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Kathleen M. Jones

ODESSA TURNS TO "FORENSIC" ENGINEERING

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INTRODUCTION

When an essentially new road fails, you need to know "whodunit" so you can go after the right culprit straight off. After all, if the problem is in the surface course only, you don't want to spend money on unnecessary major rehabilitation of the base. On the other hand, if the base has failed, surface repairs won't solve a thing.

Odessa District was faced with just such a quandary. State Highway 158 in Midland County, from the intersection of IH-20 to the end of the 4-lane section (approximately 4 miles) was reconstructed and widened in December 1988. The project was an end-result specification job consisting of 10 inches of crushed limestone flexible base and 1.75 inches of ACP surfacing. Because end-result specification was a process new to everyone involved, there were some difficulties with quality control. Raveling occurred during construction on some sections; however, these sections were replaced by the contractor before the job was accepted. Shortly after SH

FIG. 1: SH 158 surface distress.

158 was opened to traffic, major block cracking appeared (Fig. 1). Blocks from 12 by 12 inches up to 24 by 24 inches were common throughout the job (Fig. 2). The block cracking progressed to alligator cracking. No other major distresses, such as rutting, were found even though the highway carries substantial oil field truck traffic. District personnel patched several sections. It didn't control the cracking. The problem looked to some people like base failure that would need major rehabilitation, but there were conflicting opinions as to the source of the problem, and as a result, the required treatment. A little "forensic" engineering was in order to discover the facts that could pin down the culprit cause and resolve the treatment question.

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FIG. 2: Close-up of distress.

Odessa District's Lab Engineer Steve Smith happens to be on the department's Pavement Management Committee and contacted the Pavement Management Section of the Division of Maintenance and Operations (D-18PM) to see about getting some Dynaflect and Falling Weight Deflectometer (FWD) testing done on SH 158. Not only was D-18PM able to offer the requested testing, but also they have a state-funded research project 1923, "Continued Development of the Texas Ground Penetrating Radar System," in progress, headed by Tom Scullion of Texas Transportation Institute (TTI) at Texas A&M University. Odessa's problem fit the study's need to correlate FWD data and other data to the ground penetration radar output on a thin overlay. The TTI researchers could help determine the cause of SH 158's cracking using several sophisticated methods, identify potential rehabilitation strategies for Odessa District to use, and be paid out of the research project's funds, not district money.

April 5, 1991, the D-18PM and TTI team performed Dynaflect, Falling Weight Deflectometer (FWD) tests, dynamic cone penetration tests (Fig. 3) and ground penetration radar scanning (Fig. 4). The Division of Materials and Tests did extractions from road samples and performed penetration, viscosity and ductility tests on the residual asphalt (an AC 20). The layer strengths, as measured by the FWD, were input into the Flexible Pavements Design Program to evaluate the pavement's structural capacity.

TEST RESULTS

The FWD layer strengths were backcalculated using the MODULUS 4.0 system developed by TTI. The surface was fixed at 500 ksi, this being the standard practice for a thin surface. The Dynaflect and the FWD both indicated a reasonably strong base and subgrade. An average base and subgrade moduli of 40 and 23 ksi respectively were used in the pavement design run with FPS.

FIG. 3: Dynamic cone penetrometer.

Although the average strengths of the base and subgrade are high, and certainly adequate as design standards, there are two major concerns about this data. First, the surface was excessively cracked which is known to cause problems with FWD surface geophones. Second, some light rain had fallen in the area the evening before the test; because of the amount of surface cracking, moisture had to have entered the base layer. Therefore, it is difficult to draw any firm conclusions solely from deflection data.

The dynamic cone penetrometer (Fig. 5) works on the principle that rate of penetration is a function of the strength of each layer. The hammer is dropped from the fixed drop height and the penetration of the cone in each layer is recorded (Fig. 6). The SH 158 dynamic cone penetrometer locations were at mile posts 0.00 and 1.971. The rates in the base layer were 0.02 and 0.1 inches per blow (Fig. 7), which converts to CBR val-

FIGURE 4: Truck-mounted ground penetrating radar.

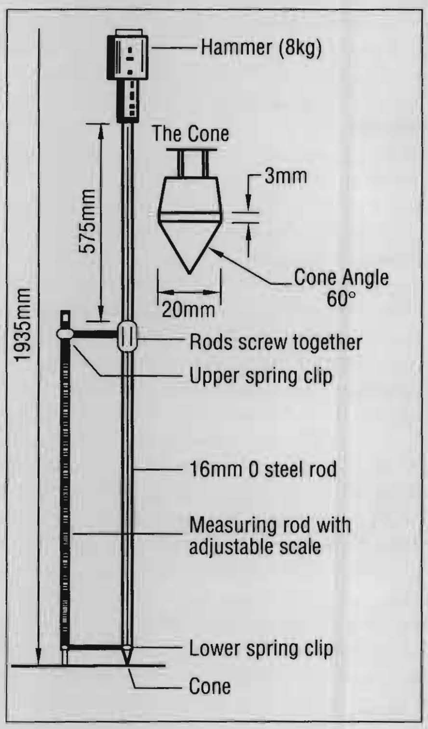

FIG. 5: Cone penetrometer schematic.

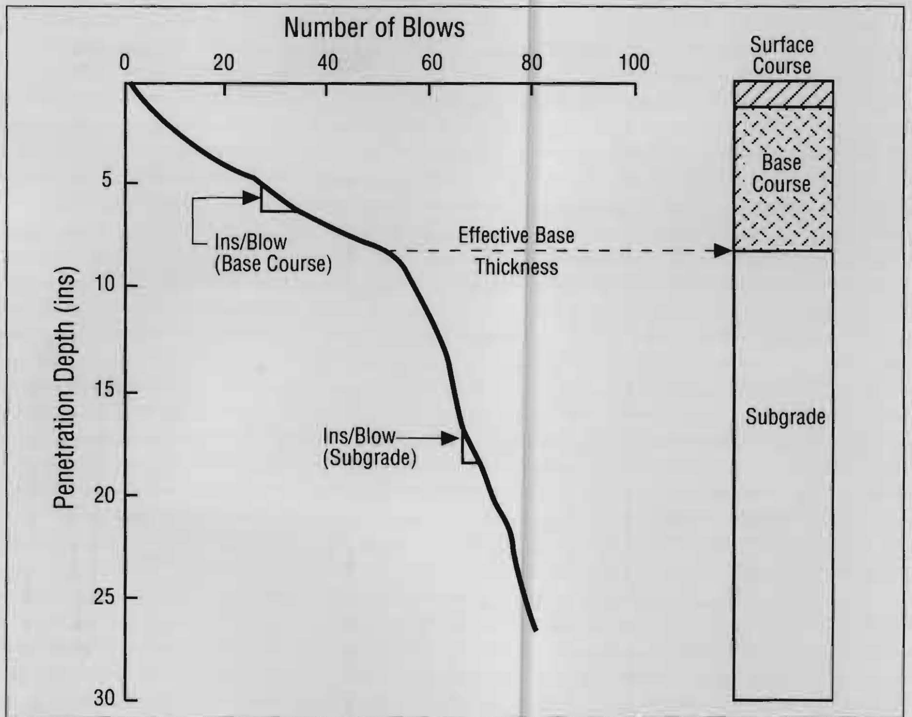

FIGURE 6: Typical penetration results from the cone penetrometer.

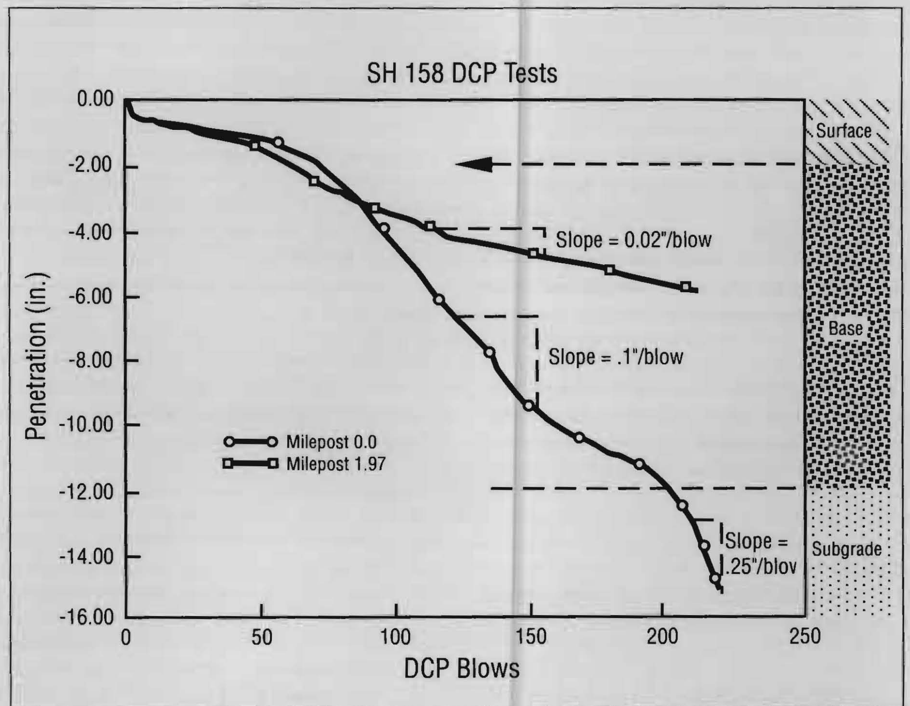

FIGURE 7: SH 158 cone penetration results.

ues of greater than 120. In both test holes, the base is Triaxial Class 1 type material.

