TECHNICAL QUARTERLY

"AN EXCHANGE OF IDEAS"

TQ8-1 MARCH 1993 *EDITOR: Kathleen M. Jones*

HOT MIX ASPHALT CENTER BEGINS INSPECTOR EVALUATIONS

The newly created Hot Mix Asphalt Center, administered by the Texas Hot Mix Asphalt Paving Association, began evaluating the first class of asphalt specialist inspectors on 11 January 1993. [See TQ7-3, "Certification of Asphalt Inspectors: Questions and Answers."] The HMA Center is not a training facility; it is a performance and procedure evaluating center.

In order to have workable Quality Control/Quality Assurance (QC/QA) specifications, the Texas Department of Transportation (TxDOT) and the construction industry need uniformity and consistency of inspection and testing. A primary focus in all the sessions of the week-long class is: "Don't guess at it; use your manual. Tests are revised over time. Don't rely on your memory." The format is hands-on, and the evaluations are open book — after all, that best simulates field conditions. You are evaluated on *how* you perform the tests, rather than what the individual results are.

The facility is spacious and well lighted. The laboratories are furnished with new or reconditioned equipment leased from TxDOT and conforming to all TxDOT requirements. The nuclear asphalt density gauges are the newest, ultrasafe low radiation type. A lot of thought and planning has gone into lab layout to provide settings that seem familiar and are accessible to the participants so that the setting does not interfere with the individual's performance.

The evaluators are all highly experienced laboratory personnel who have gone through an extensive qualifying program devised by TxDOT. The HMA Center evaluators do not certify people. They recommend individuals for certification to the Division of Materials and Tests (D-9) based on the individual's class performance. D-9 then accepts or rejects the recommendation.

The 24 people in this first Plant Operations (Level 1A) class represent 20 TxDOT districts and D-9. You'll notice the names of people with twenty and thirty years experience in the sidebar. That's because TxDOT

FIGURE 1: Dale Foster (on left) reviews sieve analysis with a distinguished set of candidates.

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policy requires that only certified personnel be allowed to perform tests on hot mix projects let under the new QC/QA specifications, while it disallows "grandfathering." This class will be the only one made up entirely of TxDOT employees. Future classes will contain an even mix of state and contractor personnel.

A survey of the districts showed that over 1,300 TxDOT employees need to be certified, and at least that many contractors' personnel. The HMA Center can handle about 1,000 people annually — provided the people are scheduled in the summer months, not just in slack time. Classes are already scheduled and filled through April. There's a backlog of people waiting for classes scheduled after April.

The QC/QA specifications are not just "out there" sometime in a nebulous future. The first five contracts to be let under the draft QC/QA specs will be let in March and April (Table 1). All testing personnel on these jobs must be recommended by the HMA Center and certified by D-9. In all but the El Paso job, a special provision in the draft specs allow contractors the option to work under the incentive/disincentive clauses. In El Paso, the incentive/disincentive requirements are mandatory.

Data collected on these projects will be used to refine the QC/QA specifications. In 1994, 10 to 15 contracts will be let under the revised specification with the incentive/disincentive requirements being mandatory. The specifications will be refined again, if necessary, before full implementation in 1995. The revisions will not affect the contracts let under the draft specifications.

Get signed up to certify as soon as you can; 1995 is not that far away!

TQ's paper includes 20% post consumer waste in the total fiber content.

TABLE 1: QC/QA projects for 1993.

DISTRICT	COUNTY	HIGHWAY	PROJECT	CONTROL	LETTING
Witchita Falls 3	Montague, etc.	FM 174, etc.	CPM 137-12-9, etc.	0137-12-009, etc.	March 1993
Abilene 8	Nolan	IH 20	IM 20-2 (167) 228	6-2-83	March 1993
El Paso 24	El Paso	SH 20	STP 92 (134) R	2-2-29	March 1992
Lufkin 11	Polk	US 59	CPM 176-4-62	176-4-62	April 1993
Pharr 21	Webb	IH 35	IM 35-1 (54) 006	18-5-47	April 1993

FIRST CLASS ASPHALT SPECIALISTS

The following people attended the first Plant Operations (Level 1A) certification sessions:

Donald Bednarz (Dst. 5),
John Betts (Dst. 19),
James Black (Dst. 3),
Joe Merrel Bowman (Dst. 23),
Helen Poe Burge (Dst. 20),
Alan John Easterling (Dst. 2),
Cloyce Evans (Dst. 11),
Gary Gillen (D-9),
Raymand Guerra, Jr. (Dst. 24),
Ronald Hatcher (Dst. 25),
Bobby Jones (Dst. 1),
Raymond Kluck (Dst. 17),
Pat Kram (Dst. 13),
Brad Norris (Dst. 12),
Dale Rand (D-9),
Chris Starr (Dst. 9),
Gervase Szalwinski, Jr. (D-9),
Maghsood Tahmoressi (D-9),
Philip Treadaway (Dst. 7),
Natividad Vargas (Dst. 18),
Jimmy Vogel (Dst. 15),
Stacy Wallis (Dst. 16),
Richard Wesson (Dst. 14)
Buck Whitehead (Dst. 8)

The HMA Center evaluators were:

Dale Foster — Sampling and Sieve Analysis
Bubba Harris — Rice Gravity and Compaction
Fred Fisher — Extraction Methods
Henry Hardy — Nuclear Asphalt Density Gauge

QUALITY ASSURANCE: TOP MANAGEMENT'S TOOL FOR CONSTRUCTION QUALITY

by **Dr. Robert P. Elliott**
Arkansas Highway and Transportation Research Center
University of Arkansas

ABSTRACT

The consistent achievement of high-quality construction requires a strong commitment throughout the highway agency. It is most important that top management be committed to quality and that the commitment be conveyed to and perceived by the agency's inspection staff. Under traditional highway specifications it is very difficult, if not impossible, for management to consistently project this commitment. The use of quality assurance (QA) specifications can alleviate these problems. QA specifications can be a tool that aids top management in promoting and achieving construction quality.

INTRODUCTION

Since the early days of highway construction there has been an almost continual effort to achieve and improve construction quality. Until the 1960s, the efforts for quality were almost universally centered on the use of traditional, method-oriented specifications. However, in the 1960s some agencies began to experiment with the use of specifications that included statistically based acceptance provisions. These specifications are commonly referred to as quality assurance (QA) specifications within the highway community.

Many highway agencies have tried QA specifications, and some agencies use them routinely. Other agencies either have not used them at all or have tried them and then abandoned them. The potential benefits of QA specifications are described, especially from the perspective of top management support for construction quality, in the hope that more agencies will try the QA approach and reap the potential benefits.

The use of QA, however, does not guarantee that benefits will be realized. Unless the QA specifications are properly developed and implemented. they may be no better (and can be worse) than the traditional specifications they replace. This has clearly been demonstrated by some of the agencies that have tried and abandoned QA specifications....

INCENTIVE — THE SOURCE OF QUALITY

To understand the benefits of QA, one must begin by examining the factors that control construction quality. Discussions on achieving construction quality usually center on inspection, testing, and sampling. In fact, the QA specification approach emphasizes inspection, testing, and sampling, but the manner in which these activities are handled differs significantly based on the following two facts:

1. Quality cannot be inspected, sampled, or tested into a product. It must be built in by the builder.
2. Quality occurs only if people want, expect, and insist on.

The traditional specification seems to assume that the actions of inspection, sampling, and testing somehow create construction quality. However, it is easily recognized that final control over the quality rests with the contractor. The contractor operates the equipment, places the material, and performs all of the actions that result in the final product. The contractor must build in the desired quality if it is to exist.

For the contractor to achieve quality, there must be adequate incentive to achieve it. The contractor must want quality, expect quality, and insist on quality. The true thrust of the QA specification is to provide an appropriate level of incentive for the contractor to want to achieve the needed quality.

Nevertheless, incentive is important not just for the contractor. The incentive for quality must begin with the designer. The designer must have a strong incentive to design and specify the required quality. The designer who has a strong incentive to produce quality designs will keep abreast of the latest developments in design methodology, material behavior, and specification preparation.

The inspector must also have an incentive to achieve quality. The inspector's job can be tough and demanding. Without the proper incentive, it is frequently easier to ignore and overlook deficiencies than it is to insist on their correction. The ultimate source of incentive for quality rests with top management of the highway agency. If top management is truly committed to quality, that commitment will filter down through the organization and provide the incentive for the designer and the inspector. The highway agency commitment will in turn instill an incentive for quality in the contracting firms. If top management of the contracting firm is also committed to quality, the achievement of quality is virtually assured.

Conversely, when the highway agency's top management gives only lip service to the achievement of quality, this attitude too is rapidly reflected throughout the organization. Relaxing requirements in one case or permitting one contractor to violate standards rapidly erodes the incentive for others in the agency to insist on quality achievement. An inspector who has rejected inferior work only to see it accepted later finds it difficult to insist on quality in the future.

Consequently, top management must want quality, expect quality, and, most significantly, insist on quality. But more than this, top management must present and demonstrate an attitude that is perceived as supporting quality. The perception of commitment and support is more important than the actual commitment itself; it is that perception that is aided by the QA specification.

To project the needed image of support for quality, top management must give every contractor on every project fair and evenhanded treatment. Top management must also insist that the contractors abide by the contract quality requirements. With the traditional type of construction specification a fair, evenhanded treatment is often very difficult; the projection of fair treatment so that it is perceived as such by the resident inspection staff is nearly impossible. The QA approach to construction specifications provides a means by which top management can deal with quality more easily, more evenly, and more fairly. An examination of the two approaches demonstrates how the QA specification aids top management .

TRADITIONAL SPECIFICATIONS

Traditional specifications are primarily method-oriented. That is, construction methods and construction equipment are specified in considerable detail and some specific "end-result" quality requirements are stated. The specified quality requirements are generally stated in absolute terms without acknowledging or making provisions for construction variability. In addition, the monitoring of the quality is relegated to the highway agency's inspectors.

Because of the limitations imposed by the equipment and method requirements and because the quality monitoring is performed by the agency, the traditional specification leaves little contractor responsibility for the end result as long as the appropriate methods and equipment are used. For example, an asphalt specification may contain specific requirements for density and mix composition. However, under the traditional specification, the mix proportioning and density testing are performed by the agency's inspection staff. If the mix and density are later found to not comply with the specification requirements, it is quite difficult to demonstrate that the contractor is responsible for the "out-of-specification" result.

In addition, because of the traditional specification's absolute nature, its lack of guidance for handling of out-of-specification construction, and the degree of judgment required in its enforcement, a large burden is placed on both the inspector and the top management of the agency. By its nature, the traditional specification creates an adversarial relationship between the contractor and inspector. As a result, the two parties directly involved in the construction may often find themselves working against one another. Management is sometimes forced to intervene and arbitrate. When this occurs, management must tread a delicate line between supporting the inspection staff and being fair to the contractor. Rarely can both sides be satisfied; it is perhaps just as rare that management can project the desired image of full support for high quality.

Nevertheless, the traditional specification can work well when the inspector is knowledgeable, experienced. concerned, and fair. However, a tough inspector can create undue hardship for a contractor, and a lax inspector can permit acceptance of grossly inferior work. Similarly, the inexperienced inspector finds it quite difficult to "police" the traditional specification. Unfortunately, most highway agencies today are faced with a rapid loss of experienced personnel and forced to rely more heavily on inexperienced inspectors.

The traditional specification places a large burden on top management of the highway agency when a decision must be made about out-of-specification construction. Some construction is so bad that the only choice is to remove and replace.

The decision to remove and replace is not too serious unless the contractor contends that all method requirements and inspector instructions have been followed. In that case, the contractor can justly contend that the cost of removal and replacement should be borne by the agency. Top management, recognizing that such a contention will frequently hold up in court, may be forced to pay for the removal and replacement. This action is usually perceived by the inspection staff as rewarding the contractor for inferior work.

The similar burden to top management comes in those instances when it is more desirable to leave the work in place. When this occurs, some pay adjustment may be negotiated. The negotiation is rarely resolved to everyone's satisfaction. Again, the inspection staff often views the negotiated adjustment as being too lenient and top management as being "soft" on quality.

Thus, regardless of whether the unsatisfactory work is removed or a pay adjustment is sought, a dispute usually develops that is not easily resolved. Also, how it is resolved can affect the attitude (and incentive) of the inspection staff. If the inspectors perceive that top management has "caved in" to the contractor, morale and the quality of future work will suffer. Unfortunately, this perception is received much more frequently than top management usually realizes.

