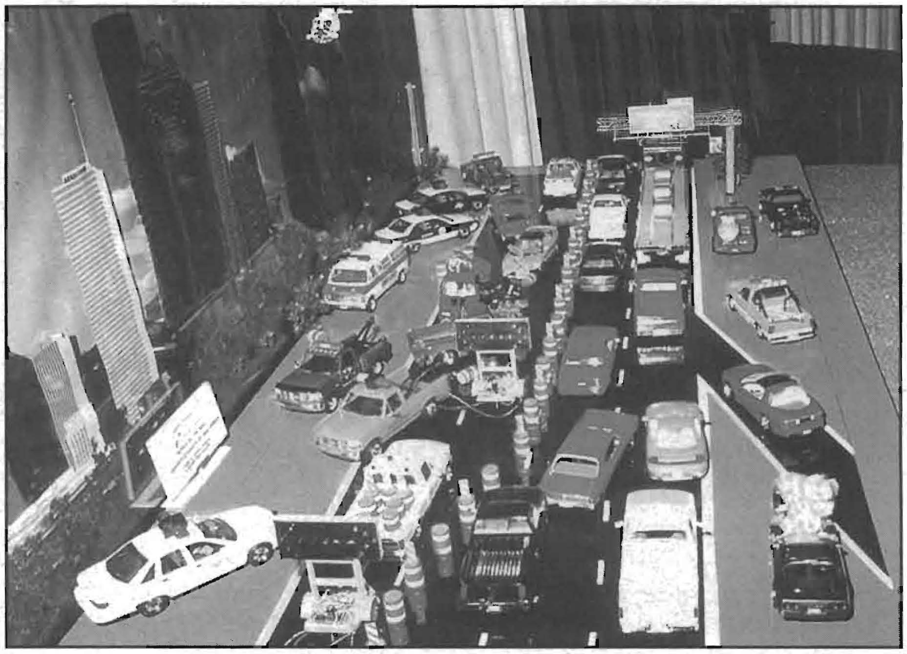

FIG. 1: Houston District's highly detailed model, built by the Traffic Control and Safety staff, sparked many conversations in the venders hall.

The conference revolved around making sure that the contractors and state personnel understood why they must correctly set up and rigorously maintain work zone traffic control and then developing necessary skills for doing just that. The tone of the whole conference was friendly, spirited, and cooperative.

The vendors hall was quite lively — lots of interesting products and information. Houston District had a spectacular table top model graphically displaying an urban freeway accident and the traffic control needed to manage it. Houston District personnel shared their booth with the Research and Technology Transfer Office (RTT). The arrangement worked well from RTT's standpoint. Houston District's modal attracted *a lot* of attention. Consequently, more people got to see research materials and vendors' product evaluation packets than might otherwise have stopped at a purely research-oriented booth. This article gives high points and tips from sessions the author attended.

TORT LIABILITY AND CONSTRUCTION

Three people from the Attorney General's Office (Grady Click, Ron Garner, and Norberto Flores) discussed tort liability regarding the construction industry. According to tort law, warning must be given if an "unreasonably dangerous" situation is created. Nearly every construction or roadway maintenance job creates such a situation for the traveling public. The concept of a "forgiving" highway is becoming both accepted by transportation professionals and expected by the public. Therefore, work zones must have well documented, enforced TCPs to be legally defensible. Proper warnings are what defense is all about.

LEGAL LIABILITY — A DIFFERENT VIEWPOINT

Tom Alcorn, a forensic traffic engineer consultant, gave a different view of tort liability, that of the plaintiff's. Mr. Alcorn handles about 150 construction zone accident investigations per year. He noted that pavement edge drop-off cases predominate currently. He explained that a plaintiff in a tort case is not always the driver(s) of the vehicle(s). There have been suits where the plaintiff has been the contractor, the state, or a subcontractor.