The truck-mounted ground penetration radar (GPR) system used in this study had been purchased as part of Research Study 1923. GPR works by sending pulses of electromagnetic energy into the pavement, then capturing the reflected energy from each layer interface. It is analogous to taking an "x-ray" of the pavement at 10-foot intervals. Amplitudes and time delays between peaks of electromagnetic waves transmitted by radar antennae are used to estimate layer properties and thicknesses in ground penetration radar testing (Fig. 8). In pavement materials, the size of the reflected signal is strongly related to the moisture content of the layer.

The SH 158 radar data was collected at 20 MPH, with traces taken at approximately 10-foot intervals. The radar did not note a distinct difference between the bottom of the base and the subgrade, indicating that they are similar materials at approximately the same moisture contents. The asphalt thickness was close to the specified 1.75 inches for the first 2 miles of the project, starting at the intersection with IH-20 and traveling southbound. The moisture content, in general, was 6 to 8 percent, not an unreasonable value for a crushed limestone the day after a rain. In general, all of the testing done so far indicated that the base and subgrade were in good condition. To determine the cause of the cracking, the team had to look elsewhere.

The laboratory test results indicated that the gradation and asphalt content of the ACP were within specification. However, the viscosity of the residual asphalt was unusually high.

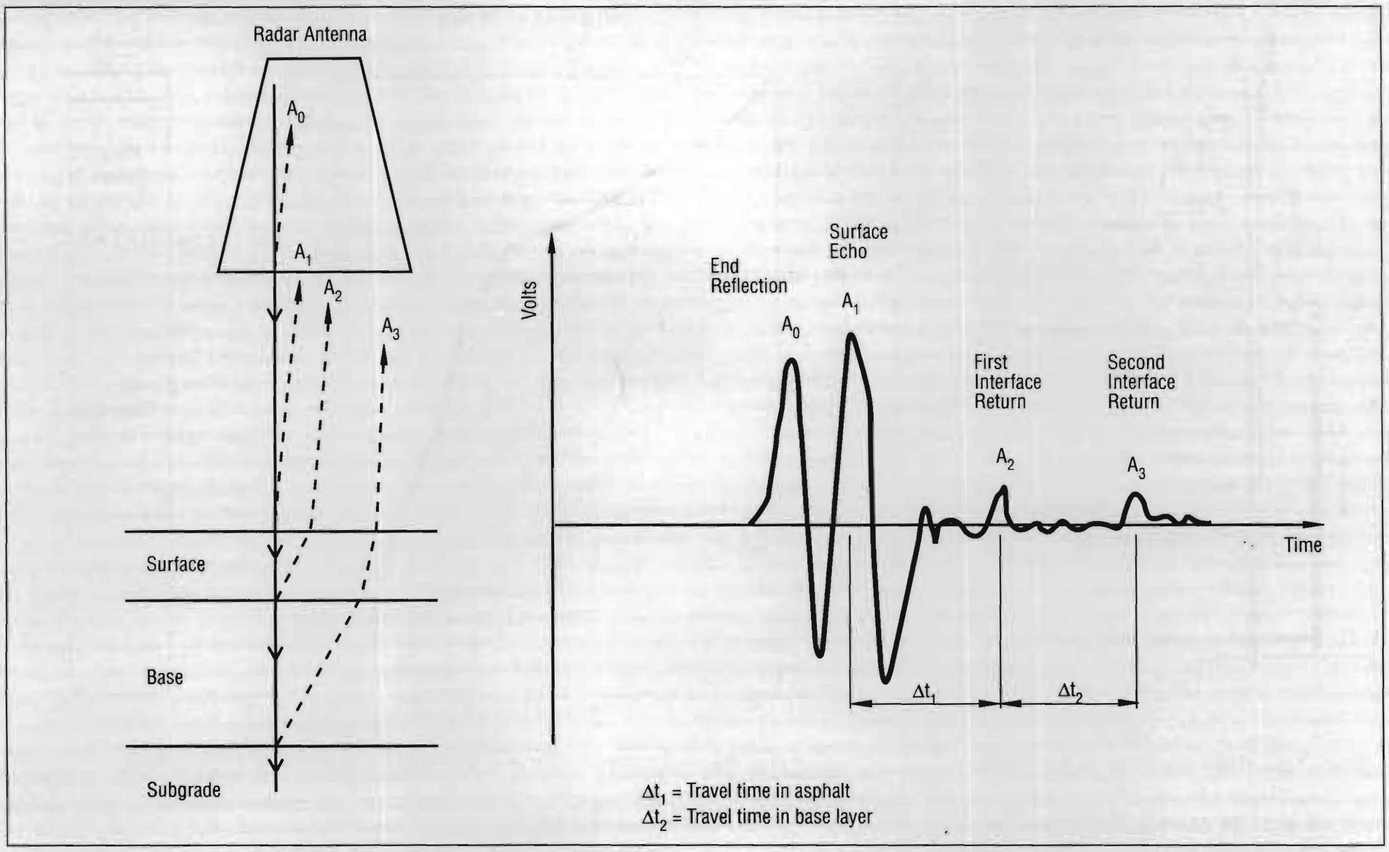

FIGURE 8: Idealized radar return signal (ignoring multiple echos).

Anticipated viscosity for an AC 20 should be below 10,000 Stokes at 140° F using test method Tex-528-C. The measured value for the SH 158 asphalt was 21,452, which is very high. The penetration test results (Tex-503-C at 77° F) confirmed the viscosity result. The expected penetration should be 20 to 30. The measured penetration of 11 indicated a very stiff asphalt that might be prone to cracking.

CONCLUSIONS

Because the base showed good strength in Dynaflect, FWD, dynamic cone penetration and ground penetrating radar tests, the TTI team ruled out base failure as the probable cause of the cracking. They recommended that the existing 1.75 inches of asphalt surface be removed and that some amount of base (left to the resident engineer's discretion) should be scarified and recompacted prior to placing a new wearing course. The analysis team and district personnel felt that although the base was adequate at the time the tests were made, it might degrade before rehabilitation could take place, particularly if the coming winter is severe.

Analysis made with the new Texas Flexible Pavement System program indicated that the surface thicknesses shown in Table 1 are required based on the the anticipated traffic levels. The rehabilitation plans were reviewed and approved recently (Fig. 9). The rehab job on SH 158 is scheduled for letting in November 1991. The ACP will be removed and the base will be scarified up to 6 inches (less if the resident engineer determines that little or no degradation has occurred), reshaped and recompacted. No asphalt or portland cement stabilization of the base is required. The

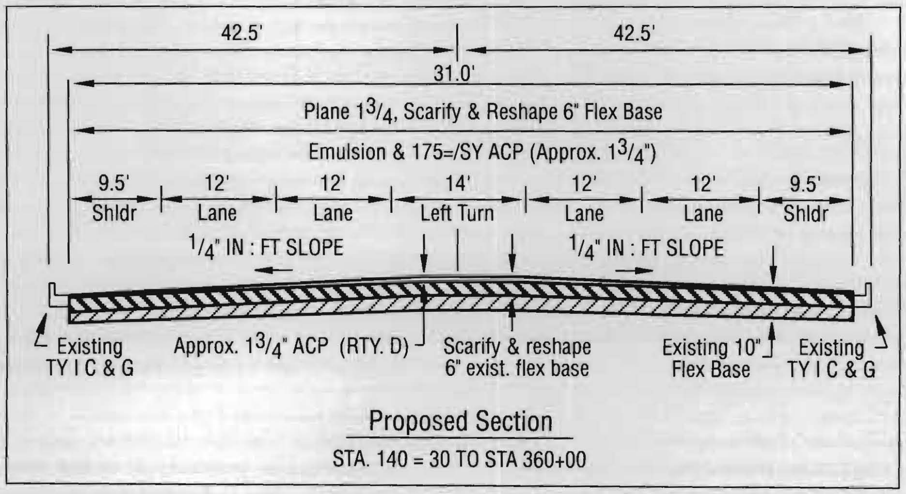

FIG. 9: Proposed rehabilitation section.

new wearing course will be 1.75 inches of ACP using an AC 20 binder.

"Forensic" engineering can answer questions that may save a district money and headaches by identifying the source of a problem before various different repairs and rehabilitations are tried. There are generally several state or federally funded research projects active in any given year dealing with a wide variety of pavement and bridge-related problems. Your problem out in your district may be one that a researcher is itching to solve to get valuable data. If you've got an itch or a pavement or bridge problem that might be helped by forensic engineering, call the Research and Development Section's Implementation Engineering Staff; Lisa Lukefahr at (512) 465-7685, Tex-An 241-7685 or Klaus Alkier at (512) 465-7643, Tex-An 241-7643.

Test results and some project information were taken from Tom Scullion's unpublished report of the findings to Odessa District. Copies of the report are available from the author or from the ***TQ*** editor.

THE CHIPS ARE DOWN

by **Jack Stephens, Ph.D., P.E.**

Jack Stephens is a Professor in The University of Connecticut's School of Engineering, Department of Civil Engineering. For copies of Professor Stephens' publication "Chip Seals Made Easy" call the Technology Transfer Library at (512) 465-7644; Tx-An 241-7644.