QUALITY ASSURANCE SPECIFICATIONS

QA specifications are designed to alleviate the problems discussed. They eliminate (or at least greatly reduce) the adversarial relationship between the inspector and contractor. They tend to create a team atmosphere with both the inspector and the contractor looking for and working for the desired construction quality. Also, they provide a specific and automatic method for handling out-of-specification construction.

Two important and distinguishing features of the QA specification are the recognition of construction variability and the inclusion of provisions for handling out-of-specification construction. In recognition of variability, the sampling, testing, and acceptance provisions in QA specifications are based on statistical principles.

A key question that has been faced and answered with the development of QA specifications is "Who really controls quality?"

Quite obviously, the one who actually is doing the construction has the true control over quality. The highway agency may test, but it does not operate the plant, run the pavers, saw the joints, or do any of the many other operations that actually instill quality.

This fact has always been recognized but under traditional specifications it has become obscured. With quality testing being performed by the agency, the contractors have come to rely on the test results for process control. For example, highway agency proportioning engineers typically tell the contractor what the plant settings should be. By this action, the control of quality is largely (if not entirely) usurped by the inspector. With this situation, the contractor's responsibility for inferior quality, can be quite questionable unless it can be shown that the contractor did not follow the directions of the inspector .

Process control is and should be the responsibility of the contractor. In recognition of this, QA specifications place responsibility for quality control testing in the hands of the contractor. For example, tests to determine the amount of water to add to a concrete mix or to determine the gate opening for an aggregate bin at an asphalt mix plant are left to the contractor. The highway agency performs tests only for the purpose of accepting (or rejecting) the construction. With this approach, the contractor is clearly responsible if the desired quality is not achieved.

The placement of process control and quality control testing in the hands of the contractor has been viewed by many as revolutionary and as an abandonment of the inspector's traditional authority. However, in the early days of road construction in this country, process control and testing was the responsibility of the contractor. In fact, many of today's tests for asphalt concrete mix design and quality control are the outgrowth of the quality control testing by the early contractor .

A common misconception regarding QA specifications is that their use precludes the use of inspectors. This is not true. Even with QA, inspection is required. Many activities and quality details can be ensured only by vigilance and observation. For example, a QA embankment density program can be quite effective. However, inspection is needed to ensure that unacceptable foreign matter (e.g., tree limbs, stumps) is not incorporated.

The use of QA specifications can be viewed as an attempt to put all the players in the quality process on the same team. Under traditional specifications, the inspector performs the tests and instructs the contractor. In too many instances, an adversarial relationship develops. The inspector tries to "catch" the contractor who may be trying to avoid following those instructions.

By placing quality control in the hands of the contractor and "after-the-fact" acceptance testing in the hands of the inspector, they both begin to strive for the same goal — construction that meets the required quality standard. Thus the designer, the inspector, and the contractor become partners on what might be called the quality team.

The magical ingredient in a good QA specification is incentive. For anything to be accomplished, one must have incentive. If contractors have sufficient incentive to provide quality, they will provide quality. The

QA specification is designed to provide that incentive. The incentive aspects of the QA specification also provide the means for handling out-of-specification construction.

The QA specification feature that serves this dual purpose is the acceptance/rejection process, which includes a pay adjustment provision. A minimum acceptable quality level is specified. If the acceptance testing shows that this level has been met or exceeded, the contractor is paid the full bid price for the work. However, if the quality is below the minimum but not so poor as to require removal and replacement, the contractor is paid a reduced amount commensurate with the quality. The amount of pay adjustment is established by the contract. There is no need to negotiate and no decision to be made. The actions are determined before the fact by the contract provisions.

Also, there is no question of responsibility. The contractor has performed the process control testing, has made the decisions on process adjustment, and has issued any instructions on plant settings. If the required quality is missing, it is clearly the responsibility of the contractor

Some QA specifications go a little farther in providing incentive to the contractor. These provisions may include a bonus for superior quality. The bonus provision usually results in a stronger incentive for good quality than does the price reduction provision. The achieving of bonus pay can instill in every worker involved in the project a sense of pride that is greater than the monetary reward. (The carrot usually works better than the stick.)

SUMMARY

The traditional highway specification tends to create a situation in which it is difficult (sometimes impossible) for top management of the highway agency to project an image of complete support for high-quality construction. The method-type provisions and the use of the inspection staff's testing for quality control create conditions in which inferior construction cannot always be rejected. When this happens, the inspection staff does not always understand and may view the acceptance of the work as a sellout. Even the negotiation of price reductions for inferior work that is left in place does not convey the image of support needed because the negotiated reduction rarely, if ever, is commensurate with the level of inferiority.

The traditional specification also tends to create an adversarial relationship between the contractor and the inspection staff that sometimes escalates to the point that management is forced to intervene and arbitrate. When this occurs, top management must tread a delicate line between supporting the inspection staff and being fair to the contractor. Rarely can both sides be satisfied; it is perhaps just as rare that management can project the desired image of full support for high quality.

Use of QA specifications can alleviate these problems. Less reliance on method-type requirements and placing quality control in the hands of the contractor makes the contractor clearly responsible for the quality of the end product. The agency is not forced to accept inferior work because of a question of responsibility. In addition, the QA pay adjustment schedule provides the contractor specific incentives for achieving the desired quality and eliminates the need to negotiate adjustments when inferior quality work is encountered. The QA approach also tends to remove the adversarial relationship between the contractor and inspection staff. Construction quality becomes a specific objective of both parties.

ACKNOWLEDGMENT

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DID YOU KNOW...

Scientists at Toshiba Corp., Tokyo, Japan, have built a miniature, magnetically levitated "transport system" using high-temperature ceramic superconductors. A linear-motor carrier, which contains the ceramic superconductors, is levitated 5 mm (0.2 in.) above a 2.2-m (7.2 ft) long magnetic test track and propelled along it at a speed of 25 m/min (82 ft/min). The 180-mm long x 120-mm wide x 45-mm high (7x5x2 in.) test vehicle can carry a load of about 3 kg (7 lb), which is twice its own weight.

Credit: "Technical Bulletins," ***Advanced Materials & Processes*** 140 (Nov. 1991):14.

AVOID NEGATIVES AND ABSOLUTES

Avoid negative and absolute statements when you communicate with employees. *Examples:*

- **Negative:** "Why can't you . . ." **Positive:** "What if we ..."
- **Negative:** "I hate it when . . ." **Positive:** Wouldn't it be better if ..."
- **Absolute**: "He always says . . ." **Non-absolute:** "I've heard him say ..."
- **Absolute**: "Nothing ever gets done right around here."
  Non-absolute: "At times, we've had problems getting things done right."
- **Absolute**: "We must do it this way." **Non-absolute:** "Here's a good idea to consider."

Source: The Little Black Book of Business Etiquette, by Michael C. Thomsett, AMACOM Books, 135 W. 50th St., New York, NY 10020 , as seen in ***Communication Briefings*** (Sept. 1992):3.

ROBOT TO FLAG ACCIDENTS

The Japanese public highway authority has developed an "accident detection robot" that can alert police and emergency crews to an expressway accident within two seconds. Reportedly the first of its kind, the robot is designed to alert rescue teams to accidents near sharp curves and accident-prone "black spots" where visibility is poor. The Hanshin Expressway Corporation says the robot will be ready for use on its tollways by 1993.

Hanshin says it developed the robot's ability to identify accidents by using four cameras installed at a troubleprone spot on an expressway for a month videotaping the thousands of vehicles that passed. During analysis of the videotapes, Hanshin researchers detected patterns in sudden directional changes, interrupted speed and momentary disorientation in vehicle movement that they were able to teach a computer to recognize.

By linking the system with cameras and television monitors, accident "replays" can be produced that start four seconds before a recorded accident. By tracking each vehicle's movement, police will be assisted in pinpointing accident causes. The system is expected to reduce chain reaction accidents and enable ambulance crews and tow trucks to gauge the scale of an accident before they arrive on the scene. Clean-ups will be quicker and traffic jams will also be reduced. In the four month test run that ended [in 1991], the robot spotted a total of 36 incidents, including 20 collisions, six sudden stops and five instances where vehicles spun out of control.

Source: Public Innovation Abroad (November 1991), as seen in ***Wyoming T² Newsletter*** 8 (Spring 1992): 7.

CAR WARS — THE ENVIRONMENT CANNOT STRIKE BACK

by the **Texas Water Commission**

Rainfall runoff flushes loose particles and liquids from the ground into our water supplies. These substances combine into a mixture called *nonpoint source pollution* that contaminates the rainfall runoff which replenishes the water supply we use for drinking, recreation and scenery. EPA estimates that nonpoint sources account for more than half of the pollution in our water supplies today. These sources, called "nonpoint" because of their diffuse, cumulative nature, generally can be traced to irresponsible use or disposal of pesticides and fertilizers, household chemicals, paints or anything else humans leave on the ground. One very significant nonpoint source of pollution is the automobile.

Just think of all the automotive products you use that you would not want mixed in with your drinking water. Gasoline, motor oil, brake and transmission fluid, antifreeze, battery acids, tire residue and a host of solvents, waxes and cleaning chemicals are common water pollutants. You would not knowingly mix any of these products with your drinking water, but do you every inadvertently rinse them from your driveway into the street gutter, or otherwise leave them on the ground for the rain to wash into the nearest drainage ditch?

Used motor oil is estimated by some experts to comprise at times as much as 40 percent of the pollution in American waterways. Leaking crankcase plugs, defective valve cover gaskets and the illicit disposal of used oil contribute an estimated annual average of *240 million* gallons to the environment nationwide. The answer: repair leaks and dispose of used oil properly by taking it to a service station or other recycler.

Antifreeze is a toxin which serves a legitimate function in the radiator, but when spilled into the environment (a particularly *illegitimate* use of antifreeze) its sweet taste attracts, and can kill, animals. Simply hosing drained radiator contents into the gutter rinses poison into an environment that can no longer dilute all the stuff we put into it. Some radiator shops will accept waste antifreeze even though they don't like to advertise it (it costs them money to have a recycler pick it up from them). For our children's sake, locate a business that will accept it or save it until a local or regional hazardous waste collection day.

Consider also the engine solvents, tar or grease removers and other tire and upholstery cleaners used in America's driveways that often end up in our water. It may be impossible to collect the rinsewater after using these products, but we must recognize the connection between them and water pollution, and learn to be frugal in our use of these materials or use less toxic products. The automobile is an entrenched part of American culture, and likely to remain so for many years. As population and traffic both increase at astronomical rates, so too does our responsibility as motorists to recognize how our use of the automobile affects the very water we depend on.

DOES HOV LANE CONSTRUCTION REALLY CLEAN THE AIR?

by **Christopher K. Leman**
Executive Director
The Institute for Transportation and the Environment
(a nonprofit research and education organization based in Seattle)

With the November 1992 deadline for revision of state air quality plans under the federal Clean Air Act of 1970, the air quality impacts of building new HOV lanes will be receiving increasing attention. Many proponents argue that HOV lane projects will benefit air quality as the lanes attract more people into carpools and transit, thus reducing trips and miles traveled.

But will the new lanes be HOV for long? Once a new facility is opened, the pressure is on. Contrary to original planning, Houston's HOV lanes were opened up to 2+ carpools. Only the Katy Freeway has been returned to 3+, and only in the peak hours. The HOV lanes on IH-5 north and IH-90 east of Seattle are now operated at 2+, even though funding and SIP approvals specified 3+. Lanes that were originally constructed exclusively for buses have been opened to HOVs in Los Angeles and Northern Virginia. New lanes on the San Diego Freeway and the Ventura Freeway that were originally proposed for HOVs were, upon construction, opened to general-purpose traffic. In approving a transit or HOV facility without guarantees, air quality regulators may eventually get a general-purpose facility that they would never have agreed to.

If the newly constructed lanes stay HOV, will they improve air quality? The California Air Resources Board (CARB) believes that they will. The CARB's May 1991 report, *High Occupancy Vehicle System Plans as Air Pollution Control Measures,* suggests that if sufficient HOV lanes are built to bring average vehicle occupancy up to 1.5 by 2000, on-road motor vehicle emissions in California cities will decrease by 5 to 10 percent. Emissions would go down because of fewer miles traveled and reduced congestion. (A critique of CARB's May 1991 report is available from Robert Johnston, Division of Environmental Studies, UC-Davis, Davis, Calif. 95616.)

Others argue, however, that HOV lane construction will degrade air quality, especially if the horizon is 20 years or more. An added HOV lane frees more space on general-purpose lanes for latent demand from solo drivers, who also — despite the best enforcement efforts — illegally use the HOV lanes in significant numbers. Unlike a transit lane, an HOV lane can actually weaken transit by attracting its riders into carpools, as Boston's Southeast Expressway HOV lane study and Oakland's HOV lane master plan study warn.