Elements of a Tort

The four required elements for a tort case are:

- defendant must owe a legal duty to plaintiff
- there must be a breach of that duty
- breach of that duty must be proximate cause or contribute to accident causation
- plaintiff must have suffered injuries or damage

Alcorn has been surprised at how many times state or contractor personnel would take the stand as a witness for the defense, but could not answer the plaintiff lawyer's question of what are the standards for traffic control in work zones. He urged people to memorize *Part III – Markings* and *Part VI – Construction and Maintenance* of the ***Manual on Uniform Traffic Control Devices (MUTCD)***. For both contractor and state personnel, a thorough working knowledge of these chapters — along with the state's supplement to the ***MUTCD***, the contract's specifications, and any special provisions and marking policies that may apply — may save lives, time, and money.

What You Need Besides a TCP

The best way to have a legally defensible work zone, Alcorn outlined, is first to have a rational traffic control plan that the driving public can follow and then:

- have and provide properly trained and certified personnel
- know and comply with all applicable contract documents
- document all actions taken on or related to traffic controls that are placed in effect at the work site
- inspect the work site at frequent intervals and correct deficiencies
- remove all material and equipment not needed at work site

- provide warnings and protections to motorists, pedestrians and workers in compliance with standards for potential conflicts and hazards that occur as a result of work being done.

How to Document your TCP

A project's TCP should be documented. Otherwise, it's the plaintiff's word against the defendant's as to the actual conditions prior to the incident. Alcorn's recommended list of documentation methods includes:

- project engineer's diary
- inspector diary
- contractor diary
- subcontractor diary
- traffic control plans
- approved modifications to TCPs
- invoices
- documented conversations
- project correspondence
- video documentation
- photographs
- state inspections
- federal inspections

Postaccident Actions

Of course, accidents can happen even in the most carefully thought-out and set up work zone. When an accident does occur, Alcorn suggested a number of postaccident actions:

- prevent secondary accidents by alerting other traffic
- take video and/or photographs of
    - vehicles involved
    - paths and positions of vehicles
    - pavement surface conditions
    - placement of traffic control devices and condition
    - skid marks and debris
- record who were operators and passengers
- get the names and addresses of witnesses
- note day and time
- note weather and visibility

Key Liability Factors

In conclusion, Alcorn reemphasized that the key liability factors are:

- injury or property damage has occurred
- a hazard existed
- the contractor was or should have been aware of the hazard
- there was negligence in not correcting or warning the public of the hazard
- there was reasonable time and method to correct the hazard

The best way to avoid liability is to know and to comply with all applicable contract documents and to have the back-up documentation to prove compliance with ***MUTCD*** and other relevant standards.

MEASURING RETROREFLECTIVITY

Sam Tignor and Travis Brooks of the Washington D.C. Federal Highway Administration (FHWA) and Jim Kellenberger of North Carolina Department of Transportation (NCDOT) held a panel discussion of the standards, development, and evaluation of reflectivity measuring devices. The FHWA is studying implementation approaches for their new mobile sign retroreflectivity devices. They are working with Minnesota Department of Transportation (MINDOT) to link the data from the unit to a predictive model in their sign management software so retroreflectivity of a sign does not have to be measured every year. A workable version of this software is due from McTrans soon. A new van-mounted Laserlux mobile unit for testing raised pavement markers is promising. It is undergoing all-weather testing for the acceptance evaluation. The Laserlux correlates well to what the driver sees on the road because of corrections to the internal measurement geometry.

Mr. Kellenberger described a quick-and-dirty field test his inspectors use to check whether glass beads in a paint stripe are sufficiently embedded. The inspectors all carry a "warp-and-woof" inspection device, which looks like a large jeweler's loupe. With this cheap device they can get a good look at the beads as soon as the paint isn't tacky. Also, they've had good success with quality control of pavement markings by getting the manufacturers, as well as the contractors and state people, together and talking about what's going on and what they need to do.

There was quite a bit of discussion of how the 6005 section (All Weather Visibility) of ISTEA will affect pavement marking contracts and contractors in FY 1997.