Once again the summer maintenance is done. The agony of "will it rain before the emulsion fully breaks" is past for another season. While the memory is clear we should consider how it went as there is always next year. The best criteria ruling on the success of this season's work is "are the chips still there." If so they will probably stay and several years have been added to the life of the roads.

If the chips did not stay as well as expected, causes should be considered in order to secure a better job next year. It is rare that the quality of the emulsion is the cause of poor chip retention. Unfortunately no one takes a sample of the emulsion at the time of the work and so if the chips do no stick, the character of the binder cannot be checked. Resolve next year to fill a coffee can and keep for a few weeks just in case.

The difference between a good and a bad job is often some small detail. In the case of a chip seal the small thing is often the dust n the chips. Dust on the chips increases sharply the time needed for the binder to reach the chip surface and traffic may whip the chips off before the bond develops.

Those chips that didn't stick to the pavement, were they of one size? Early in the nineteenth century, a Scotsman named John Macadam discovered that small pebbles mixed with large gave the most dense surface but that if mixed and applied all at once, the small interfered with the bedding of the larger. His solution was a coarse layer first, followed by progressively finer layers creating what became to be known as Macadam pavement. If multiple seals are placed, the second could use small chips. For a single layer, a good rule is that the smallest chips should not be less than three quarters the size of the largest.

The blacker areas that are or threaten to bleed can have several causes. The quantity of emulsion spread is an obvious factor. Are the chips there but lost in the excessive quantity used? Or were the chips thrown off and the insufficiently deep emulsion exposed? Chip shape can contribute to bleeding. Were the chips crushed? The term chip is misleading as it implies a small flat piece. Particles with all dimensions nearly equal are far easier to work with. If a material has many flat chips, it is difficult to determine the quantity of emulsion to spread. If enough is used to retain chips that land on edge, a chip that falls flat will disappear into the emulsion. If the quantity is set for the flat lying chips, those on edge will be lost to traffic.

Are there bare patches where the old pavement shows with little discoloration from the emulsion or can patches of the chip seal be pealed off? If so, the implication is that silt-sand was not addquately swept from those spots and bond did not occur.

While the memory is clear we should consider how it went as there is always next year. The best criteria ruling on the success of this season's work is "are the chips still there."

One last question. Were there too many complaints about traffic throwing chips? The modern radial tire doesn't pick up stone as readily as the old bias-ply tire. Today, most stone pick up is due to binder on the top surface of the stone. The spreader should drop the stone vertically into the binder layer and the roller should push the chips down into the binder with rotation. The construction traffic should avoid cramped turns, hard breaking and other actions that roll the stone over exposing the sticky side to traffic.

So next year we will use a one-size clean, well-shaped chip and pray for good weather.

From *Technology Transfer*, Vol 6 (Fall 1988).

CORRIDOR-WIDE TRAFFIC MANAGEMENT

Excerpted by ***Mohanan Achen*** *from, "Synthesis of Traffic Management Techniques for Major Urban Freeway Reconstruction," FHWA/TX-90/1188-1, by G. L. Ullman, R. A. Krammes, and C. L. Dudek of Texas Transportation Institute at Texas A&M University*

INTRODUCTION

Urban freeway construction is rather complicated because it involves huge traffic volumes and significant impacts on motorists and businesses. Major traffic disruptions can result from just a minor reduction in highway capacity. A corridor-wide traffic management approach acknowledges the fact that these disruptions also influence traffic flow on other freeways or alternative routes. In addition to an efficient traffic control plan for the construction zone itself, improvements may be required in the other routes and transportation modes; in other words, a corridor-wide traffic management plan.

Roadway space has to be shared by the construction activity and the motorists. There is a tradeoff involved between the allocation of space between these two activities. Construction activity will be significantly accelerated if sufficient roadway space is allocated. However, the motorists will incur extra costs due to longer travel times because of diversion or delay caused by increased congestion.

The Texas Department of Transportation's (TxDOT) basic policy during major urban freeway construction projects has been to maintain the same number of freeway lanes during peak periods as were available before construction began. Recent trends indicate that the efficiency of construction has been sacrificed to a certain degree to reduce the adverse impacts on motorists, adjoining property owners and affected communities. Ideally, the division of roadway space should provide at the lowest overall cost.

Study 1188, ***Corridor Analysis for Reconstruction Activities, Traffic Control Strategies and Incident Management***, was performed to assist engineers in developing corridor traffic management plans for future major construction projects. Research Report 1188-1 synthesizes experiences of 12 completed or on-going urban freeway projects nationwide (Table 1). This article presents a synopsis of this interim report's findings on the effectiveness of various strategies and their potential applicability in Texas.

CORRIDOR TRAFFIC MANAGEMENT PLAN

A corridor traffic management plan encompasses not only the freeway under construction, but also the alternative routes and modes in the corridor. Such a plan concerns itself with two major traffic management issues: the proportion of normal freeway capacity that should be maintained through the construction zone and the corresponding volume of traffic that will divert to other routes and transportation modes and consequently must be accommodated. The three main components of this plan are:

1. The construction zone traffic control plan.
2. Improvements to alternative routes and modes in a corridor.
3. A public information program.

CONSTRUCTION ZONE TRAFFIC CONTROL PLANS

Traffic control plans can be classified in terms of the restriction to normal capacity of the roadway being constructed. If it is possible to maintain the same number of lanes during construction, the associated travel impacts from reduced traffic capacity will be minor. The three basic options used by the 12 projects reviewed were:

1. Reducing lane widths and/or reducing or eliminating shoulders while maintaining the same number of travel lanes as existed before construction;
2. Closing down some lanes in one or both directions on the highway being constructed;
3. Totally closing off the construction zone to traffic: traffic has to seek alternative routes.

Regardless of the traffic control plan used, maximizing freeway construction zone or corridor capacity is desirable. If substantial unused capacity exists in the corridor or if capacity improvements can be effected on alternative routes and modes, long-term lane closure may be reasonably accommodated. However, the least restrictive strategy should be employed to minimize travel impacts on the public from the construction project.

A number of techniques are available to optimize the capacity of the construction zone. They include:

1. **Portable Concrete Barriers (PCBs).** PCBs have been used at nearly every major construction project to date. Primarily a safety tool, PCBs separate the work area from the travel lanes, separate opposing traffic flows, or separate HOV traffic from mixed-use traffic. By allowing traffic to operate adjacent to the work area with little or no buffer area, the roadway capacity is increased.
2. **Paddle Screens**. Paddle screens help reduce accidents by reducing driver distractions. They have only been utilized on two projects within the scope of this study, Boston and Miami. (Waco District is using some currently, but that project is not within the scope of 1188). In Miami, it was predicted that the screens would result in travel time, vehicle operating cost and accident cost savings of about $13,500,000 during the 5-year project for a benefit-cost ratio of 4:1.

3. **Ramp Closures or Restriction to HOVs**. Both these techniques can maximize traffic flow and roadway capacity and eliminate vehicle merging conflicts. Restricting ramps to HOV usage is a good method to promote HOV utilization during construction. It is inexpensive to effect ramp closures. For HOV ramp restrictions, informing the public would be the major expenditure. On the I-376 construction project in Pittsburgh, it was estimated that ramps saved HOV travelers an average of 8 minutes per person trip. If all HOV modes are considered, HOV ramps saved users 2,900 hours of delay per day at this site.
4. **Shoulders as Temporary Travel Lanes**. This technique improves traffic operations by providing an additional travel lane and reduces construction time by allowing work to proceed on a greater portion of the roadway. Recent results suggest that converting the inside shoulder to a travel lane may decrease accidents significantly on high-volume facilities. It is not advisable to convert both inside and outside shoulders to travel lanes in normal situations because accident rates may increase. Also, there are delays associated with incidents that could have been moved to the shoulder which actually exceed the benefits of improved traffic flow from two additional travel lanes.
5. **Reversible Lanes**. Reversible lanes should only be considered during peak periods of unbalanced traffic flow on the freeway with a significant volume traveling through the construction zone. This technique is more suitable for radial than circumferential freeways. Barrier-separated reversible express lanes helped maintain peak travel times on I-93 construction in Boston despite the minimal traffic diversion from the freeway.
6. **Incident Management Techniques**. Five techniques to reduce incident detection, response, and removal times during construction are:
   (a) Providing free tow-truck service,
   (b) Initiating or increasing courtesy (or service) patrols,
   (c) Installing emergency phones for motorists,
   (d) Using existing freeway surveillance systems, and
   (e) Increasing police patrols.

For the I-95 construction in Miami, service patrols are expected to assist nearly 4,000 motorists during the 5-year project, reducing delays by 350 hours per incident and yielding a benefit-cost ratio of 23:1. On the same project, it is predicted that the telephone system would reduce incident detection time by an average of three minutes per incident with a benefit-cost ratio of 13:1.

TABLE 1: Urban projects reviewed by 1188-1.

CITY	ROUTE	CONSTRUCTION DATES
Chicago	IH-94	1978-1980
Pittsburgh	IH-376	1981-1982
Houston	IH-10	1983-1984
Syracuse	IH-81	1984
Boston	IH-93	1984-1985
Seattle	IH-5	1984-1985
Philadelphia	IH-76	1984-1989
Minneapolis	IH-394	1985-1992
Detroit	US-10	1986-1987
Hartford	IH-91	1986-1990
Milwaukee	IH-94	1987-1989
Miami	IH-95	1987-1991

IMPROVEMENTS TO ALTERNATIVE ROUTES

The most common response of motorists to significant capacity reductions is to change routes. Therefore, improvements on alternative roads to accommodate the additional traffic pressure are important.