Some respond that the increase in SOV travel on a highway newly served by an HOV facility is less than the resulting decrease in SOV travel on nearby arterials and other streets. Obviously, the SOV and air quality impacts of each HOV project must be analyzed carefully. According to EPA's *Transportation Control Measure Information Documents* (1992), the high emissions typical of short trips mean that HOV trips fed by park-and-rides do not benefit air quality. The advantage assumed for high speeds in HOV lanes may also not withstand recent CARB findings that emissions are actually higher at such speeds than at 30 to 40 MPH.

There is a way to create HOV lanes without promoting more SOV travel. Converting an existing general-purpose lane to HOV creates the greatest incentive to switch from solo driving and is far cheaper to implement. Short-term carbon monoxide problems (which are likely because of increased congestion on the remaining general-purpose lanes) are sometimes held against this alternative, even though it would almost certainly do the most in the long run to reduce carbon monoxide, ozone, and other air pollutants.

Many in the HOV field believe that drivers would fight conversion, as they did Caltrans's abortive 20-week conversion of lanes on the Santa Monica freeway. But that effort was poorly managed and marketed. It occurred more than 15 years ago, before many drivers had even heard of HOV lanes. And southern California drivers are hardly typical of those in other parts of the country. In fact, in northern California, other states, and Canada, some ramps and arterial and highway lanes have been converted to HOV from general-purpose lanes without incident. It does not appear to be the place of engineers and planners to make judgments about what alternatives to exclude from the public agenda. Elected leaders and the public need to be given all the options and comparisons of their long-run impacts.

Air quality regulators will need to be cautious about proposals that HOV lane construction be favored as a transportation control measure in state air quality plans. The stakes are high. HOV construction could be a key to cleaner air. Or, in the name of air quality, could lead us farther from that goal.

For more information, contact Christopher Leman, Institute for Transportation and the Environment, 85 East Roanoke, Seattle, WA 98102, (206) 322-5463.

Reprinted with permission from ***TRB Newsline*** 18 (Sept. 1992):3, Transportation Research Board, National Research Council, Washington, D. C.

FLASHING PADDLE GETS DRIVERS' ATTENTION

Flaggers often have trouble getting the attention of drivers as they approach a work zone. Naturally, workers depend on the flagger to prevent disastrous accidents.

The new Flashing Stop/Slow Paddle developed by SHRP has two high-intensity, quartz halogen lamps that drivers can see from as far as 1,000 feet away. If cars don't appear to be slowing, the flagger operates the lights by pressing a button on the side of the paddle pole. The lights flash alternately 10 times, and then the sign automatically resets. Ten rechargeable D-cell batteries in the handle of the paddle provide all the needed power.

The Flashing Stop/Slow Paddle is larger than the standard paddle: 24 by 24 inches, rather than 18 by 18. It is mounted on a 5-foot staff so the flagger's arm is not fatigued by the extra weight.

SHRP-sponsored closed-track and open-road tests of the new Stop/Slow

Paddle showed that the sign was not only more visible to drivers, but also resulted in quicker reactions and earlier braking. Texas Department of Transportation's San Antonio and Austin Districts participated in the field tests. They used the new device in routine daily maintenance situations for up to two months with excellent results. Both districts reported that cars reduced their approach speeds significantly without increasing traffic conflict due to sudden braking actions.

The Federal Highway Administration (FHWA) still considers the Flashing Stop/Slow Paddle to be experimental. TxDOT is awaiting FHWA's approval for general use of the device before purchasing large numbers. Until the approval comes through, districts might consider using a larger plain paddle (24 by 24 inch) on a 5-foot staff as a means to improve driver awareness. For more information, contact Mr. Lewis Rhodes P.E., D-18TS, (512) 416-3330, Tex-An 249-3330.

The bulk of the article was excerpted from ***SHRP Product Alert 8*** (July 1992): 1-2.

TRUCK-MOUNTED ATTENUATORS (TMAs): A RESEARCH SUCCESS STORY

by **Mohanan Achen**
Center for Transportation Research
The University of Texas at Austin

INTRODUCTION

Originally, impact attenuators or crash cushions were developed to reduce hazards associated with fixed roadside objects. The success of fixed-site crash cushions was followed by the development of mobile systems. These systems were attached in a variety of designs to work vehicles to protect department personnel, equipment, and the public from injury and damage caused when errant vehicles crash into highway operations equipment. Truck-mounted attenuators (TMAs) refer to portable crash cushions which can be suspended or cantilevered from the rear of work vehicles.

The motivation for the development of these portable cushions was the high rate of accidents during highway work or in work zone areas. Accident rates for maintenance workers on slow-moving, on-the-road operations are three times greater than other work settings and between 1982 and 1987, the number of construction zone fatalities increased 43 percent nationally [Ref. 1].

There are significant benefits in using TMAs. A 1985 report on highway safety devices by TxDOT estimated a savings of $23,000 per accident in injury and damages for a vehicle hitting a TMA instead of an unprotected vehicle [Ref. 3].

The forerunner of today's TMA was a crash cushion trailer developed in 1972 by Texas Transportation Institute (TTI). It absorbed energy using thirty 20-gauge, 55-gallon steel drums, three drums wide and ten drums long. The TTI crash cushion trailer was 22.5 feet long and 5.8 feet wide and weighed 2,010 pounds [Ref. 2]. Like many first attempts, it wasn't entirely successful.

WHICH ONE IS BEST?

Many other systems have been developed through various research programs since the TTI crash cushion trailer. In comparison with the original TMAs, the newer models are lighter and are more maneuverable. Newer models mount and unmount from trucks more easily. Improvements like the tilt-up option with a manual or hydraulically operated locking devices are common. Manufacturers claim their devices provide

Continued on page 20.

MIDLAND BRIDGE YIELDS VALUABLE INFORMATION ON FATIGUE CRACKING

by **Kathleen M. Jones**
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Texas Department of Transportation
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Texas Department of Transportation

FIGURE 2: Example of fatigue cracking around connection plates and the welds on the bridges.

INTRODUCTION

Fatigue cracks in a multigirder (4 or more closely spaced girders) steel bridge are a serious maintenance problem, though not usually one that should panic people into closing the bridge immediately without further investigation. Plain multigirder bridges, after all, are not fracture critical structures. Fatigue cracks take stress and time to propagate. The crack you found during today's inspection did not occur last night, in all likelihood, and probably won't be measurably longer tomorrow. This fact does not mean you can ignore fatigue cracks. They are a serious problem, and they do need to be repaired, but in most cases the bridge does not need to be closed.

In order to successfully repair a fatigue crack, a structural engineer must determine what initiated it. If the originating stress is not relieved, the welded repair detail will crack like its predecessor. Constantly repairing a chronic cracking problem drains maintenance funds. Two related Texas research studies attacked evaluating and successfully repairing chronic fatigue cracking in existing bridges. This article presents some useful results from both studies.

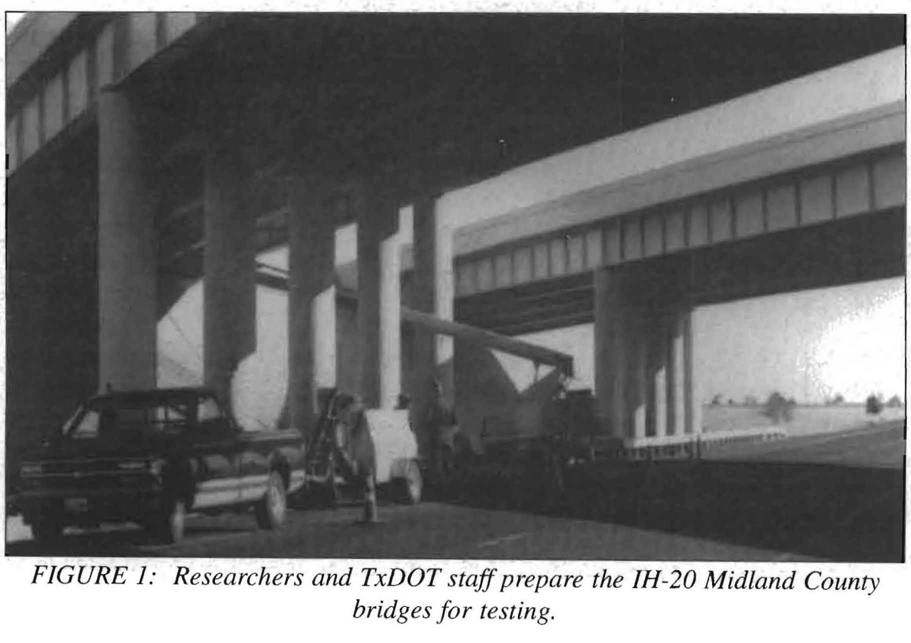


FIGURE 1: Researchers and TxDOT staff prepare the IH-20 Midland County bridges for testing.

SCOPE OF RESEARCH

The IH-20 Midland County bridges (Fig. 1) in Odessa District (District 6) have experienced repeated fatigue-related problems (Figs. 2 and 3). Distortion caused these problems — the result of unintended interaction between the longitudinal girders and the cross-frame diaphragms (Fig. 4). The bridge was in no immediate danger of collapse, however. So, the Texas Department of Transportation (TxDOT) contracted with Texas Transportation Institute (TTI) to investigate the source of the cracking and devise a permanent repair in Research Study 1313, *Evaluation and Repair of Fatigue Damage to Midland County Bridges*. A follow-up study, *Repair Procedures for Fatigue Damage in Steel Highway Bridges* (TTI 1360) is reviewing and categorizing fatigue cracking in Texas bridges, developing repair procedures tailored for TxDOT, and providing a means of identifying potential fatigue problem areas so they can be remedied before fatigue damage occurs.

CONSTRUCTION DETAILS

The IH-20 Midland County bridges are east- and westbound multiple steel girder spans on a 60 degree right-hand skew located at the junction of IH-20 with US 80 and the Missouri Pacific Railroad. Built of four 48 inch deep plate girders in 1966, the structures were widened with a fifth girder on the shoulder side of each span in

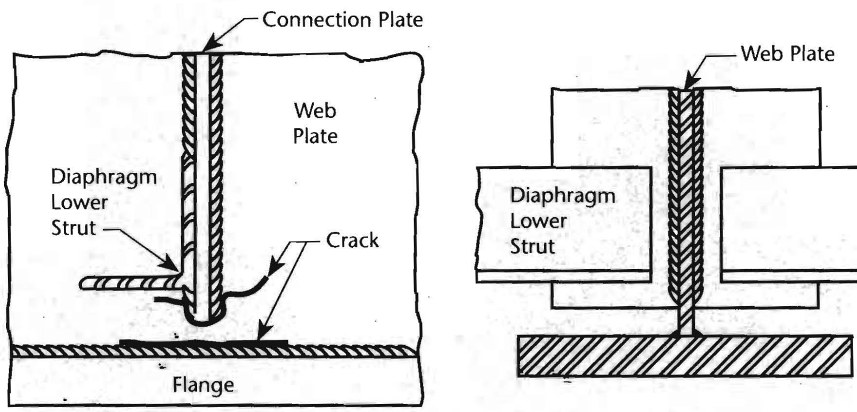


FIGURE 3: Schematic of crack development at unstiffened web gap.

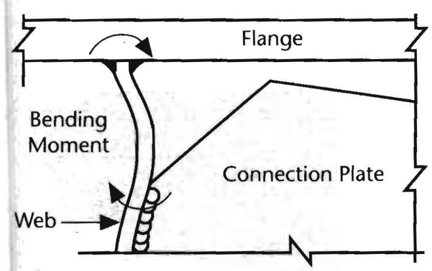


FIG. 4: Web gap distortion.

1983. Transverse web stiffeners were placed at 5-foot intervals with cross-frame diaphragms at 15-foot intervals.

Problems

Original construction included two types of diaphragms, B and C (Figs. 5 and 6). The ends of the diaphragm diagonals were welded to either the upper or the lower struts without the use of a gusset plate. Also, the ends of the connection plates were not rigidly attached to the girder tension flanges. Instead, they were a tight-fit detail — a common construction practice in the 1960s.

The diaphragms used in the 1983 widening were Type Bs with the top strut eliminated. Again, the ends of the connection plate were not connected rigidly to the tension flange. This time they were provided with a 1-inch web gap. The total of 400 diaphragms in this pair of bridges means that 800 connection plates existed without rigid attachment to tension flanges. Additionally, due to girder misalignment and other 1983 construction imperfections, many diaphragm connections are offset between girders 4 and 5.