UPDATE ON MUTCD PART VI

Phil Russell, a consultant who has been working on the update of the ***MUTCD***, explained some of the new features of *Part VI – Construction and Maintenance* in the general session and in his breakout in-depth session on Wednesday afternoon.

Noncompliance with the current ***MUTCD*** is still a problem, even though it's been out for nearly ten years. Mr. Russell feels this noncompliance in part is a result of conflicts and discrepancies within ***MUTCD*** itself and in part because of honest misinterpretation by contractors and state officials. In the new ***MUTCD***, the required parts will be in bold so they catch the eye immediately.

The FHWA released *Part VI – Construction and Maintenance* for comment in September 1993. They are allowing a period of eighteen months for comments from state DOTs and private industry to straighten out items that may need correction or improvement. This period will end in December 1994. Lewis Rhodes and his staff in TRF have been reviewing this portion of the manual for Texas, but districts may want to take a closer look at it as well.

Some of the new material in *Part VI – Construction and Maintenance* includes provisions for transit, forty new typical applications for advanced, buffer and work zone setups, and a section on pedestrian and worker safety. Figure 2 is an example of one of the new work zone setups. A copy is available on loan from the RTT Library. Call Dana Herring at (512) 465-7644.

TXDOT'S SAFETY REVIEW

George Lantz, P.E., (CMD) of the Traffic Control Team discussed TxDOT's Safety Review Program. A safety review ensures that a project's approved traffic safety plan has been implemented correctly. The review consists of an office and a field visit, followed by a close-out session at the end of the project. District inspectors might want to be on the lookout for a few improper practices that seem to crop up fairly regularly:

- lane closure signs that are not covered or removed when the lane is no longer closed
- not-in-use signs that can still be read at night through their burlap covering
- barricades and signs nailed instead of jointed with approved fasteners
- insufficient offset of barricades parallel to the traveled way

MOCK PARTNERING PANEL

Annie Dadian-Williams, P.E., (CIO) presented a mock preconstruction partnering meeting with a panel consisting of construction company and TxDOT personnel. The audience participated in the problem identification and resolution processes. The problem that the panel gave number one priority was hiring and keeping people knowledgeable about traffic control devices. Although several people expressed skepticism at first, they became more enthusiastic as the discussion went on and they saw how effective lines of communications could be set up and used flexibly to provide what was needed to move a job forward quickly and safely.