Signalized intersections restrict the overall traffic-carrying capacity of the alternative routes in the corridor and affect the ability to accommodate large amounts of diverted traffic during major freeway construction. Signal timings and phasings can be adjusted to improve signal coordination. The cost of changing signal timings is minimal, yet the benefits have been dramatic. During a statewide signal retiming program, 750 of North Carolina's traffic signals were retimed. The result was an average operating cost savings of $51,815 at a benefit-cost ratio of 108:1 per year.

Signal equipment improvements implemented prior to construction have proved effective. With these improvements, greater flexibility for time-of-day changes is provided and smoother traffic progression is provided. The effects of the improvements will depend upon changes in the traffic volumes and turning percentages, roadway geometrics, the operations of other nearby traffic signals, the type of equipment being replaced, and operating conditions at the intersection before the improvements were made. Improvements in traffic signal hardware will continue to benefit the public even after construction is over.

Other improvements that can be implemented at intersections on alternative routes are temporary left-turn prohibitions, addition of turning bays, intersection widening and police officer control during peak periods. Turning prohibitions are the least costly to implement although some enforcement is necessary after implementation. Channelization and widening are more capital intensive, but continue to provide benefits after the project is over. Police control is labor-intensive and expensive but useful at the beginning of construction projects when the traffic impacts have not been determined yet.

Examples of other roadway improvements are reversible lanes, conversion to one-way streets, pavement markings or stripings for additional lanes or guidance purposes, parking prohibitions, pavement improvements and signal and lighting improvements. Experience has indicated that these improvements have helped accommodate the diverted traffic without significantly increasing congestion levels.

The less expensive techniques should be given first consideration. The cost-effectiveness evaluation should also include post-construction benefits. Improvements involving either intersections or roadway segments should be established before the project starts.

IMPROVEMENTS TO ALTERNATIVE TRANSPORTATION MODES

In an effort to encourage motorists to use public transit during construction periods, some states have spent large sums of money on initiating, expanding, or improving public transit services.

Bus Services

Efforts to improve or expand existing bus services include: express bus services; additional buses on existing routes to maintain or decrease service headways; feeder service to rail and rapid transit; and on-call backup buses. Successful diversion of motorists to this mode will depend on conditions within the construction zone. Obvious, large-scale savings in travel time and convenience must be available in order to attract riders.

When a feeder bus service to terminal stations along Boston's rapid transit system was expanded during I-93 construction, an additional 1700 passenger-trips per day occurred in the second year after expansion. This increase was attributed to diverted freeway motorists at southern terminals. Pittsburgh and Milwaukee also had substantial gains in ridership during construction. However, Syracuse, Detroit and Seattle showed only marginal gains.

HOV Lanes

An HOV lane for buses and carpools with three or more persons was established as part of the construction of I-81 in Syracuse to speed up travel to the downtown area. The average usage of the lane was such that costs to the transportation agency were $1.51 per car (1987 dollars). In Minneapolis, an interim HOV lane was built during the construction of US 12 into I-394. It provided additional route capacity and the opportunity for motorists to familiarize themselves with the concept of HOV lanes. In the first year of operation, 2,000 vpd used it including buses, vanpools and carpools with two or more persons. The travel time was reduced by 8 minutes for vanpools and carpools and by 15 minutes for buses. The benefit-cost ratio was estimated at 1.1:1.

FIGURE 1: Katy Freeway HOV in operation.

The success of the permanent Katy Freeway HOV lane in Houston is well documented (Fig. 1). Peak-hour travel time savings average 15 minutes per vehicle or approximately 1930 hours total per day, on a typical nonincident day. Assuming 250 days of operation, this represents annual time savings of 482,000 hours. At $9 per hour, this equates to $43 million a year – without considering travel time saving increases due to incidents or reconstruction on the freeways. [RS 1146, "The Status and Effectiveness of the Houston Transitway, 1988" (Draft)].

Commuter Park-and-Ride Lots

The introduction and expansion of

park-and-ride lots is an important part of transit and ridesharing improvements. From experiences in Pittsburgh and Boston, the key to a successful park-and-ride program was discovered to be the flexibility to add or delete space or discontinue the unused lots. Temporary measures such as leasing land or procuring existing shopping center parking space would be prudent.

Ridesharing Programs

Expanded commuter matching programs and public information campaigns have been undertaken in some areas to promote ridesharing programs. Incentives are required from employers to help ridesharing programs to succeed. Establishment of HOV lanes and ramps encourage ridesharing programs.

Commuter Train Services

The initiation or expansion of commuter rail service is costly. Efforts in rail service expansion were not too successful in Chicago, Boston, and Pittsburgh where the ridership did not rise significantly. However, in Philadelphia, ridership increased approximately 1300 person-trips per day on one of the lines. Use of this mode by commuters will depend primarily on construction zone conditions. If there is no significant change in freeway capacity, there is not much increase in transit ridership. As with buses, significant benefits in terms of travel times and convenience must be readily apparent to motorists to encourage a large scale defection from cars to trains.

In general, the increases in ridership on transit systems in relation to a construction project is not influenced by the dollar value of the programs implemented, but is more dependent upon the magnitude of travel time or cost savings.

PUBLIC INFORMATION PROGRAMS

Public information programs increase public knowledge and acceptance of the project and the inconveniences that it may cause. These programs promote the use of alternative routes and modes to reduce congestion on the freeway during construction.

These public information programs target motorists using the freeway, residents living adjacent to the freeway, and nearby businesses. The public is informed about project schedules, ramp closings and other events pertinent to their day-to-day lives.

The three important elements of a public information program are:

1. keep the public informed of the conditions through the construction zone and of the availability of travel alternatives;
2. coordinate the actions of all public agencies directly involved in the project; and
3. maintain communications with major public and private groups affected by the project.

A public information program must convince the public that the project will be beneficial in the long term. The public needs to be assured that the agencies involved are trying to reduce the inconvenience to the public as much as possible.

The success of these programs is evidenced by the fact that knowledge and acceptance of the freeway construction projects among the public is very high when these programs have been implemented. The lack of congestion at the beginning of projects could be attributed to the awareness of the public because of these public information programs. These programs have also been credited for the positive attitude of the public towards the projects and the agencies involved.

Public Information Tools

The tools used depend on both the intended audience and the amount of information. To provide general information to a large audience, organize press conferences, media events, press tours and news releases. Public service announcements, paid advertising, interviews and press kits accomplish the same thing. For a smaller group of people with particular interests, public meetings and presentations would be sufficient. Posters, pamphlets, newsletters, maps and special mailings can be used to inform the public of construction in the area and changes related to the construction. They can also be used to promote commuter use of alternative routes and modes during construction.

In Seattle, Boston, Pittsburgh, Philadelphia, Detroit and Minneapolis, toll-free hotlines were provided to inform the public on current traffic conditions and construction schedules. These hotlines also give the public a chance to voice their concerns and complaints about a project. Highway advisory radios which provide real-time information concerning freeway and corridor travel conditions, have been utilized successfully in Seattle and Chicago and has been proposed for Miami.

Special informational signing has been a feature on almost all of the construction projects. Information on alternative routes or advertisements on ridesharing can be provided using these signings. In Detroit, an ombudsman was employed to resolve home or business problems caused by construction activity in affected communities.

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PRECAST CONCRETE TRAFFIC BARRIERS WITH NEW SINGLE SLOPE FACE DESIGN

by **Harold Cooner**
Resident Engineer
Austin District

Harold Cooner, energetic, foreward-looking engineer, a leader in creative solutions in both the department and the community, passed away shortly before this article went to press. We are deeply grieved. It is as a memorial, then, that we present this last of many contributions.

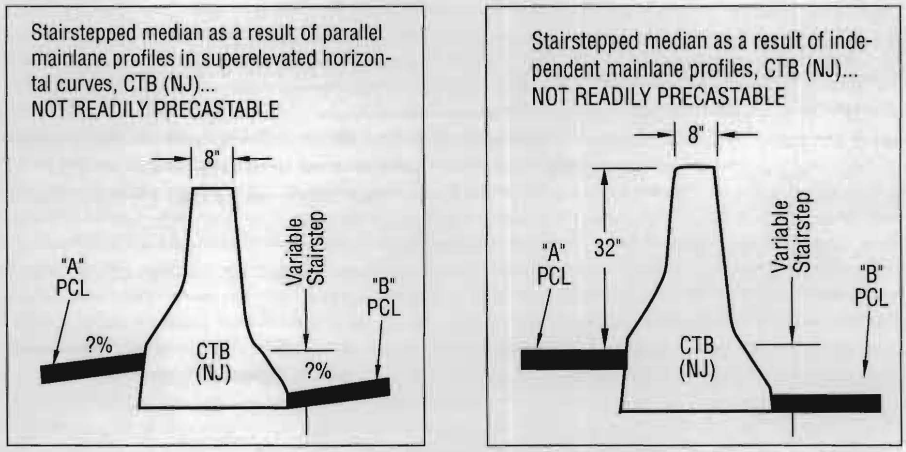

FIGURE 1: Cast-in-place CTB (NJ).