ADVICE FROM RESEARCH STUDY 1360

When an inspector detects fatigue cracking in a *nonfracture critical* steel bridge, districts should consider the following:

STEP	ACTION
1	Determine the severity of the cracking based on: • Location — load bearing or nonload bearing area? • Member type — primary or secondary? • Size relative to member — is it significant? • Orientation to stress — perpendicular or parallel? Perpendicular is more serious. • Age of structure (number of load cycles) — the more cycles the less remaining fatigue life.
2	Decide: is the crack severe enough to close the bridge immediately? In other words, if the cracked member broke, could the bridge collapse without warning? • If *no*, go to step 3. • If *borderline*, consider: Would a detour around the closed bridge be more dangerous to motorists in terms of accidents per mile per day than closing the affected (usually outside) lane and load-posting the bridge until repairs are made? *Call the BRINSAP Section* of the TxDOT Division of Bridges and Structures (D-5), 512/416-2174 or Tx-An 249-2174. • If *yes*, close the bridge, set up the detour, and notify D-5.
3	Monitor the crack growth or go to step 4, depending crack severity. Note: the crack may have been present for sometime and may have stabilized or stopped growing.
4	Drill holes at the crack tips to prevent immediate additional crack growth.
5	Check similar details at all other locations on the bridge. Note: the same conditions that caused fatigue cracking at one place often exists elsewhere on the structure.
6	Determine the source or driving force behind the fatigue cracking to ensure successful, appropriate repair.
7	Develop a repair procedure based on step 6.

PROBLEM ID

In July 1990, an inspection report inventoried 109 cracks on the girder webs and the web-to-flange welds, as well as failures of diaphragm-to-diaphragm stiffener connections (Fig. 7). The cracking was related to the number of live loads the bridges had experienced, the three-dimensional out-of-plane bending these loadings caused in the unstiffened web, and the high local bending stresses in the offset, eccentrically loaded diaphragms. This

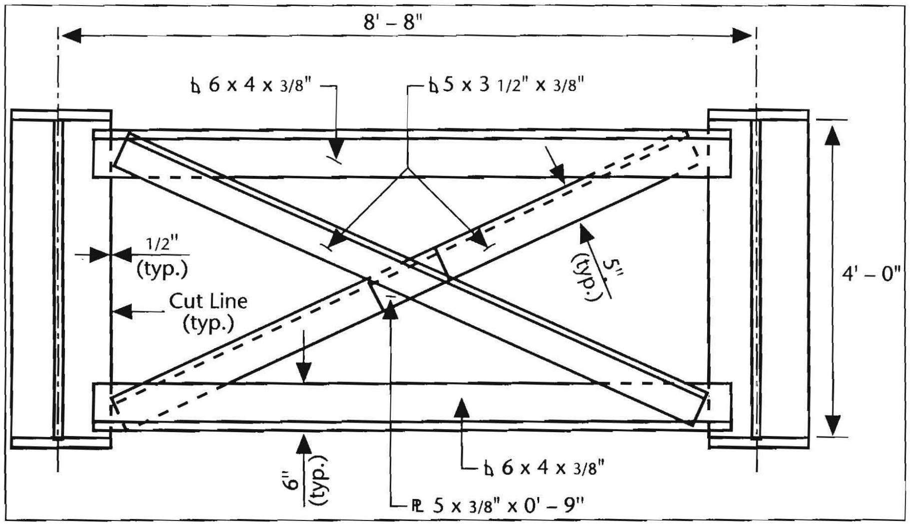


FIGURE 5: Schematic of existing type B diaphragm.

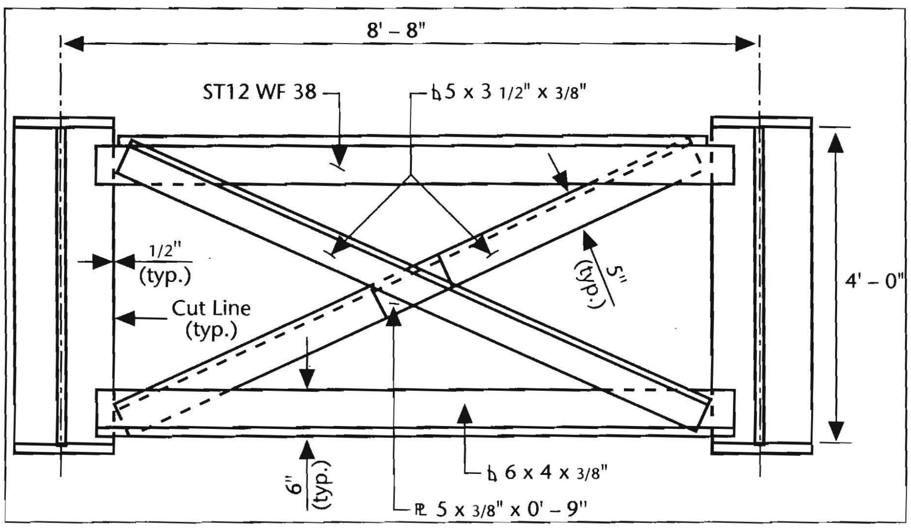


FIGURE 6: Schematic of existing type C diaphragm.

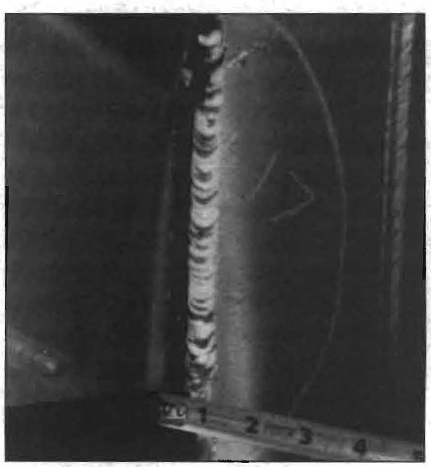


FIG. 7: Detail of failed diaphragm connection.

sort of distress seems to be common in many heavily skewed steel bridges.

Dynamic Load Testing

TxDOT personnel fitted strain gauges in suspect areas (Table 1 and Fig. 8). A TxDOT truck of known weight and axle configuration provided the known load condition. The driver isolated himself from normal traffic, maintained a constant speed of 50 MPH, and remained in a designated lane for each specific pass.

The most significant lane position was the center of the driving lane. This lane is the predominate truck position for the bridges and the one the field analysis of the strain gauges showed to have caused the distortion problems. The other truck positions shed light on the overall bridge behavior, however.

In addition, strains were recorded for several tractor semitrailers for Gage Groups 4 and 6. While the weights of these vehicle are unknown, researchers were able to observe the bridge's behavior under normal truck traffic.

Dynamic Load Testing Results

The recorded stress ranges indicated that the eccentric diagonal connections induced high local bending stresses into both the upper and lower diaphragm struts. The magnitude of the stress are high enough to cause fatigue cracking of the type observed in the diaphragm members. The stress measurements also indicated that the upper strut was nonload bearing under service conditions. (This fact was used in the redesign of the diaphragms.)

Finite Element Analysis

Finite element analysis models provide a theoretical way to assess various parameters, in this case, ones contributing to distortion-induced fatigue such as girder spacing, diaphragm spacing, and severity of the skew.

Researchers developed a three-dimensional finite element model of the tested span and correlated it with the field measurements. From this "as-built" model, they developed three others: one with all type B diaphragms removed, one with all the diaphragms removed, and one with a staggered pattern that attempted to maintain the original load distribution of the structure, while reducing the number of repairs necessary. For all four finite element models evaluated, researchers passed a unit axle loading of 10 kips over the structure in the driving lane and developed influence lines.

Finite Element Results

The largest deviation in flange stress occurred in the "all diaphragms removed" model. The "type B diaphragms removal" and the staggered pattern models showed less deviation of stress, and therefore, researchers considered these two models more acceptable solutions. However, the finite element analysis showed that diaphragm removal should not have a harmful effect on the serviceability of the concrete deck because the actual slab stress values are low.

Based on the load testing and the finite element analysis, the researchers recommended that all the diaphragms be removed and replaced with a modified diaphragm (Fig. 9) placed in a staggered pattern that would eliminate the bending stresses that had started the fatigue cracking. The repair job was designed and let on that plan.

REMOVE ALL THE DIAPHRAGMS?

Was the finite element analysis too conservative or too liberal? Could all the diaphragms be removed permanently on other similar bridges without affecting the lateral stability of the bridge? Certainly diaphragm removal solves the two major types of fatigue cracking afflicting these structures: web gap cracking and diaphragm member cracking. Also, removal without replacement is less costly.

One unquestionable way existed to prove whether or not bridge types similar to the Midland County bridges needed any diaphragms at all: a full-scale field test. When the contractor removed all the diaphragms on the eastbound bridge, the researchers retested the bridge's behavior. Preliminary results from this field data indicate that it might be possible to remove the diaphragms entirely from a similar structure. Early results on the behavior of the modified diaphragm also look good.

IMPLEMENTATION OF REPAIRS

Types of Repairs

Once the contractor removed the old diaphragms, the crews began to repair cracks in the girder webs and flanges. The researchers recommended that three types of repairs be used (Table 2). Twelve locations with similar crack patterns were repaired. Four locations used type 1, four used type 2 and four used type 3. All cracked flange-to-web welds had 1-inch holes drilled from the frontside with the holes centered on the crack tip. The long-term performance of these repairs will be monitored under Research Study 1360 as well as routine inspections.

Construction

The following series of photos show how the repairs were carried out and what they looked like when finished (Figs. 10 to 16).

TABLE 1: Summary of gage group locations.

GAGE GROUP NUMBER	DESCRIPTION OF GAGE GROUP LOCATION
1	Type C' diaphragm members, diaphragm number 40, bay D, positive moment region.
2	Type B diaphragm members, diaphragm number 40, bay C, positive moment region.
3	Type C diaphragm members, diaphragm number 43, bay C, negative moment region.
4	Type C' diaphragm members, diaphragm number 43, bay D, negative moment region.
5	Bottom flanges and diaphragm lower struts at diaphragm Line 40
6	Type C diaphragm members, diaphragm number 39, bay C

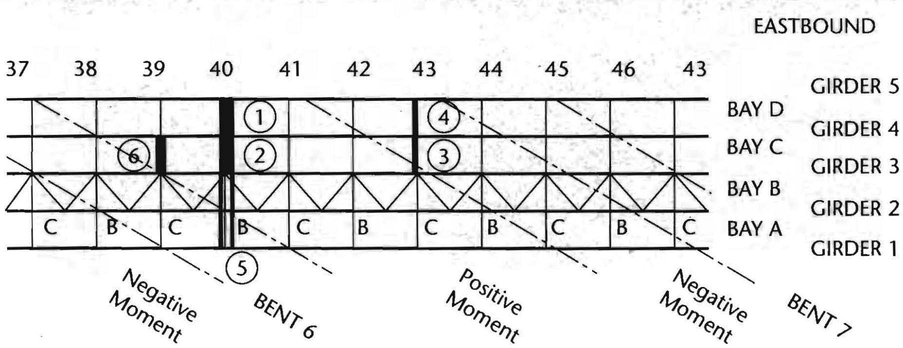


FIG. 8: Schematic of gage placement.

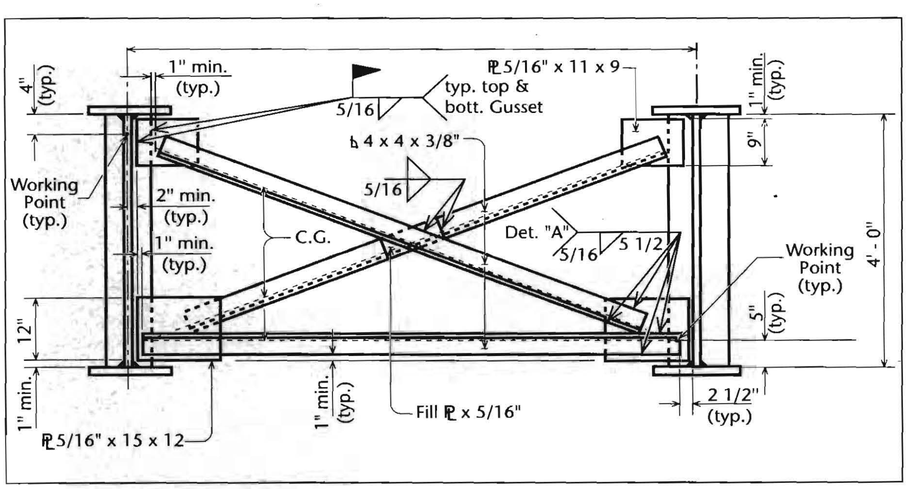


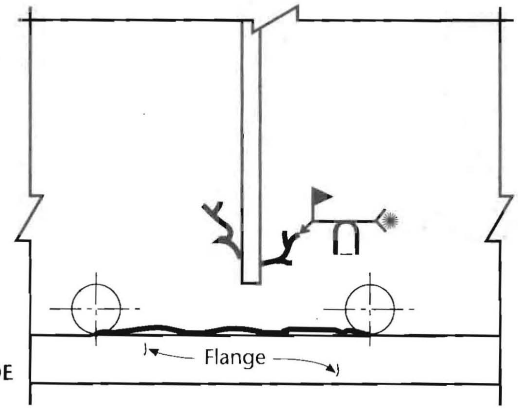
FIGURE 9: Schematic of modified interior diaphragm designed during 1313.