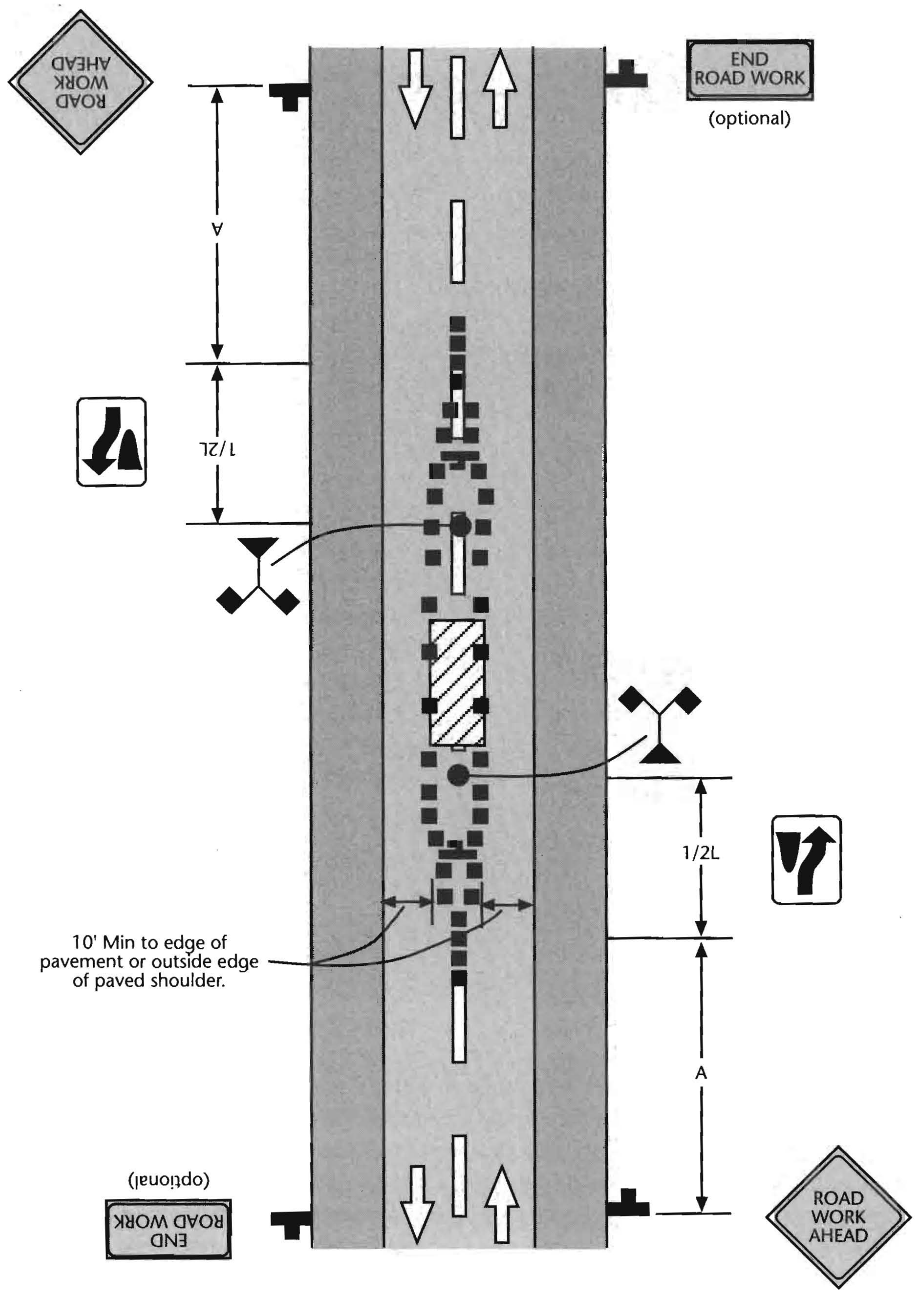

FIG. 2: Work zone setup for activity in the center of a low-volume road.

CONCLUSION

Mr. Templeton discussed the future directions TxDOT will take regarding work-zone construction. Communication, he stated, is the most important point of a traffic control plan. The plan, and its legal aspects, must be understood by both the contractor's staff and TxDOT inspectors so that they can present it on the road in a way that the driving public can understand. One way to promote effective communication is through partnering. He said that 130 projects had been partnered in the last two years, most with very positive results.

Good traffic control in a work zone requires dedication, enthusiasm, commitment and teamwork. Contractors and TxDOT personnel need to work together so everybody can win. Traffic safety is the responsibility of every individual on a project — you should ask yourself every time you drive though your project: Is this traffic control plan what you'd want your special loved person to face?

Mr. Alcorn's presentation material was used by permission.

> ***EDITOR'S NOTE***
>
> For the latest information on how the driving public responds to signs, signals and markers, attend the 1994 TxDOT Transportation Conference Session 3 on Tuesday, October 18, at Texas A&M University. Lewis Rhodes, TxDOT Traffic Administrative Engineer, and Drs. Gene Hawkins and Katie Womak (TTI) will present results from their research project, ***Motorist Understanding of Traffic Control Devices.*** The Research and Technology Transfer Office's booth at the conference will also feature information from this interesting and significant project. If you can't attend Session 3, watch the videotape. To borrow a copy from the RTT Library, call Librarian Dana Herring after 1 December.

SHRP CORNER

TEXAS DOES SHRP

by **Tom Yarbrough**, P.E.
Implementation Engineer
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Texas Department of Transportation

Congress established the Strategic Highway Research Program (SHRP) in 1987 as a five-year, $150 million research program to improve the performance, durability, and safety of our nation's roadways. A set-aside of one quarter of one percent of federal-aid highway fund bankrolled the program. The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) authorized another $108 million for the continuation of the long-term pavement performance program and implementation of SHRP products.