INTRODUCTION

In 1987, the Texas Department of Transportation (TxDOT) recognized potential benefits associated with a new shape of concrete traffic barrier (CTB). Ideally, if the barrier were capable of being precast, this new shape would have two primary advantages over the conventional concrete traffic barrier with New Jersey shape of face CTB (NJ):

1. The new shape could be permanently positioned in medians with a minor stairstep, i.e., a differential in vertical profile elevations of the left and right mainlanes. This characteristic is particularly desirable since the department has many miles of proposed expansion of rural interstate in the triangle formed by IH-45, IH-35, and IH-10 between Houston, Dallas, and San Antonio. Generally, the expansion from four to six mainlanes is accomplished by filling in an existing, depressed median and developing a flush median with continuous concrete traffic barrier. Stairsteps in the median are commonplace because of existing superelevation of left and right mainlanes in horizontal curves, existing independent profiles of left and right mainlanes, or as a result of differential overlays, nonuniform settlement, etc. of the individual roadways. In the past, only cast-in-place construction had been used to construct CTB(NJ) in stairstepped medians (Fig. 1).
2. The new shape would accommodate future pavement overlays without becoming functionally obsolete (Fig. 2). The conventional CTB(NJ) allows for only three inches of overlays – up to the first breakpoint in shape of face (Fig. 3); pavement milling or possibly removing and resetting precast CTB(NJ) becomes necessary for thicker overlay accumulations.

SELECTION OF A NEW SHAPE

The author recommended a trapezoidal barrier cross section because it could be placed in a stairstepped median on the lower roadway and the face configuration would still be identical for both directions of mainlane travel. The trapezoidal shape could be precast with simple form construction. The initial design included a 8 inch wide top to be compatible with possible mounting of illumination atop the barrier and a minimum height of 42 inches to accommodate minor stairsteps and future pavement overlays. The Texas Transportation Institute (TTI) then evaluated the slope of the barrier face, which in turn, determined the base width.

TTI used various barrier/vehicle crash simulation programs to arrive at a promising slope of face, then conducted four high-speed crash tests with passenger cars as prescribed by national standards for the testing and evaluation of barriers (NCHRP 230). Results indicated that the new barrier

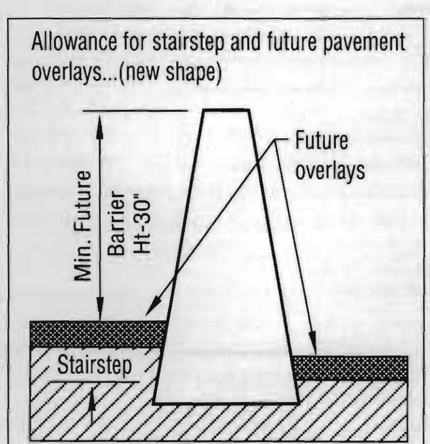

FIG. 2: New shape handles overlays.

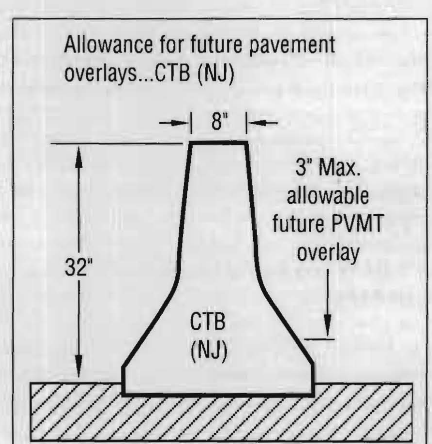

FIG. 3: CTB (NJ) allows only 3-inches.

shape compared favorably from a safety standpoint with the crash results for the traditional CTB(NJ) shape.

The new shape was referred to as single slope concrete barrier, or SSCB. The trapezoidal shape had an 8 inch top, 24 inch base, 42 inch height, and 10.8 degree slope of face in its basic configuration (Fig. 4). In comparison to CTB(NJ), the new single slope design is 10 inches taller and 200 pounds per foot heavier (Fig. 5). The crash-tested precast units were 30 feet in length and had a provision for grouted, dowelled joints when permanently positioned.

EXPERIMENTAL PROJECTS

The SSCB design was selected for experimental use on two adjoining projects on IH-35 in Hays County. These projects provided for additional lanes to be constructed in the median area between Buda and the northern city limits of San Marcos.

Both contracts required that the roadway SSCB be precast so that barrier segments could be used in temporary locations for traffic handling purposes. The contractor had the option of precast or cast-in-place bridge barrier; cast-in-place techniques were actually used on bridge structures.

The two construction projects totaled approximately seven miles (40,000 feet) of the basic 42 inch high SSCB at a cumulative low bid of $18.54 per linear foot, comparing favorably to a statewide average of approximately $20 per linear foot for in-place, conventional CTB(NJ). Approximately 7,000 feet of 48 inch high precast barrier and over 8,000 feet of 54 inch high precast barrier were used in the higher stairsteps encountered in superelevated horizontal curves. Costs were $20.96 and $24.53, respectively, for the 48- and 54-inch heights. Hunter Industries of San Marcos, Texas, was the low bidder on both projects. For each of the three barrier heights (42, 48, and 54), the base width varied while the slope of the face (10.8°) was held constant.

Drawings were developed and included in the TxDOT plans for bridge, SSCB(1), and roadway, SSCB(2), precast barriers (Figures 6 and 7).

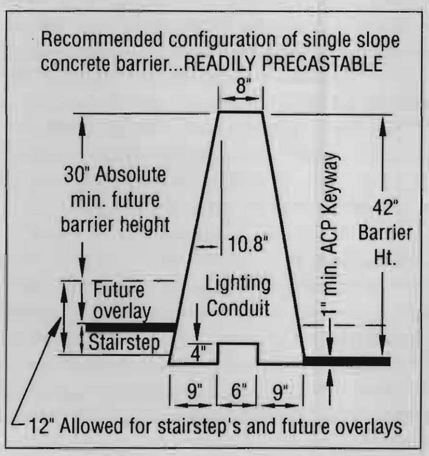

FIG. 4: Recommended configuration.

PRECAST FABRICATION

Hunter Industries elected to design and construct forms and then cast all precast barrier segments in the field in a fabrication yard along IH-35 near Buda, Texas. They fabricated eight forms for the 42-inch barrier, one for for 48-inch barrier height, and one form for 54-inch barrier height. The steel forms were positioned so as to cast the barrier in an inverted fashion. The end sections were removable to facilitate lifting the barrier segments from the forms. Another removable section formed the drainage slots and the longitudinal void to accommodate conduit (when used) which were located on the barrier base.

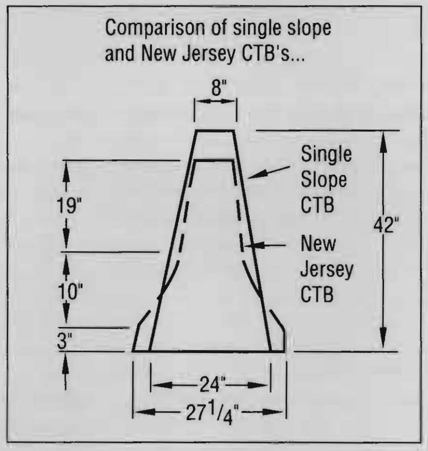

FIG. 5: SSCB compared to CTB (NJ).

Reinforcing steel, typically ten #5 bars longitudinally, and #4 bars vertically on 12 inch centers, was tied on a nearby rack, then moved with a fork lift and set in the forms.

The forms were positioned for ease of dumping concrete from ready mix trucks, and platforms provided for ease of vibrating the freshly poured mix. Specifications allowed Class A (5 sack), C (6 sack), or H (6 sack) concrete. The contractor desired to remove the precast units approximately

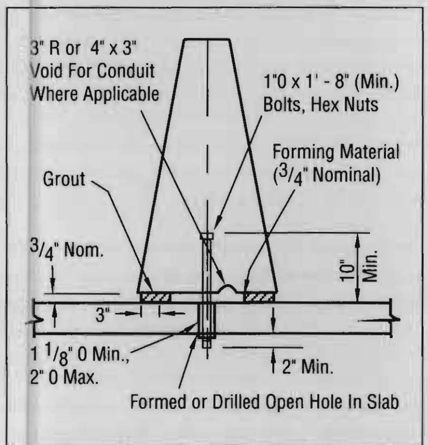

FIG. 6: SSCB(1) for bridge slabs.

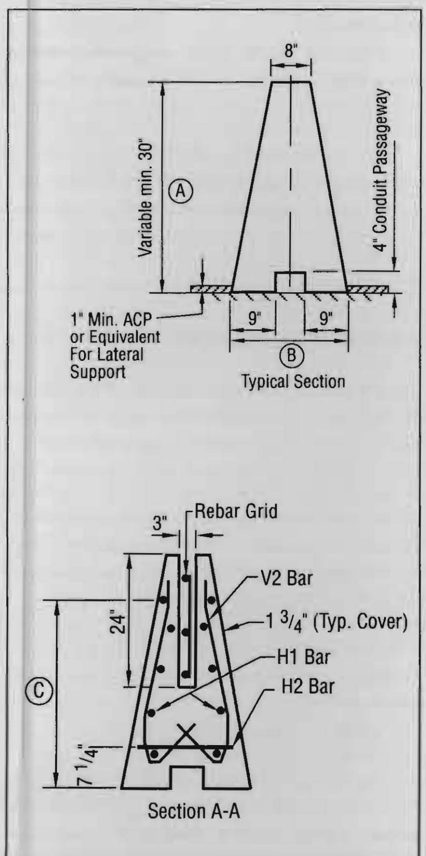

FIG. 7: SSCB(2) typical section and rebar detail.