TABLE 2: Three types of repairs.

TYPE DESCRIPTION	TYPICAL DETAIL	CONSIDERATIONS

1 Air arc gouge and reweld.
Gouge entire length of crack and weld. Grind flush.

FRONTSIDE



- Difficult to do well in the field
- May induce new, uncalculated stresses
- Cracks that extend completely through the web must be backgouged
- Replaces lost cross section

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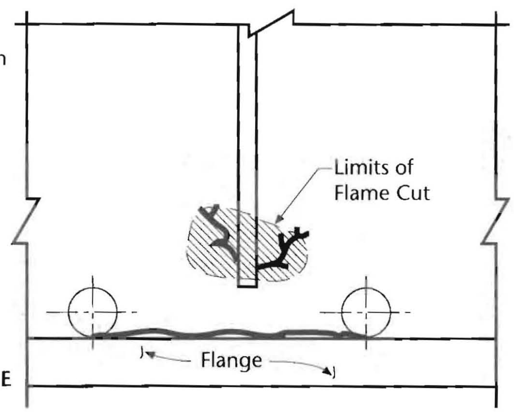
2 Flame cut.
Flame cut shaded area of web plate from the backside. Grind edges smooth.

FRONTSIDE



- Fairly easy
- Effective
- May remove too much cross section in rare cases
- When cracks are associated with a stiffener, as they were here, a portion of the stiffener must be removed from the frontside. (See example.)

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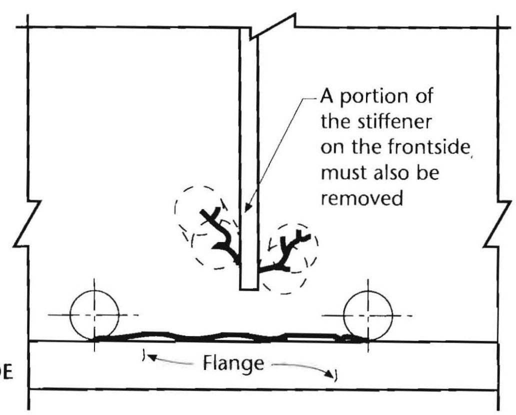
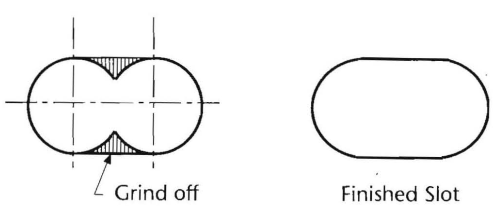
3 Drill crack tips.
Drill holes at crack tips. Grind smooth any overlaps to form slots.

FRONTSIDE

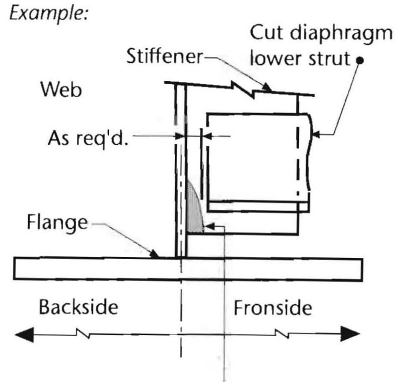


SLOT DETAIL



- Easy
- Effective
- When cracks are associated with stiffener, a portion of the stiffener must be removed from the frontside.

Example:



For locations repaired by flame cutting or hole drilling, shaded portion of stiffener shall be removed and ground smooth.

FIG. 10: Both ends of toe weld cracks were drilled in all three types of repairs.

FIG. 11: Repair types 1 and 2 required welding equipment for air arc gouging and flame cutting respectively.

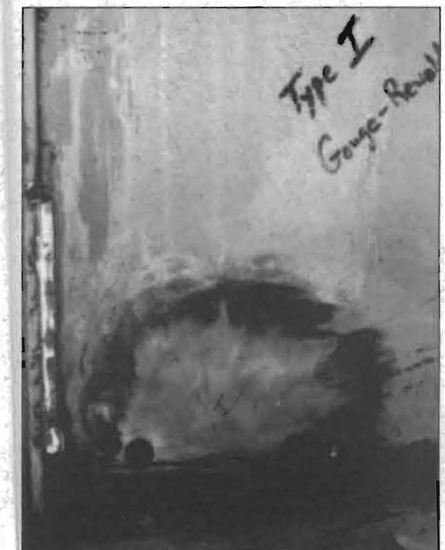


FIG. 12: Typical finished type 1 repair.

FIG. 13: Grinding the edge of a flame cut smooth.

FIG. 14: Typical finished type 2 repair.

FIGURE 15: Smoothing overlapping drill holes to form slots.

FIGURE 16: Typical finished type 3 repair.

WHAT HAPPENS NEXT?

Currently TxDOT and TTI personnel are in the middle of cataloging and categorizing fatigue-prone details in Texas steel bridges. They will identify suitable (preferably nondestructive) crack detection methods for fatigue-prone connection details. Also, they will develop guidelines for structural engineers detailing economical comprehensive repair procedures for the common types of fatigue damage found in Texas.

A laboratory test program will evaluate repair procedures for details unique to Texas or details that have not been adequately tested to date. Various welded repair schemes will be made at the laboratory under simulated field connections. Each specimen will be subjected to constant cycle loading to ensure the design has adequate fatigue strength.

BENEFITS

The most obvious immediate benefit of Research Studies 1313 and 1360 is the repair of the Midland bridges and the design of a modified cross-frame diaphragm with a staggered placement that should not reinitiate fatigue cracking.

Future benefits will include:

- **Guidelines** for comprehensive identification and repair procedures of fatigue-proning photographs and sketches for clearer understanding, to be used by both TxDOT and contract engineers.
- **New method** for estimating remaining fatigue life. While Texas has already developed a practical piece of equipment for field testing remaining life of existing structures, the mathematical models used need improvement. The current procedures, developed in NCHRP 299, *Fatigue Evaluation Procedures for Steel Bridges*, often yield negative remaining fatigue life, even when field test data is used, for details that are not showing any signs of distress. The finite model analysis calibrated to actual bridge stress data will be used, in part, to improve the fatigue life models.
- **Fatigue life extension procedures** for preventive maintenance. Used before significant fatigue damage has occurred on details whose estimated fatigue damage exceeds its fatigue strength, these procedures are often less complicated and more economical than the repairs required for fatigue cracking. Possible procedures include toe weld peening or grinding.

CALL FOR PROBLEM STATEMENTS

The Research Section of the Division of Transportation Planning (D-10R) is soliciting problem statements for possible study under the department's cooperative research program.

Input is needed from employees whose transportation-related problem could be solved if professionals were able to devote enough time to its study. Employees are invited to submit a short description of their problems (one page or less) to D-10R by May 3, 1993.

Problem statements will be evaluated by subject-area committees and by the department's Research and Development Committee. Selected problem statements will be sent to universities for conversion into research proposals, which are again reviewed by the Research and Development Committee. Those approved by the committee will become research studies on September 1, 1994. **Problem statements should be submitted by May 3, 1993** to: Mr. Alvin R. Luedecke, Jr., P.E., Director of Transportation Planning, TxDOT, Division of Transportation Planning, Attn: D-10R, P.O. Box 5051, Austin, Texas 78763. Questions may be directed to Ms. Lana Ashley or Ms. Sylvia R. Medina at (512)465-7404 or TxAn 241-7404.

by Lana Ashley

Assistant Research Administrator

Research Section Transportation Planning Division

TxDOT

SUMMARY

Fatigue cracking in multigirder steel bridges is a serious problem, even though it usually does not mean the bridge is in immediate danger of collapse.

Research Study 1313 provide a much-needed answer to the problem of out-of-plane distortion fatigue cracking in the webs of heavily skewed multigirder steel bridges. Odessa district implemented the three types of crack repairs and the staggered diaphragm pattern using the modified diaphragms developed in the study.

Research Study 1360 will:

- **monitor** the long-term performance of the Midland bridge repairs, develop a catalogue of fatigue-prone details along with guidelines on how to identify and repair them in cost-effective, practical ways,
- **develop** and test new welded retrofit details,
- **improve** methods of estimating remaining fatigue life, and
- **examine** methods to extend fatigue life in details prior to fatigue damage.

DOCUMENTATION

1. Bloschock, M. J. "Implementation Plan, Project 2-5-91-1313." Memo to Research Section, 31 January 1992.
2. Design Section, Division of Bridges and Structures, Texas Department of Transportation (TxDOT). "Activity 302, Funds for Interagency Contract Bridge Repair of Eastbound and Westbound Structures, Midland County, CSJ: 0005-15-003, IH-20." Memo to Byron C. Blaschke, P. E., 23 May 1991.
3. Keating, P. B., and A. R. Crozier. *Evaluation and Repair of Fatigue Damage to Midland County Bridges (Draft), Tx-92/1313-1.*
4. Research Section, Division of Transportation Planning, TxDOT. Research Study Contract 2-5-93-1360, *Repair Procedures for Fatigue Damage in Steel Highway Bridges.*

FIRST SMA EXPERIENCE IN TEXAS

by **Paul E. Krugler**, P. E.
Asphalt Pavement Engineer
Division of Materials and Tests
Texas Department of Transportation

OVERVIEW

The Texas Department of Transportation has considerable interest in the stone matrix asphalt (SMA) concept primarily for its rutting resistant potential. After viewing the placement of SMA in Michigan and Maryland, the Fort Worth District finalized plans, prepared the mix design, and constructed the first SMA project in Texas.

The project planning required SMA placement on two existing pavements. The first is the 2.2-mile Business Loop to IH-35 through the small city of Alvarado. One inch of the existing pavement was milled and approximately 1 1/4 inches of SMA was placed on both the single north- and southbound lanes. The traffic level is between 3,000 and 4,000 ADT (annual average daily traffic) through Alvarado. The second placement location is a 3.9-mile section of State Highway 171 running northwest just outside of Cleburne. This is a two-lane rural roadway carrying between 2,000 and 3,000 ADT. Approximately 1 1/4 inches of SMA was placed on both lanes and shoulders. Both existing pavements were aged to the point that they were generally deteriorating. The Alvarado section was distressed to the point that it was milled both to remove existing material and to improve ride quality.

MIX DESIGN

The mixture was composed of a blend of three limestone coarse aggregate stockpiles, a limestone dust mineral filler, an AC-20 asphalt cement, Wetfix 300 antistrip, and Arbocel cellulose-fiber/asphalt pellets (0.3 percent fiber by weight of the mixture). The coarse aggregate was a relatively hard limestone, having a Los Angeles Abrasion loss of 25 percent, and it had a good angular, blocky shape.

The optimum asphalt content was found to be 6.0 percent by weight using 50-blow Marshall compaction. The Texas gyratory compactor seemed to overdensify and also degrade aggregate in the specimens. The Marshall hammer was used for this reason. While fiber/asphalt pellets were used for plant production, a corresponding amount of loose fiber was used in making the laboratory design mixtures. This change facilitated the mixing and fiber dispersion processes. Otherwise, standard mixing and testing procedures were used.

CONSTRUCTION

Plant Operations

The contractor for the project was Duininck Bros., Inc. He used a Barber-Greene drum plant which included a mid-drum RAP collar. The fiber/asphalt pellets were metered onto a belt which introduced them through the RAP collar. The mineral filler was stored in a lime silo; the addition rate was controlled through continuous weighing of the weigh pod below the primary storage silo. The filler was blown into the drum 13 feet from the discharge end and 1 foot after the addition of the asphalt cement. This system was successful in keeping the majority of the filler in the mixture, although some was lost and ended up in the wet scrubber settling pond.

Plant production began on August 26, 1992, with one truckload of trial mixture. Besides laboratory testing, the contractor placed the mixture with a paver in his plant yard to get a look at how it would handle on the road. This is recommended for any contractor doing first work with SMA. No job-mix formula adjustments were thought necessary based on the trial mixture.

Project production began the next day with 1,333 tons being placed. The plant operated at 260 TPH. Eight days of production were necessary to complete the project. Only one adjustment to the job-mix formula was required. That was to raise the asphalt content by 0.2 percent. The only significant cold feed adjustment was made at the beginning of the second day. The mineral filler feed rate was increased to get the desired quantity of passing No. 200 material into the mix. The effectiveness of that adjustment and the relative consistency of fines in later production can be noted in Table 1.