SHRP produced 130 "products" in four functional areas. These products include test methods and equipment, software, manuals, traffic operations and safety equipment, and specifications. The strategically targeted areas for which SHRP products were developed are:

- **Highway Operations**
  - Pavement Maintenance
  - Pavement Condition Evaluation and Repair
  - Worker Protection and Traffic Control Devices;
  - Snow and Ice Control
- **Concrete and Structures**
  - Concrete Bridge Physical Condition Assessment — Diagnostic Tools
  - Concrete Bridge Protection and Rehabilitation
  - Concrete Research (including Concrete Performance, Alkali-Silica Reactivity, Freeze and Thaw Conditions, Nondestructive Tests for Quality Control, High-Performance Concrete, and Optimum Concrete Technology)
- **Asphalt**
  - Performance-Based Specifications
  - Asphalt Binder Performance Tests
  - Accelerated Performance Tests for Asphalt Mix
  - Asphalt Sample Preparation and Conditioning
  - Products for Suppliers
- **Pavement Engineering**
  - Pavement Monitoring and Management Tools
  - Information Management System
  - Traffic Monitoring Tools
  - Pavement Analysis Test Methods

TxDOT Executive Director Bill Burnett has been named chairman of the American Association of State Highway and Transportation Officials (AASHTO) SHRP Implementation Committee, and it is expected that Texas will lead the nation in the use of SHRP products. TxDOT Assistant Executive Director for Field Operations Bobbie Templeton was appointed SHRP state coordinator, and in April 1994, a TxDOT SHRP

Implementation Steering Committee was formed to guide TxDOT.

Technical Working Groups (TWGs) have been formed for each of the four SHRP functional areas. There are nine TxDOT members on each TWG, as well as a representative from both the Research and Technology Transfer Office and the Federal Highway Administration (FHWA). The task for the TWGs is to evaluate the SHRP products in their respective functional areas and determine their viability for use in Texas, then encourage appropriate use of proven products. The plan is outlined below.

1. Assimilate and organize existing data on each SHRP product, including the SHRP program research summary, past experience by TxDOT and other state DOTs, information from specialists, FHWA personnel, and industry.
2. Create a strategic plan for evaluation and implementation of products for each functional area, including prioritization of product evaluation, field trials, and implementation plans. District support will be solicited for implementation and testing. Upon completion of product trials, teams may recommend improvements for the products.
3. Develop or modify appropriate specifications, test procedures, or construction methods following normal TxDOT procedures for TWG-recommended SHRP products.

To ensure that all interested TxDOT personnel are kept informed, each SHRP product will be input into the Technology Transfer System (TTS) information database, accessible via the department's mainframe. TTS entries will be updated upon completion of product evaluation and whenever significant milestones are reached in implementation. Each of the four TWGs will also submit progress reports, updating the status of each group's evaluation and implementation efforts, for publication in the department's ***Technical Quarterly***.

Evaluation and implementation (if recommended) of all SHRP products for use in Texas are formidable, yet necessary, tasks if TxDOT is to reap full benefits from the SHRP program. With the formation of the TxDOT SHRP Implementation Program, the department has the necessary framework to lead the nation in implementation of SHRP products. Implementing appropriate SHRP products should result in increased performance, decreased maintenance, and improved safety on Texas highways.