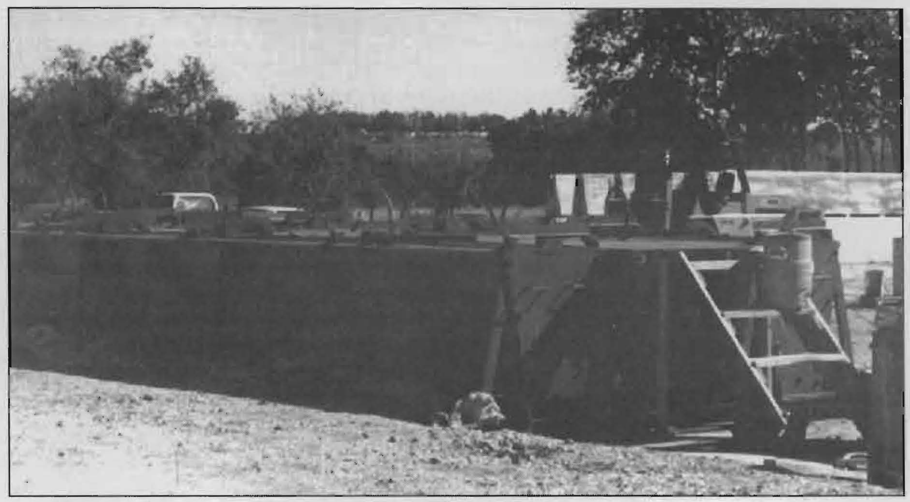

FIGURE 8: Steel form with removable end.

twenty hours after casting so that a daily pour could be made. The use of Class C concrete was necessary to obtain the necessary strength for early removal from the forms.

Standard Specification Item 514 "Concrete Traffic Barrier" was the pay item, and Standard Specification Item 421 "Concrete for Structures" governed the quality characteristics for concrete.

The 30 foot long segments were removed from the forms using threaded inserts at prescribed lifting points. Segments were temporarily stored in a sand pit, rolled 180 degrees then moved with a fork lift and stored in stacks. Figures 8 and 9 illustrate the precasting operations.

FIELD PLACEMENT

The new, precast SSCB was set in locations along IH-35 using a 35-ton crane (Fig. 10) for handling.

In their temporary roadway location, barrier segments were connected in a structurally light fashion by placing a rebar cage in adjoining vertical slots. Barrier mass provided the necessary resistance to sliding or overturning as had been proven in crash tests at TTI.

After being set in permanent locations, barrier segments were connected at the joints by grouting the rebar cage into a vertical void that had been precast in the barrier ends. Barrier units were also keyed in with two inches of asphaltic concrete pavement placed adjacent to each side of the barrier base. These measures provided for complete barrier stability during impacts.

ACCIDENT EXPERIENCE

The SSCB was accidentally impacted seven times by various vehicles in both temporary and permanent barrier locations. There were no fatalities nor serious injuries attributed to barrier/vehicle interaction. Safety performance was therefore acceptable as had been anticipated after the crash testing evaluation performed by TTI.

SUMMARY

The newly developed single slope concrete traffic barrier has been shown to be a safe, economical barrier on two experimental projects on rural IH-35 in Hays County (Fig. 10). The shape is simple, and the configuration lends itself readily to central or on-project precasting operations.

The increased height of the new barrier reduces headlight glare, and the combination of increased height and mass contribute to the crash containment of heavy, high-center-of-gravity trucks. These by-product advantages also contribute to the attractiveness of the new barrier configuration.

It is anticipated that this barrier will be used on IH-35 in the remaining expansion areas of TxDOT Austin District through San Marcos and south to the Comal County line. Adjoining TxDOT San Antonio District has indicated a strong interest in using

FIGURE 9: Filling the forms.

FIG. 10: Precast units in casting yard.

FIGURE 11: 35-ton crane placing precast barriers.

this barrier shape for adding lanes in the median area of IH-35 southward in Comal County.

Due to its straight forward design, ease of construction, advantages including precastability in stairstepped medians, and its simple accommodation of to future pavement overlays, this new barrier shape should experience more widespread use.

HOPE FOR THE FUTURE

by **Walter H. Kraft, P.E.**

Walter H. Kraft is a senior vice-president of Edwards and Kelcey, where he is chief of traffic engineering and transportation planning and project administrator and technical consultant on transportation study and design projects. He has been with the firm for 27 years. Kraft, the author of many published technical articles, is a graduate of Newark College of Engineering and New Jersey Institute of Technology (NJIT), where he received a Doctor of Engineering Science degree. Kraft is a registered Professional Engineer in 10 states and is a licensed Principal Planner in New Jersey. He is a Fellow of the Institute of Transportation Engineers; in 1987, he served as the Institute's international president

This article is based on a presentation made by Dr. Kraft at ITE's international conference, "Beyond Gridlock: Getting There from Here," held in Dallas in March 1989.

Is there hope for the future? This is a question to which one wants to answer "Yes." For without hope we cannot dream, and without dreams or vision, we will not achieve.

Dreams have helped us to achieve greatness. Where would we be if the Wright brothers did not dream of flying. Thomas Edison did not dream of recording sound, Gustave Eiffel did not dream of building a tower, Alexander Bell Did not dream of transmitting sound through wire, Marconi did not dream of transmitting sound *without* wires, and Roebling did not dream of building a suspension bridge? In more recent times, we have had innovators with vision in our own profession, including Alan Gonseth, with his foresight of the present traffic congestion crisis; Alan Voorhees, with his pioneering efforts in transportation planning; Henry Barnes, with the use of media to build support and develop a consensus; Jack Leisch, with the human factors aspects of highway design; William Phelps Eno, with his work on traffic regulations; and Carlton Robinson, with his efforts to bring the transportation community together in Washington, D.C., to present a unified approach on transportation issues. There are, of course, others that I could mention, because every transportation professional is an innovator.

TECHNOLOGICAL ADVANCES

We often hear the phrase, "innovation through technology," because we have been innovative through our use of technology. We frequently say innovation is reliant on advances in technology. Such thoughts can only stifle our dreams. Most discoveries that will advance the use of technology in our field during the next 10 years have probably already been made. We need to uncover these discoveries, no matter where and how they are being used, and then evaluate them in terms of our needs. This process is not always quick or easy. Chester Carlson's invention of xerography, for example, took 21 years from invention to commercialization.

Let's look within our own field — transportation. How long did it take for each stage of technological advancement in intersection control to proceed — from semaphores, to fixed time controllers, to actuated controllers, and to computerized traffic signal systems including changes from analog to digital systems and mechanical to solid-state equipment? How long did it take us to adapt the concept of routing telephone messages through a communications network to routing traffic through a transportation network?

To dream, we need to put aside our prejudices so that we can explore and discover as a child would, even though our exploration might take us down some blind alleys. San Francisco State University offers a technology-based course (Basic Design 300) in which students are asked to bring food items to class and to use them to build a tower at least 36 inches tall. While this might seem like a simple task, each student is required to eat — in one sitting — his or her tower. One student built a beautiful structure using five loaves of bread, but had difficulty eating the tower in one sitting. Another student built a tower out of crushed ice, but found that there was over a gallon of water to drink. One innovative student built a tower out of bread cubes covered with chocolate, which was a pleasure to eat [Ref. 1]. Like these students, we should look for different materials with which to build our towers.

Where should we look for new technological discoveries? Everywhere. Back when the first satellite was launched, who would have thought that someday we would be using satellites to track vehicles on earth? Surveying, which may engineers used to consider subprofessional, has become a high-tech field, with some state registration boards requiring four years of college in addition to a stated number of years of experience. Satellites and surveying are used on many proposed vehicular navigation and route guidance systems being developed in Europe, Japan, and the United States. For example, Autoguide is such a system currently being tested in England and Germany. To use this system, the driver enters his or her destination into a small computer on the dashboard. An arrow on the computer screen and an electronic voice give directions to the driver. The reasonably priced system costs $350 to $550 to purchase and install and has annual operating fees of $50 to $180.

We may encounter some nightmares in our dreams of future systems. Human factor considerations (especially those of our aging population), which we transportation engineers realize are important, may require increased emphasis if we are to develop effective and safe innovative systems. Airplanes are among the most complex machines in use today. Yet mechanical failures are rarely cited as the primary cause of a disaster. The Federal Aviation Administration states that "nearly two-thirds of all fatal jetliner accidents are attributed, at least in part, to human error: mistakes made by pilots, controllers, or maintenance workers" [Ref. 2]. Concern has been expressed that the use of advanced technology may result in a breakdown of the man-machine interface, causing the pilot to be in danger of feeling "out of the loop" and being a passive cockpit bystander — possibly being bored. In response, the FAA recently began researching human factors. Perhaps we can use their discoveries for our in-vehicle navigation systems.

The California Department of Transportation (Caltrans) recently completed a study, using econometric models, on the relationship between transportation system health and economic prosperity. Some of their predictions could become nightmares. They predict that if highways are allowed to deteriorate, then by 1995:

- The gross national product will drop by $365 billion;
- Prices will increase by 5%;
- Employment will decline by 2.6 million persons;
- Private productivity growth will continue to slow down; and
- The United States will continue to decline in international competitiveness.