Testing

The produced mixture was fully tested at the plant laboratory. All daily field test results may be found in Table 1. Production testing found the mixture to generally be in close compliance with the mixture design. The exception was the asphalt content. The rather erratic nature of these results cannot be fully explained. Neither the appearance of the mixture nor other test results indicated that the asphalt content was actually varying to the extent shown. The asphalt content was determined by centrifuge extraction using SC-150 solvent.

Additional specimens were compacted each day using 50-blow Marshall compaction. These were shipped to the Division of Materials and Tests for additional testing. This testing included:

- density,
- Hveem stability,
- Marshall stability and flow,
- indirect tensile strength, and
- static creep.

The static creep test was performed at 104°F with a load of 10 psi for 60 minutes and a relaxation period of 10 minutes. Creep stiffnesses, permanent

TABLE 1: SMA field testing results.

Item	Design JMF	Production Day													Project Average
		1		2		3		4		5	6		7	8	
		8/27	8/27	8/28	8/28	8/29	8/29	8/31	8/31	9/2	9/10	9/10	9/11	9/12	
+5/8	0	0.6	0.6	0.7	0.5	0	0	0.6	0	0.5	1.2	0.6	0.6	0	0.45
+1/2	9.3	10.3	12.1	9.2	9.5	8.6	8.4	12.5	15.4	6.6	11.2	10.9	12.7	11.7	10.7
+3/8	31.0	37.5	40.3	35.2	31.4	27.3	32.6	35.9	38.7	28.3	38.7	34.1	34.5	35.9	34.6
+4	71.7	74.1	74.6	70.3	70.0	67.2	70.6	71.5	72.3	69.6	73.3	70.6	72.9	72.1	71.5
+10	84.9	86.6	86.6	83.7	83.4	83.4	81.1	85.2	85.5	84.2	85.5	84.8	85.7	84.5	84.6
+40	86.5	88.1	87.6	85.1	84.6	85.0	85.4	86.3	86.7	85.3	86.8	86.1	87.0	85.8	86.1
+80	86.9	88.8	88.0	85.7	85.1	86.2	85.7	86.6	87.2	85.7	87.6	86.6	87.4	86.2	86.7
+200	90.1	92.4	92.6	88.6	88.5	89.9	89.6	89.1	90.4	88.4	90.1	90.1	89.8	88.9	89.9
-200	9.9	7.6	7.4	11.4	11.3	10.1	10.4	10.9	9.6	11.6	9.9	9.9	10.2	11.1	10.1
Asphalt Content	6.0	7.2	6.2	6.3	6.9	6.3	7.1	5.8	6.2	6.9	6.0	6.0	6.1	6.3	6.4
RICE	2.423	2.446	2.469	2.462	-	2.449	-	2.475	-	2.431	2.478	-	2.466	2.445	-
Ga	2.327	2.371	-	2.367	-	2.388	-	2.336	-	2.325	2.348	-	2.334	2.341	-
Lab Density	96.0	96.9	-	96.2	-	97.5	-	94.4	-	95.6	94.8	-	94.7	95.7	95.7
Hveem Stability	30	Performed at Central Lab													28
Field Air Voids		6.1	-	13.4	-	8.3	-	8.3	-	6.2	6.5	-	6.8	6.7	7.8

TABLE 2: *SMA Central Lab testing results, US 377 Johnson Co. CSJ 80-4-67, etc.*

Production Date	Design Asphalt (%)	Laboratory Density (%)	Hveem Stability	Marshall Stability (lbs)	Marshall Flow (in/100)	Tensile Strength (psi)	Creep Stiffness [lbs/in(2)]	Permanent Strain (in/in)	Slope of SS. Curve (in/in/sec)	Recovery Efficviency (%)
8/27/92	6.0	94.5	28	796	15	123	7,857	2.8E-04	1.7E-08	76.7
8/28/92	6.0	95.7	28	1,008	14	193	9,057	3.0E-04	1.8E-08	71.3
8/29/92	6.0	96.2	26	1,187	12	161	7,135	3.7E-04	2.3E-08	72.6
8/31/92	6.0	94.0	31	817	13	126	8,148	2.8E-04	1.9E-08	76.8
9/2/92	6.2	95.4	29	805	24	102	10,175	3.9E-04	2.0E-08	59.2
9/10/92	6.2	93.9	27	803	17	128	10,637	3.2E-04	2.4E-08	67.5
9/11/92	6.2	93.9	26	637	16	93	9,101	3.1E-04	2.2E-08	70.6
9/12/92	6.2	94.9	26	766	17	97	7,691	3.5E-04	1.8E-08	72.4
Average	6.1	94.8	28	852	16	128	8,725	3.3E-04	2.0E-08	70.9

strains, slopes of the curves and recovery efficiencies were determined from the creep test results. The results of all of these tests are shown in Table 2.

The average Hveem stability of 28 — compared to the rather promising results from the other tests — is evidence that Hveem stability is not a reliable indicator of rutting resistance for SMA mixtures. Frictional characteristics of the fine aggregate fraction may play a significant role in Hveem stability. The absence of much of these fines may cause lower test values, yet rut resistance may be good because of the coarse aggregate skeleton.

Roadway Operations

The mixture was hauled to the laydown sites in bobtail and live-bottom trucks. All trucks were required to have insulated haul beds and use covers during transit to preserve heat. The mix temperature in the truck at the plant ranged in the area of 275°F to 315°F. The farthest laydown site was a 36-mile haul. Temperature loss during the haul was minimal; no asphalt migration was noted; and the mixture came out of the trucks cleanly.

The surface to be overlaid was tacked with 0.018 to 0.020 gal/SY of diluted, polymerized SS-1 emulsion. The dilution was 60/40 emulsion/water.

Placement was accomplished with standard paving equipment. Although it handled well through the paver, handwork and raking were very difficult. Handworked areas were frequently obvious.

Compaction was easily accomplished with 2 to 3 passes of a steel wheeled roller. Rolldown of the mat was quite minimal as the aggregate was simply being "seated." In-place densities, or field air void levels, were generally good, averaging 7.8 percent air voids for the entire project. The daily air void levels may be found in Table 1. The 13.4 percent air voids found on the second day of placement was believed to be related to cooler mixtures arriving at the laydown site, higher passing No. 200, and perhaps slightly lower asphalt content.

The fresh mat could be opened to traffic within 15 to 30 minutes of the completion of rolling. A dilute solution of lime water was sprayed on the pavement to speed cooling, although this was probably unnecessary. The addition of the dilute lime water may have had the added benefit of slightly killing asphalt tackiness on the surface. No mixture pickup, ravelling, or displacement was observed when the fresh mat was placed under traffic. No distress has been observed on either SMA pavement section after four months of service.

CONCLUSIONS AND RECOMMENDATIONS

1. Based on only one project, the TxDOT remains optimistic about the potential of SMA as a highly rut resistant, dense pavement layer. At least four additional projects are in the planning stages for next construction season.
2. Hveem stability does not appear to be a properly discriminating test for rutting resistance of mixtures containing approximately 80 percent aggregate retained on the No. 10 sieve. The static creep test should be further investigated to fill this role for SMA mixtures.

3. Further investigation into laboratory compaction procedures is warranted to determine the most suitable equipment and method for SMA.
4. The gravimetric system of metering mineral filler employed on this project was effective in obtaining a rather uniform amount of passing No. 200 material in the produced paving mixture.

ACKNOWLEDGMENTS

The considerable efforts of the Fort Worth District, particularly Mr. Carl Utley, P.E., Mr. David Bass, P. E., and all of the Cleburne Area office personnel made this first Texas trial of SMA a success. Thanks are also offered to Mr. Maghsoud Tahmoressi, P.E., Mr. Dale Rand, P.E., and the Bituminous Section of the Division of Materials and Tests for their support in the laboratory testing analysis.

RETREADS SAVE BUCKS AND ENVIRONMENT

Local governments looking for ways to stretch their tax dollars have discovered what commercial truckers have known for better than two decades: retreading tires saves big dollars without sacrificing quality, dependability, or length of service. A retread can be purchased for a fraction of the price of a new tire. For example: a new bias ply grader tire costs around $240. That same tire can be retreaded for half the amount. Savings are even more substantial with radial tires.

While slashing your tire budget, there are ecological benefits in using retreaded tires as well. A quality truck tire casing has the potential of up to four lives as a retread, somewhat reducing the waste disposal problems that tires can present. Since tires are basically petrochemical products, it requires 22 gallons of oil to manufacture one new truck tire. Most of that oil can be found in the casing, which is reused in retreading. Therefore, 15 gallons of oil are saved each time a truck tire is retreaded. On a national basis, over 400 million gallons of oil are saved annually by retreading. In addition to the oil savings, a potential trip to the land fill can be avoided if the casing is retreaded rather than discarded. A substantial amount of landfill space can be saved as the result of retreading.

From ***Oklahoma Local Government News*** (Winter 91-92).

TMAs from page 9...

for consistently safe cushioning for both light and heavy automobiles over a range of impact speeds. With so many models and features to select and with very little information on how TMAs held up to weather exposure and road vibrations, department personnel were hard pressed to determine which of the TMA designs gave the most protection. That's where TxDOT's research program comes back into the picture.

PERFORMANCE CRITERIA

In June 1989, TTI was hired by TxDOT to assess the performance of several TMAs. Under Research Study 991, *Development of Performance Specifications for Truck-Mounted Attenuators,* TTI was given the task of defining an "acceptable" TMA. TxDOT is using the results of this study to set minimum performance requirements for TMAs.

Researchers used three basic performance criteria for this study:

- **Crashworthiness** — the amount of protection afforded to the drivers of vehicles that impact TMAs and to the drivers of the vehicles to which the TMAs are attached;
- **Fatigue** — the endurance of the TMA under real-world operations; and
- **Moisture resistance** — the susceptibility of the TMA to collection of moisture during inclement weather.

TTI experimented with seven different TMA models (see Table 1) [Ref. 2]. Six out of the seven TMAs used vermiculite concrete, aluminum honeycomb, or related materials as their shock absorbing core. The Connecticut Department of Transportation (ConDOT) TMA consisted of four, 2-foot diameter open-ended steel pipes mounted in a cantilevered, telescoping box-beam frame.

TEST PROGRAMS

In keeping with three basic criteria, researchers conducted three different test programs: crash testing, vibration testing, and moisture testing. The ConDOT TMA model did not undergo the moisture or vibration tests. The vibration test apparatus was not designed to accommodate this type of TMA, and moisture was judged not to affect the performance of this TMA due to its design and construction materials.

Crash Testing

The twin objectives of the crash testing program were to assess the overall benefit of TMAs relative to control tests where no TMA was used and to compare the performance of individual makes and models of TMAs with respect to one another. Researchers conducted twenty-one different crash tests in four test series. Each test series involved striking vehicles of different weights at different

TABLE 1: TMA physical data.

Type	Length (in.)	Width (in.)	Approx. Weight with Mounts (lbs.)	Road Clearance (in.)	Crush Distance (ft.)
Energy Absorption Alpha Model	81.75	93.00	820	12	-
Energy Absorption Hexfoam Model	85.75	96.00	1200	12	6
Hexcel Model 3000	84.50	92.25	1200	12	6
Hexcel 4000	82.25	92.25	880	12	-
Renco	81.50	95.50	1250	11-12	-
Markings & Equipment Corporation	83.00	93.25	890	12	-
Conneticut DOT	105.13	72.00	1500	6-8	8

impact speeds. All collisions were conducted head-on with no offset. Three types of passenger cars weighing 1,800 lb, 3,500 lb and 4,500 lb (and a 4,500 lb pickup truck) were used [Ref. 2]. The TMAs being evaluated were mounted on a dump truck that had been ballasted to 14,000 lbs prior to the attachment of the TMA [Ref. 2].

Researchers evaluated the TMAs using the performance criteria stipulated in NCHRP Report 230 and TRB Circular 191 (see sidebars). Test series 1, head-on impact into a TMA by a 4,500-pound passenger car traveling at 45 mph, was the baseline test. Any commercially available TMA should be able to pass this NCHRP 230 standard test. All the current models passed the NCHRP 230 requirements.

Very few cars today are 4,500 pounds. Test series 2 yielded data on how TMAs decelerate 1,800-pound cars traveling at 45 mph.

Very few cars travel at 45 mph, even (or especially) through work zones. Researchers structured test series 3 to gain information on what is more real-world representative: a 3,500-pound car impacting at 55 mph. From the outset, researchers expected that none of the makes or models of TMAs in the study could meet NCHRP 230 or TRB Circular 191 performance criteria under the severe conditions of test series 3. The purpose was to determine the relative standing of several TMAs — to determine which one inflicted the least impact velocities and the lowest accelerations to the occupants. The TMAs completed 40 hours of vibration testing and 24 hours of moisture testing before they were crash tested in series 3.