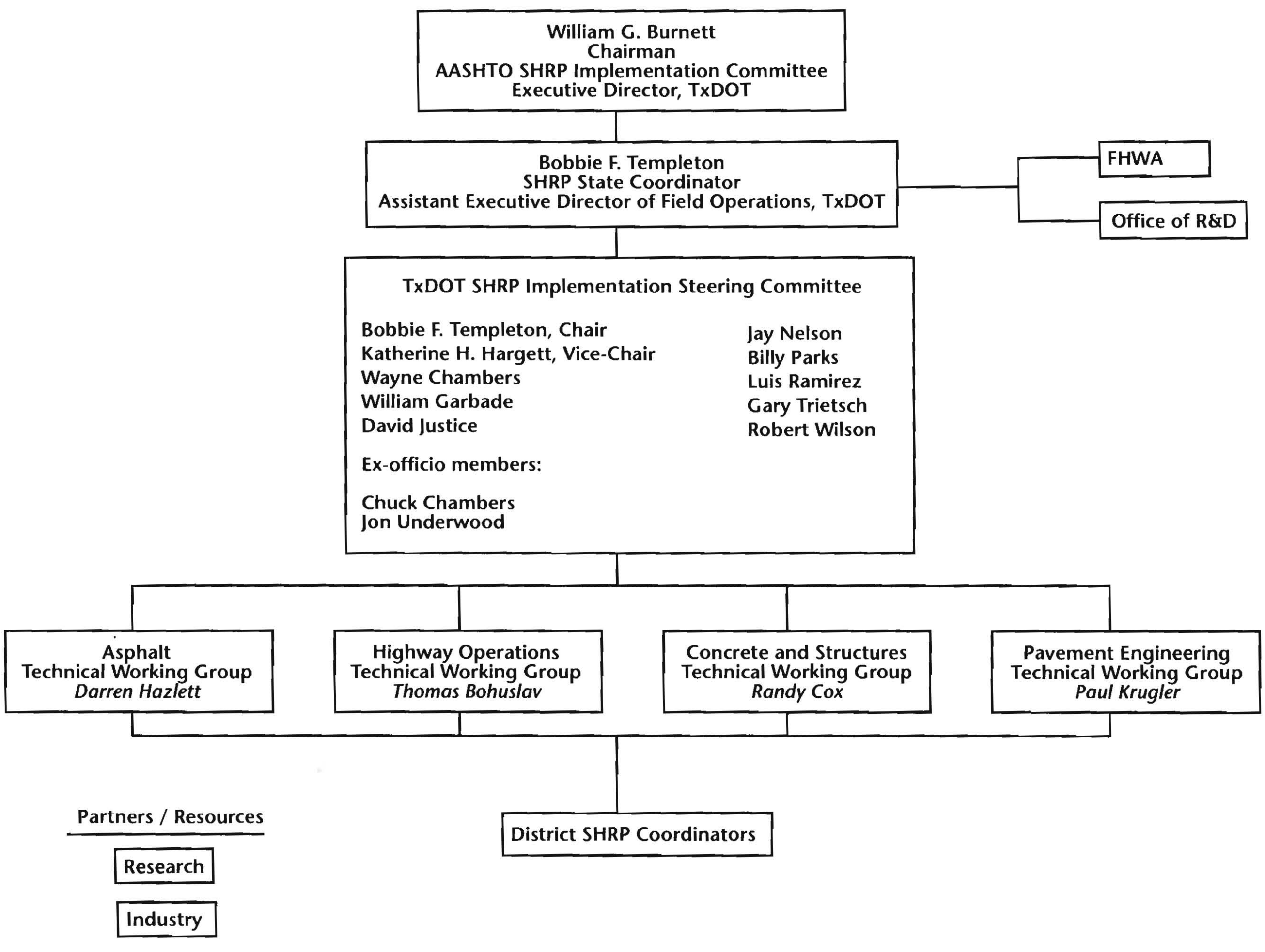

FIG. 1: Organizational chart of TxDOT's SHRP Implementation Committee.

CHECK YOUR STRUCTURES' ALKALI-SILICA REACTIVITY

Almost a quarter of a million miles of streets and highways in the United States are paved with portland cement concrete, as are bridge piers and abutments. But the structural integrity of those bridges and roads is threatened by a common, yet often unrecognized, problem called alkali-silica reactivity (ASR).

ASR is nothing new. Highway departments and others in the industry have known about it for more than 50 years. Frequently it goes undetected because of unfamiliarity with the symptoms of ASR-induced distress.