As a result, the private sector will see costs transferred to it at a ratio of seven to one, based on a benefit-cost ratio of savings in transportation operating costs to roadway capital outlay that exceeds 6.8 [Ref. 3]. To avoid this nightmare, we need to dream of innovations that will bring a different future. For example, think of the changes that an in-vehicle navigation system could bring about. One change could be the elimination of all directional signs, which would mean savings in construction and maintenance costs.

Increased use of knowledge-based expert systems could also bring a different future. These systems are interactive computer programs that incorporate judgment, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks. The knowledge of our experts could then be retained and an expert's knowledge could be made more widely available.

To induce change, we need to review our methods and dream of what could be done. The California Program on New Technology for Highways (PATH) is attacking lane capacity and safety in all ways to improve efficiency through the use of narrower lanes, shorter distances between vehicles, increased speeds, and reduced length and size of vehicles. Consider:

What would happen if some 12-foot lanes were narrowed to 8 feet and restricted to automobile use? One result would be an increased number of lanes on segments of our freeway system.

Suppose that the distance between cars were shortened so that flows of 1,800 to 2,000 vehicles per hour with 1.8- to 2.0-second headways could change to flows of 3,600 to 7,200 vehicles with 0.5- to 1.0-second headways. Such a change is possible with the use of radar collision avoidance systems, smart cruise control, and intervehicle communications.

How much would freeway level of service be improved if peak-hour speeds were increased from about 30 miles per hour to 55 miles per hour?

Some current ramp metering systems are helping us to achieve this change.

What increase in parking density would we achieve if vehicle sizes were reduced? The Lean Machine by General Motors is 3 feet wide, 10 feet long, and weighs about 400 pounds. How many of these vehicles could we park in our current parking garages? Also, such vehicles could probably use 6-foot travel lanes.

Our dreams can bring about such changes.

RESOURCES

As we know, the traditional sources of funding for transportation are not adequate to help us meet our present and future challenges. Emphasis has changed from traditional sources to others, including developer contributions and user fees. Voters in nine counties in California have decided to increase their sales tax by one-half cent for periods ranging from 10 to 20 years and to dedicate this amount to transportation. This provides about $400 million per year (which is typically divided equally among transit, local road, and regional road projects). Construction of toll roads is again being considered in many areas.

What could our dreams of future funding include? I can think of the following:

- Continued government involvement,
- Increased user fees,
- Greater willingness on the part of voters to dedicate taxes for transportation, and
- Continued developer participation.

Perhaps you can think of others.

Between 1976 and 1986, the number of scientists and engineers in the U.S. workforce increased by 7%, as compared to an overall increase in the workforce of 2%. In 1986, more than 4.6 million scientists and engineers were employed in the United States. But we still have a shortage of engineers.

In 1976, about 47% of all engineers were over age 40. By 1986, that age group had increased to 59%. We are not attracting enough young engineers into the profession, which is a reflection of the school systems in the United States. A recent survey indicated that:

- Only 40% of U.S. students can solve a complex math problem;
- Only 42% can understand a science problem; and
- Parents do no encourage their children in math and science.

To help us meet the future personnel demands of our profession, we need to:

- Excite students in math and science;
- Welcome foreign or foreign-born engineers;
- Utilize retired engineers in the work force on a part- or full-time basis;
- Make greater use of knowledge-based expert systems; and
- Increase the status and compensation of engineers, so that we can attract the brightest minds to our profession in government, the private sector, and academia.

With such a labor force, we can dream and innovate, and thus achieve great things.

CONCLUSION

Is there hope for the future? I say, "Yes," for there must be hope if we are to maintain our civilization and national well-being. One measure of our nation's well-being is the quality and extent of our public works projects. Transportation, because of its direct connection to our quality of life, is an indication of our civilization. This link has been obvious since earliest time and has promoted many dreams. Therefore, let us never stop dreaming, and let us have continued hope for the future.

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CORRIDOR-WIDE TRAFFIC MANAGEMENT

Continued from Page 9...

SUMMARY

Impacts of a major construction project extend beyond the freeway being reconstructed to alternative routes and modes in the entire traffic corridor. Therefore, a corridor-wide traffic management plan may be needed. Such a plan has three components: (1) a traffic control plan for the construction, (2) improvements to accommodate traffic diverted to other routes and other modes, and (3) public information programs for nearby residents, businesses, and motorist affected.

Interdependent are the traffic control plan for a project and the plan to improve alternative routes and modes. Data indicate that the most common change in travel patterns during construction is the diversion of traffic to alternative routes. The greater the reduction in freeway capacity, the more traffic will divert to alternative routes and the greater the need for improvements to minimize delay and congestion within the corridor as a whole.

Each construction project is unique, and it has proven difficult to predict how motorists will change their travel patterns in response to a construction project. Traffic management techniques that are effective at one project may not work at another. Consequently, a corridor traffic management plan needs flexibility. Certain techniques, particularly low cost improvements such as signal timing changes, turn prohibitions and parking restrictions on alternate routes have consistently proven to be cost effective. Conversely, the cost effectiveness of other techniques, particularly improvements of alternative modes, has varied depending on location.

A strategy used on several projects reviewed during this research has been to accelerate the implementation of improvements scheduled for alternative routes so that they are in-place before construction begins. Similarly, some more costly planned improvements can be put on hold until conditions during construction are evaluated and the need for action is verified. A final alternative is to implement actions on a temporary basis, and then to reduce or eliminate those actions found to be unnecessary.

More specific guidelines and a corridor analysis methodology are offered in the recently published, *Corridor Traffic Management Guidelines for Major Urban Freeway Reconstruction*, Research Report FHWA/TX-91/118-4F available from the Library: (512) 465-7644 or TexAn 241-7644.

WICHITA FALLS' FIELD TRIAL FOR SLOPE STABILIZATION

Wichita Falls District has experienced repeated slope failures on a section of Loop 370 (Bus. 287), known locally as East Scott Street, near the Burlington Railroad underpass. Starting on February 11, 1991, district maintenance forces cut out the failed material from the two recent slides (Fig. 1). This material was taken by dump truck to a gore area near US 287 and spread out using two maintainers so that the Fibergrid, a type of polypropylene fibrillated fiber with a staple length of about one inch, could be added the next day. Unopened, the fiber is about 1/8 inch wide. Mixing with soil causes filaments of the fiber to spread in a pattern similar to expanded metal. The addition of Fibergrid mesh does not increase the peak strength of the soil; it allows the the soil to maintain its peak strength over a longer strain. In other words, it is supposed to increase the tensile strength of the soil by acting like an instant root mesh system. This is the first field test of it as a slope stabilization material.

FIGURE 1: Excavated slide area.

Initial lab tests of the failed slope material had indicated an average PI of less than 6. Triaxial samples were molded in the district lab from the failed soil with 0 percent, 0.2 percent, 0.4 percent and 0.6 percent by weight. Based on the initial lab reports and their experience with the polypropylene fibers, Synthetic Industries' representatives opted for an application rate of 0.2 percent polypropylene fiber by weight to dry weight of soil. At this application rate, an estimated 120 twenty-pound bags of fiber were needed for the job.

The clay on site appeared to have a significantly higher PI than indicated by the initial lab samples, perhaps in the twelve to eighteen range. The Synthetic Industries personnel were not sure the fiber could be worked into this heavier plastic clay without the aid of additives and a pugmill or rotomill. Also, they expressed concern that the coconut oil used to make the fiber easy to spread would keep the fiber from sticking in the clay and unfolding as it was worked in. This problem did not develop, however. The coconut oil either rubbed off with the repeated working of the soil or was dissolved by the water in the soil. Raw soil control samples were taken on site, as well as field-blended samples for more triaxial testing by the district lab.

The fibers were broadcast by hand over windrows made by the two maintainers (Fig. 2). The maintainers turned the windrows over, and a tractor pulled a small agricultural disk harrow through the material repeatedly. Originally, the blending was projected to take about two hours. In actuality, it took over 5 because of the unexpectedly heavy clay, but the fibers were satisfactorily worked into the clay. 128 bags of the polypropylene fiber were used.

The red clay went though a color change as the fibers became thoroughly mixed. There were two reasons put forth for the change: (l) the fibers contain carbon black as ultraviolet protection and the application rate is high enough for the black fibers make the soil appear darker; (2) the polypropylene tends to wick moisture away, tending to dry the soil and causing the color to change.

As a sort of "quickie" experiment, the Synthetics Industries' engineer spread a gallon ziplock bag full of polypropylene *monofilament* and had the disk harrow run over these white fibers twice. They appeared to work into the clay much more quickly in two passes than the fibrillated fibers did in five or more. The Synthetic Industries representatives hope that monofilament may prove to be as useful or more useful than fibrillated fiber for plastic clays.

The slide sites themselves received slightly different treatment before the field-blended fill was returned. The slide site nearest the railroad overpass had an obvious seepage place. A fifteen foot French drain was installed here. No drain was installed in the slide site that is uptraffic of the railroad overpass. Both sites, however, had keyways stepped into the face of the failures with a Gradall to provide a less slick interface between the undisturbed soil and the fiber-blended material. The maintenance crew blended fill back into the slide area using the Gradall and a bulldozer.

FIG. 2: Fibergrids before mixing.

FIG. 3: Close-up.

As of September 1991, both experimental sites were holding up well – they have already outlasted previous repairs – even though rainfall has been unusually high all summer. In the first three weeks of September, more than 8 inches has fallen. The all time high for that area for the month is 10.5 inches. The grass is notably greener and denser over the Fibergrid-repaired slopes, probably due to several factors such as aeration of the clay and wicking action of the fibers. The healthy vegetation implies a good root system development that will continue to hold the slope.