Vibration Testing

The TMAs were mounted on to a vertical half-inch steel plate and oscillated vertically at a frequency of 7 Hz through 0.6 inches for a duration of 40 hours (approximately 1,000,000 cycles) [Ref. 2]. The 40-hour vibration test typically occured for 8 to 10 hours per day for 4 to 5 days [Ref. 2]. The horizontally positioned TMAs were initially vibrated for a few minutes on the TTI test fixture to eliminate any slack in the system. With the help of reference points on the left and right rear corners of the TMA cushion, sagging, if it occured, was determined by periodically measuring the height of these reference points relative to the ground. A TMA failed this test if sagging exceeded 0.5 inches during the 40-hour test period [Ref. 2]. The TMA could also be disqualified if severe damage like

NCHRP REPORT 230 CRASH TEST PERFORMANCE CRITERIA: SYNOPSIS OF OCCUPANT IMPACT VELOCITY AND OCCUPANT RIDE DOWN ACCELERATION

Occupant impact velocity and occupant ride down acceleration are fully defined in NCHRP Report 230. Basically, *occupant impact velocity* is the velocity with which a vehicle occupant's head strikes the interior of the vehicle during a collision. *Occupant ride down acceleration* is the maximum average deceleration that a vehicle occupant's head undergoes (over 10 msec), after the occupant's head has come into contact with the interior surface(s) of the vehicle.

Occupant impact velocity and ride down acceleration are calculated (in the longitudinal and lateral directions) based upon *vehicular* accelerations and simplifying theoretical assumptions (e.g., the vehicle occupant's head moves two feet in a frontal collision before impacting interior surfaces). The equations for making these calculations are provided in NCHRP Report 230. (Note: Neither occupant impact velocity nor occupant ride down acceleration is calculated from accelerations to the heads of anthropomorphic dummies.)

Maximum acceptable limits for occupant impact velocity and occupant ride down acceleration, are shown below:

	Longitudinal	*Lateral*
Occupant Impact Velocity (fps)	40	30
Occupant Ride Down Acceleration (g's) (Max 10 msec ave acc)	20	20

[Ref. 2, pg. 56.]

TWO COMMENTS ON THE PERFORMANCE CRITERIA OF TRB CIRCULAR 191

(1) To evaluate crash cushions (including TMAs) it is necessary to calculate "average deceleration." But there are two methods for calculating average deceleration in TRB Circular 191. In the first, the change in speed of the impacting vehicle is calculated over the stopping distance of the vehicle. In the second, the highest average vehicular deceleration over a 50 msec interval during the collision is calculated. Which method is more appropriate for evaluating TMAs?

In TMA crash tests, vehicle deceleration is not constant throughout the collision. For stiff or heavy TMAs, there may be rapid deceleration shortly after the initiation of the collision. For softer, less resistant TMAs, initial decelerations may be relatively small — followed by high terminal decelerations as the impacting vehicle "bottoms out" and strikes the dump truck. When ". . . the deceleration signal is not fairly constant . . . the maximum 50-msec method gives a more conservative result and is recommended." (TRB Circular 191, p 21)

(2) According to TRB Circular 191, in a frontal collision, the average deceleration on a vehicle striking a crash cushion (i.e., a TMA) must be less than 12 g's in order to be judged acceptable. The phrase "average deceleration" as used in TRB Circular 191 implies "resultant deceleration." Now, obviously, if a crash is *purely frontal,* "average resultant deceleration" and "average longitudinal deceleration" are identical. However, if the crash is slightly off center, or if the crash is conducted at an angle, lateral decelerations will differ from 0 and resultant deceleration will differ from longitudinal deceleration.

Most TMA crash tests reported in the literature have been frontal tests — or frontal tests at slight angles (0 to 15 degrees) or small offsets (0 to 36 inches). The decelerations reported for these tests have typically been *longitudinal* decelerations, though it should be acknowledged that resultant declerations for most of these tests would probably not differ appreciably from the reported longitudinal decelerations. Throughout this paper, when TRB Circular 191 evaluation criteria are cited, maximum 50 msec average longitudinal accelerations will be shown. The acceptable threshold for a maximum 50 msec average longitudinal acceleration will be assumed to be 12 g's.

TABLE 2: Summary of TMA test program data.

	Car 4,500 lbs - 45 MPH			Car 1,800 lbs - 45 MPH				Car 3,500 lbs - 55 MPH			PU Truck 4,500 lbs - 45 MPH			Inches sag over time. > 0.5"/40.0 hrs fails test.			% weight gain of TMAs passing vibration test.
	TEST SERIES 1			TEST SERIES 2				TEST SERIES 3			TEST SERIES 4			VIBRATION TEST			MOISTURE TEST
TMA	LOIV (1)	LORA (2)	MAX 50 (3)	LOIV (1)	LORA (2)	MAX 50 (3)		LOIV (1)	LORA (2)	MAX 50 (3)	LOIV (1)	LORA (2)	MAX 50 (3)	RT	LT		x>5.0% Fails
Energy Absorption (Alpha)	A	A	M	U	A	A		A(39)	U(-39)	U (-24)	A	A	M	.031/40.0	0/40.0		1.2%
Energy Absorption (Hexfoam)	A	A	A	U	U	U	*†	-	-	-	-	-	-	5.0/16.1	5.0/16.1		-
Hexcel (1989)	A	A	-	A	A	U		A(35)	U(-32)	U (-21)	-	-	-	.375/40.0	.375/40.0	††	19.5%
Hexcel (Developmental)	A	A	U	A	A	U	*†	-	-	-	-	-	-	-	-		-
Renco	A	A	U	U	U	U	†	-	-	-	-	-	-	1.25/4.0	1.06/4.0		-
Markings & Equipment Corp.	A	A	U	U	U	U	†	-	-	-	-	-	-	.125/40.0	.125/40.0		54.7%
ConDOT	A	A	U	A	A	U		A(35)	U(-53)	U (-24)	-	-	-	N/A	N/A		N/A

(1) LOIV = Longitudinal occupant impact velocity, adjusted for impact speed differences. Acceptable (A) ≤ 40 feet per second; Unacceptable (U) > 40 fps. NCHRP 230 criterion

(2) LORA = Longitudinal occupant ride down acceleration, adjusted for impact speed differences. Acceptable (A) ≤ 20 gravitational units (absolute value); Unacceptable (U) > 29 g's (absolute value). NCHRP 230 criterion.

(3) MAX 50 = 50 millisecond average longitudinal acceleration. Acceptable (A) ≤ 12 g's (absolute value); Unacceptable (U) > 12 g's (absolute value). M = Marginally acceptable. TRB Circular 191 criterion.

* Unacceptable occupant compartment penetration.

† Unacceptable vehicle underide.

†† Aluminum skin cracked and buckled; therefore, only marginally acceptable.

popped rivets, cracks and distortions resulted from the vibration tests. Only those TMAs that passed the vibration test underwent the moisture test.

Moisture Testing

Real-world TMAs are exposed to rain. A TMA's capacity to absorb energy can be degraded if it retains water. Researchers simulated rain in a 12 foot x 12 foot x 12 inch water-recirculating chamber. After weighing a TMA, the chamber sprayed the TMA continuously with water for 24 hours to simulate a 6-inch-per-hour rain [Ref. 2]. At the end of spraying, the TMAs drained for one hour, and then were reweighed. The weight gain is the difference between both measurements. If the weight gain exceeded 5 percent, the TMA was deemed unacceptable [Ref. 2].

Results of Experimentation

Based on crash testing results, acceptable TMAs were the Energy Absorption (Alpha Model), Hexcel TMCC and the Connecticut DOT. The three TMAs that passed the 40 hour vibration test were the Energy Absorption (Alpha Model), Hexcel TMCC, and Markings and Equipment Corporation. The Energy Absorption (Alpha Model) was the only one that passed the moisture test. Table 2 is a summary of test data.

Researchers decided that the test program could successfully distinguish desirable/undesirable TMA characteristics.

TMA PERFORMANCE SPECIFICATIONS

The performance specifications adopted clearly show their relationship to the research test program. Most of Research Study 991's sample specification was used verbatim including a note that an eccentric crash test, rather than head-on only, may soon be required. The sidebar contains excerpts from TxDOT specifications, *Attenuator, Crash, Truck Mounted*, as an example.

RESULTS

The Division of Equipment and Procurement (D-4) and the Division of Maintenance and Operations (D-18) adopted most of TTI's recommendations as soon as the resport was published. Over 200 TMAs have been purchased under the new specifications.

Research Report 991-1's sample specification proposed that TxDOT encourage "the market to move toward units capable of providing the same level of protection and meeting the referenced criteria and requirements for vehicles weighing up through 3,500 lbs, while traveling at speeds up through 55 MPH." Manufacturers, having seen the results of the research, have improved all aspects of their products. Several are on the verge of marketing a true 60 MPH truck-mounted attenuator.

TxDOT's sponsored research and adoption of TMA performance specifications has generated interest and positive comment from other state DOTs. This study is a good example of appropriate research carried out in a timely manner and implemented swiftly and willingly — in other words, a research success story.

For more information on the TMA performance specifications, contact the project's technical coordinator, Mr. Glenn Hagler of D-4 at (512) 416-2082, Tex-An 249-2072.

FROM TXDOT SPECIFICATION 550-42-02: ATTENUATOR, CRASH, TRUCK MOUNTED; PART II, SECTION 3 "TESTING AND CERTIFICATION"

3.2 ENVIRONMENTAL TESTING:

3.2.1 Vibration Tests

Test Procedure: Vertical sinusoidal oscillation through 0.6 inch amplitude at a 7 Hertz frequency for a duration of 40 hours. (Vol. 2, Final Report, TTI)

Passing Criteria:

Quantitative: A maximum rear corner sag of 0.5 inches a the end of the 40 hour test period.

Qualitative: No structural failures permitted. No reasonable expectation of impairment of energy absorbing capability permitted. TMA skin may experience minor distorations, minor cracking, and minimal loss of rivet integrity.

3.2.2 Moisture Test

Test Procedure: Determine TMA dry weight before exposure to moisture testing. Position the TMA within a moisture chamber in the normal horizontal operational position. Subject the TMA to 24 hours of 6 inch per hour simulated rainfall on its top and sides. Allow the TMA to drain and dry in the chamber for one hour. Determine the TMA weight gain in percent of original TMA dry weight. (Vol. 2, Final Report, TTI)

Passing Criteria:

Quantitative: The TMA weight gain as a result of the moisture test shall not exceed 5% of the original TMA dry weight.

Qualitative: No reduction in energy absorbing capability or structural integrity as a result of moisture testing.

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3. Anderson, R. W. *Transafety Reporter* (November 1988).
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IS IT OKAY TO COPY MY COLLEAGUE'S SOFTWARE?

No, it's not okay to copy your colleague's software. Software is protected by federal copyright law, which says that you can't make such additional copies without the permission of the copyright holder. By protecting the investment of computer software companies in software development, the copyright law serves the cause of promoting broad public availability of new, creative, and innovative products. These companies devote large portions of their earnings to the creation of new software products and they deserve a fair return on their investment. The creative teams who develop the software — programmers, writers, graphic artists and others — also deserve fair compensation for their efforts. Without the protection given by our copyright laws, they would be unable to produce the valuable programs that have become so important in our daily lives: educational software that teaches us much needed skills; business software that allows us to save time, effort and money; and entertainment and personal productivity software that enhances leisure time.

Q *That makes sense, but what do I get out of purchasing my own software?*

A When you purchase authorized copies of software programs, you receive user guides and tutorials, quick reference cards, the opportunity to purchase upgrades, and technical support from the software publishers. For most software programs, you can read about user benefits in the registration brochure or upgrade flyer in the product box.

Q *What exactly does the law say about copying software?*

A The law says that anyone who purchases a copy of software has the right to load that copy onto a single computer and to make another copy "for archival purposes only." It is illegal to use that software on more than one computer or to make or distribute copies of that software for any other purpose unless specific permission has been obtained from the copyright owner. If you pirate software, you may face not only a civil suit for damages and other relief, but criminal liability as well, including fines and jail terms of up to one year.

Q *So I'm never allowed to copy software for any other reason?*

A That's correct. Other than copying the software you purchase onto a single computer and making another copy "for archival purposes only," the copyright law prohibits you from making additional copies of the software for any other reason unless you obtain the permission of the software company.