When silica or silicates present in the aggregate react with alkali components in the cement, it forms a gel-like substance in the concrete. The gel tends to absorb moisture; as the gel expands, it causes the concrete to crack. ASR by itself doesn't always cause a structure to fail; more often, it weakens or degrades a structure to the point where other factors, such as traffic loads, bring on premature failure.

As a result of the Strategic Highway Research Program's research, highway departments and contractors have new tools for diagnosing and preventing ASR, as well as extending the service life of structures already beset with ASR-induced distress.

THE PROCEDURE

Suspect ASR when cracks in a map or longitudinal pattern contain clear, glassy or white powdery deposits. However, many of these deposits are merely calcium carbonate, which is not indicative of ASR.

SHRP's new procedure is an easier, quicker way to identify the potential presence of ASR — before serious distress sets in and while there is still time to take corrective action. The procedure involves removing a small piece of the concrete from the structure and treating the specimen with a uranyl acetate solution. The specimen is then examined under ultraviolet light. Areas that glow with a yellowish-green fluorescence mark probable ASR gel sites. No fluorescence means no ASR problem. Absolute confirmation of ASR reaction products must be done by other tests, since other alkali products may fluoresce with a similar yellowish-green color.

SHRP's *Handbook for the Identification of Alkali/Silica Reactivity in Highway Structures* explains the procedure. The handbook also describes the nature of the ASR problem, and color photographs clearly.

ASR gel effects can be mitigated, thus prolong the life of the affected structure. Laboratory tests of hardened mortar showing signs of ASR-induced expansion have found that an application of lithium hydroxide (LiOH) solution can prevent further expansion. Lithium hydroxide also reduces expansion when sodium chloride solutions are present (as would result, for example, from the application of deicing salts). To test this hypothesis in the field, an ASR-affected pavement section in Nevada was spray treated with LiOH solution and is being monitored.

LONGER PAVEMENT LIFE

Much of the damage caused by ASR-induced expansion can be avoided in new pavements through better testing and selection of aggregates for the concrete mix. Some current test methods fail to identify those aggregates that are slow to react, but which cause abnormal expansion in highway structures in the long run. As a result, an aggregate may be wrongly judged to be nonreactive.

An optimal procedure for identifying potentially reactive aggregates would be rapid (taking less than a month), reliable (able to distinguish between innocuous, slowly reactive, and highly reactive aggregates), and capable of identifying ways of modifying cement-aggregate combinations' ASR susceptibility. One such procedure, developed at the National Building Research Institute in South Africa, has been refined by SHRP. Mortar bars are placed in a normal solution of sodium hydroxide for 14 days at 176 degrees F; the bars are measured at regular intervals to determine the amount of expansion. The procedure also can be modified to determine the safe cement alkali levels and the quantity of pozzolans and other admixtures required to control expansion caused by ASR.

Experimental pavement sections were built in Albuquerque, New Mexico; LiOH was added to the concrete mix to offset the effect of the highly reactive aggregate. The test sections will continue to be monitored over the next 15 years to determine how LiOH in the mix affects pavement performance.

SHRP's research also yielded guidelines for a concrete mix design that would be safe from ASR. The guidelines recommend specific combinations of cement, coarse and fine aggregates, and admixtures (both pozzolans and chemicals) that will resist ASR in new concrete pavements. The guidelines will be submitted to the American Association of State Highway and Transportation Official Subcommittee on Materials for possible adoption as an AASHTO standard.

The results of SHRP's research into eliminating or minimizing the effects of ASR are reported in a new publication *Eliminating or Minimizing Alkali/Silica Reactivity* (TTS file location MS-5462) and *The Handbook for Identification of Alkali-Silica Reactivity in Highway Structures* (TTS file location number MS-2027). These reports are available on loan to TxDOT personnel from the Research and Technology Transfer Library. Call Librarian Dana Herring at (512) 465-7944.

Gerald Lankes, P.E., of the Materials and Tests Division is handling TxDOT's ASR training. Call him at (512) 465-7331 for more information.

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