Q *At my company, we pass disks around all the time. We all assume that this must be okay since it was the company that purchases the software in the first place.*

A Many employees don't realize that corporations are bound by the copyright laws, just like everyone else. Such conduct exposes the company (and possibly the persons involved) to liability for copyright infringement. Consequently, more and more corporations concerned about their liability have written policies against such "softlifting". Employees may face disciplinary action if they make extra copies of the company's software for use at home or on additional computers within the office. A good rule to remember is that there must be one authorized copy of a software product for every computer upon which it is run.

Q *Do the same rules apply to bulletin boards and user groups? I always thought that the reason they got together was to share software.*

A Yes. Bulletin boards and user groups are bound by the copyright law just as individuals and corporations. However, to the extent they offer shareware or public domain software, this is a perfectly acceptable practice. Similarly, some software companies offer bulletin boards and user groups special demonstration versions of their products, which in some instances may be copied. In any event, it is the responsibility of the bulletin board operator or user group to respect copyright law and to ensure that it is not used as a vehicle for unauthorized copying or distribution.

Q *What about schools and professional training organizations?*

A The same copyright responsibilities that apply to individuals and corporations apply to schools and professional training organizations. No one is exempt from the copyright law.

Q *I'll bet most of the people who copy software don't even know that they're breaking the law.*

A Because the software industry is relatively new, and because copying software is so easy, many people are either unaware of the laws governing software use or choose to ignore them. It is the responsibility of each and every software user to understand and adhere to copyright law. Ignorance of the law is no excuse. If you are part of an organization, see what you can do to initiate a policy statement that everyone respects. Also, suggest that your management consider conducting a software audit. Finally, as an individual, help spread the word that the users should be "software legal."

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COMPUTER TIP:

Wipe your computer screen with a used fabric softener sheet to reduce static.

Source: Ricki Letowt, *Letowt on Computing*, 22 Nostrum Road, Norwalk, CT 06850, as seen in ***Communication Briefings*** 11 (Oct. 1992):1.

DID YOU KNOW...

A near-frictionless magnetic bearing has been built from a high-temperature, Y-Ba-Cu-O superconductor by scientists at United Technologies Research Center, East Hartford, Conn., and the U.S. Department of Energy's Argonne National Laboratory, Argonne, Ill. A perfected version could be a key component of highly efficient flywheels capable of storing 50 to 500 MJ of energy. Superconducting bearings reportedly can have 25 times less friction than conventional magnetic bearings and about 1,000 times less friction than car and truck bearings.

Source: "Technical Bulletins," ***Advanced Materials & Processes*** 140 (Nov. 1991):14.

SUBTERRANEAN PLANE ON DRAWING BOARD

Soaring beyond magnetic levitation as a transport mode, the Fujita Corporation hopes to revolutionize the future of interurban transport with a plane that will fly underground. Dubbed the "geoplane," the $230 billion proposal calls for the development of a passenger aircraft that would fly in a huge tunnel between Tokyo and Osaka, about 150 feet below ground level. The tunnel, about 180 feet wide, would be divided into three levels. Two of the levels would be reserved for incoming and outgoing geoplane flights, and the third for linear motor cars and commuter transport services. The outer wall of the tunnel would house optic fiber and power cables.

The ambitious plan would tackle the above-ground congestion and land shortage head on. As envisioned by Fujita, one of Japan's leading construction companies, the stub-winged plane would run on turboprop engines and cover the 400-km stretch between Tokyo and Osaka in about 50 minutes. At lower speeds, the geoplane would hug the surface of the runway, at its cruising speed of 600 km/h, and would fly 1 meter above the runway surface. The company describes the projected 400-passenger geoplane as superior to the linear motor car. The hitch is the $230 billion price tag of the system. The planes are estimated at $380 million a copy. Fujita has joined with the Nagare Research Corporation to draw up in-depth studies of the projected system.

From AASHTO's ***International Transportation Observer***, as seen in ***The Virginia Eclectric*** (Sept. 1992): 7.

DID YOU KNOW...

Research has shown that improvements to traffic sign systems have one of the highest benefit-to-cost ratio of all highway improvements. *Source*: ***Moving Forward*** 11 (Jan. 1993): 1.

WHAT DOES THAT SIGN MEAN?

by **David Dennis**
Communications Specialist
Texas Transportation Institute
Texas A&M University

Transportation needs evolve and so do the devices that control transportation. After you've passed driver's education, how well have you, the average citizen, coped with the evolving transportation system? This question is one transportation professionals needed to have answered.

A study conducted for TxDOT by the Texas Transportation Institute (TTI) at Texas A&M University entitled "Assessment and Improvement of Motorist Understanding of Traffic Control Devices" (TTI 1261) is a detailed examination of motorists' comprehension of signs, signals and lane markings. While not complete, preliminary results indicate that some Texas drivers may need to improve their understanding of certain signs, markings, and signal indications.

TTI researchers John Mounce, Katie Womack and Gene Hawkins have reached the halfway point of their three-year TxDOT-sponsored study. They are currently analyzing survey data gleaned from answers to questionnaires obtained in 12 cities across Texas.

Much of the study focuses on human factors. Researcher Hawkins summed up the purpose of the study by saying, "We want to determine if ... messages are understood as they are intended to be. Are there changes that can be made to the devices to make them do a better job? Or should we do a better job of educating Texas drivers?"

Driver reaction to traffic control devices can be broken down into three areas: (1) Do drivers see the device and is the device legible? (2) Do drivers understand the message? (3) If seen and comprehended, do drivers comply with the message? "Our study addresses the second area, driver comprehension of the message," said Hawkins.

THE SUSPECT DEVICES

This is not the first survey of motorist comprehension of traffic control devices. In 1979 and 1980, the American Automobile Association conducted studies. However, neither study produced conclusive information that pointed to specific problematic devices. The Texas Transportation Institute also conducted surveys in 1978 and 1981. These TTI studies were used to assemble the first list of suspect signs, markings and signals.

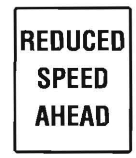
Other factors considered in the selection of devices for the survey were: devices that had never been surveyed; the consequence of misunderstanding the message; whether the device is included in the *Texas Drivers Handbook;* the frequency of usage of the device itself; opinions of transportation professionals within TxDOT and elsewhere; and any special interests of the project's technical panel. While many traffic control devices are the result of experiments and research, some represent a solution based on engineering judgment. Based on these criteria, the research team initially selected 60 messages or devices for the survey. Preliminary survey results indicated that 14 of these were clearly understood, leaving 46 devices to be used in the final survey.

THE SURVEY

The survey consisted of a 15-minute video tape that featured these 46 different traffic control devices. This tape was viewed and a questionnaire administered at driver's license offices in Tyler, Paris, Houston, Lufkin, San Antonio, Beeville, El Paso, Eagle Pass, Amarillo, Levelland, Temple and Athens. Questions developed for the survey were worded in order to identify what problems exist, for whom these problems exist, and the pervasiveness of such problems. Each question was multiple choice with one desirable response, two responses within the realm of possibilities and one "not sure." The survey was given to a statistically valid representation of 1,754 Texas drivers based on sex, age, ethnicity, and language spoken.

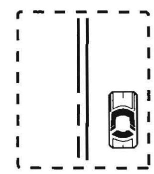
The data will allow TTI researchers to develop alternatives for misinterpreted devices and test their effectiveness on a smaller sample to see if the changes increase understanding of the message or device.

REDUCED SPEED AHEAD
sign (R2-5A), TMUTCD Section 2B-14
What does this sign mean?
1) 1.9% The speed limit will be higher ahead.
2) 3.7% The speed limit ahead will be strictly enforced by the police.
3)* 93.2% The speed limit will be lower ahead.
4) 1.1% Not Sure.

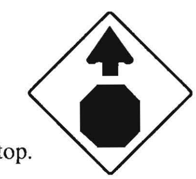


ROUGH ROAD
sign (W8-8), TMUTCD Section 2C-30.2
What is the purpose of this sign?
1) 7.2% To let motocyclists know they should use caution.
2) 2.5% To let motorists know the road will be noisier ahead.
3)* 88.7% To let motorists know the pavement is in poor condition.
4) 1.7% Not Sure.

No-Passing Zone markings
TMUTCD Section 3B-3
If you are traveling in the right lane, which of the following statements is true about the center line?
1) 5.8% This is a two-way road where you are allowed to pass.
2)* 88.0% This is a two-way road where you are not allowed to pass.
3) 3.2% This is a one-way road where you are allowed to change lanes.
4) 3.0% Not Sure.


Stripes are yellow in survey

Stop Ahead sign (W-31a)
TMUTCD Section 2C-15
What is this sign telling you to do?
1) 2.1% Stop when you see this sign.
2)* 87.4% Be prepared for a STOP sign ahead.
3) 7.6% At the next STOP sign you should go straight after you stop.
4) 2.9% Not Sure.



WATCH FOR ICE ON BRIDGE
sign (W19-2), TMUTCD Section 2C-41
When you see this sign, what should you do?
1) 2.5% Don't drive on the bridge if there is ice on it.
2) 11.5% Slow down and gently apply the brakes while you are on the bridge.
3*) 84.0% Slow down, don't brake or make sudden turning movements on the bridge.
4) 2.1% Not Sure.

FIGURE 1: Five devices with good driver response.

PRELIMINARY RESULTS

A quick glance at early survey results show an average correct response rate of 64%, with older drivers exhibiting a possible comprehension problem. "This may be due to changes in signs over the years or a lack of driver's education programs when these drivers obtained a license," noted Hawkins.

Of the 46 devices surveyed, the five devices with the highest rates of comprehension are depicted in Figure 1. Actual survey questions are also included. Asterisks denote correct answers.

The five devices with the lowest rates of comprehension are depicted in Figure 2.

PROTECTED LEFT ON GREEN
sign (R10-9a), TMUTCD Section 2B-37
If you want to turn left at this intersection and the green light is on, what should you do?

1) 34.7% Yield to oncoming traffic. They will have a green light also.
2) 47.5% Wait for a green arrow. Then turn left.
3)*15.5% Turn left. Oncoming traffic will have a red light.
4) 2.3% Not Sure.

GROOVED PAVEMENT AHEAD
sign (W-812), TMUTCD Section 2C-30.5
What is the purpose of this sign?

1) 16.5% To let motorists know the road will be slippery when wet.
2) 39.5% To let motorists know the road will be noisier ahead.
3)*29.2% To let motorcyclists know they should use caution.
4) 14.7% Not Sure.

Turn sign (W1-1R)
TMUTCD Section 2C-4
What does this sign mean?

1) 10.7% There is an intersecting road to the right ahead.
2)*31.9% You should drive 30 miles per hour or less to make the next turn.
3) 45.2% You should turn right at the next intersection.
4) 12.2% Not Sure.

Curve sign (W1-2L)
TMUTCD Section 2C-5
How should you respond to this sign?

1) 65.0% The road will curve to the left a short distance ahead and you should slow down before reaching the curve.
2)*32.4% The road will curve to the left a short distance ahead, but you may drive the curve at the speed limit.
3) 1.7% The next mile of highway has several curves and you should slow down.
4) 0.9% Not sure.

Two-Way Left Turn Lane sign (R3-9B)
TMUTCD Section 2B-19
Which one of the following statements is true when you see this sign?

1)*44.6% The center lane is to be used only for making left turns.
2) 6.7% You will be able to make only left turns at the next intersection.
3) 43.7% The center lane is to be used only for making left and right turns.
4) 5.0% Not Sure.

FIGURE 2: Five devices with poor driver response.

POSSIBLE OUTCOMES

Once the results of this survey are complete, several measures can be taken to improve the comprehension of roadway messages surveyed. Changes being considered include redesigning the devices themselves, better explanation of the devices in the *Texas Drivers Handbook,* and placing more effort on traffic control devices in driver's education classes to increase understanding. Several of the lowest rated devices are not illustrated or explained in the current *Texas Drivers Handbook,* or in driver training classes.

A new national *Manual of Uniform Traffic Control Devices* (MUTCD) is scheduled to be published in 1996. A new edition of the Texas MUTCD may follow the national manual. The TTI researchers hope that their results will have a positive impact on both publications.

Additionally, TxDOT is considering proposals for public education programs aimed at increasing the awareness of traffic control devices. These efforts should help raise awareness of traffic control devices used on Texas roads and highways.

An informed driver is a safer driver. This joint research project between TTI and TxDOT should produce better traffic control devices and a safer driving experience for all Texans.

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1. Mounce, J. M., H. G. Hawkins, Jr., K. N. Womack. *Assessment and Improvement of Motorist Understanding of Traffic Control Devices,* FHWA/TX-91/1261. College Station: Texas Transportation Institute, Texas A&M University, 1991.
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