TECHNICAL COORDINATORS' WORKSHOP

by **Lisa Lukefahr**
Research Engineering Assistant
Division of Transportation Planning

The Research and Development section held two seminars in August for technical coordinators of research studies. Technical coordinators are extremely important to the success of any research. They are the department's experts who make sure that projects stay on target. Mr. Alvin R. Leudecke, P.E., commenced the workshop by welcoming all the attendees and introducing the speakers. The first speaker was Mr. Bobbie F. Templeton, P.E., who presented the R&D Committee's perspective on the role of a TC. Ms. Linda Smith, P.E., gave a brief overview of the department's research program, including an explanation of all parties involved. Mr. Mike Leary, P. E., of the FHWA explained the role of the FHWA and gave a national perspective of research.

At this point, the TCs began working on groups of seven to ten people, with a D-10 team leader leading the discussion. D-10 group leaders were Ms. Lana Ashley, Ms. Lisa Lukefahr, Ms. Sylvia Medina, Ms. Tanya Pavliska, and Ms. Linda Smith, P. E. Each TC was given a notebook with organizational charts, examples, definitions, and other tools. Approximately 80 minutes were spent discussing every aspect of the research program, including all facets of:

- problem statements;
- project agreements;
- project management; and
- implementation.

The group discussions were informal with opportunities to ask questions about specific, real-world problems. This format also provided an occasion for each TC to give input back into the program by making suggestions for improvements. Research personnel plan to respond to these issues.

Workshop attendance for both days combined was 68 people. Fifty-five of these were technical coordinators with HPR projects active in FY92 – a 69 percent attendance rate of active TC's. Many of the remaining 13 attendees were appointed to represent a TC who was unable to attend. An evaluation form was provided to the workshop attendees to rate the effectiveness of the information and of the presentation. The evaluation indicated that 59 percent of the attendees felt they did not have adequate information on their role as a TC prior to the workshop. Only 3 percent (2 people) felt that they still did not have adequate information to carry out their TC duties after the workshop. The workshop notebook and a new *Departmental Informational Exchange,* "How Technical Coordinators Make the Research Program Work (T^2.4-3)," are available through the Library: (512) 465-7644, Tex-An 241-7644.

ACCIDENTS ARE NOT A FACTOR IN SELECTING WORK ZONE TRAFFIC CONTROL

BACKGROUND

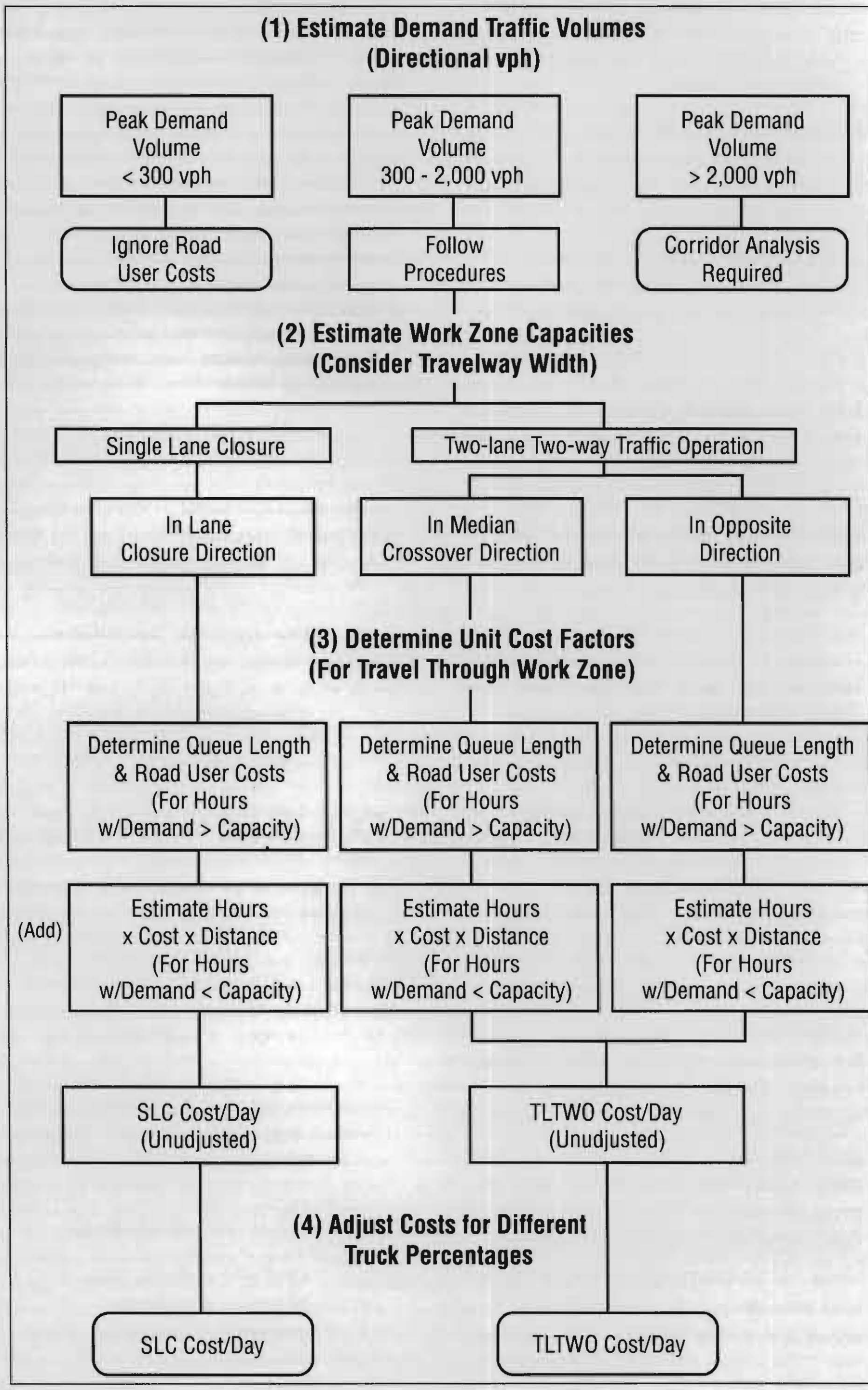
This FHWA research project, *Construction Costs and Safety Impacts of Work Zone Traffic Control Strategies* (FHWA-RD-89-210), was initiated to determine the costs and safety impacts associated with traffic control through work zones on rural, four-lane, divided highways. The research compared construction projects using a single-lane closure (SLC) versus closing one roadway, constructing crossovers, and using the other roadway for two-lane, two-way operations (TLTWO). Data were collected for construction costs and accident experience for 51 projects located in 11 states. Traffic data were collected on 25 projects where traffic delays occurred.

RESULTS

The study found accident rates were not significantly different between the two traffic control strategies. Therefore, the selection of the control strategy is primarily based on the type of construction. If traffic congestion is expected to be a problem, the construction costs and traffic delay should be studied before selecting the control strategy.

ACCIDENT ANALYSIS

The accident rates for each project were determined for "before" construction and "during" construction. The change in accident rates varied among projects with a "during" rate increase of 600 percent to a reduction to 35 percent of the "before" accident rates. It was found, however, that there was no statistical difference in the accident rates for SLC versus TLTWO over the time period covered. There was no significant difference found in total accident rates "before" versus "during" construction for all projects, but the fatal plus injury accidents had a significant increase during construction for both strategies. In an analysis of accident rate change, it was found the SLC projects tend to show more of an increase, and the TLTWO projects more of a decrease in accident rates "during" construction.



STRATEGY SELECTION

Study findings showed that where traffic volumes were between 10,000 and 30,000 vehicles per day and there was no noticeable congestion, the type of traffic control, SLC or TLTWO, was primarily dependent on the type of construction project. Table 1 shows the seven types of construction with the appropriate traffic control strategies.

The flow chart and Table 1 results are not a substitute for the need for sound engineering judgement and the careful consideration of all alternatives in the selection of the most cost-effective control strategy for the given project.

COSTS

A summary was developed of the construction costs per day and cost per mile for each project. There was a wide range in costs even within each type of construction due to the nature of work included within each project. Cost of one-way median crossovers for TLTWO ranged from $7,111 to $70,605. It was not possible to develop unit prices for traffic control because of the diversity of bidding practices.

TRAFFIC STUDIES

Lane traffic capacities were measured where delay occurred in work zones. The research bindings suggest the capacity of a lane for SLC is about 1,800 vehicles per hour (vph). However, there are circumstances such as work activities that can significantly reduce the maximum traffic flow to as low as 950 vph. The maximum flows for TLTWO are approximately 1,550 vph for the crossover lane about 1,800 vph in the opposite lane. These values may also be reduced with geometric restrictions.

TABLE 1: Traffic contrtol by project type.

PROJECT TYPE	SUGGESTED CONTROL STRATEGY
Concrete Pavement Recycling /Overlay	TLTWO
Concrete Pavement Restoration	SLC
Asphalt Concrete Pavement Overlay	SLC
Bridge Deck Overlay	SLC
Bridge Deck Replacement/Widening	TLTWO
Reconstruction	TLTWO
New/Interchange Construction	*

SLC=Single Lane Closure
TLTWO= Two-Lane,Two-Way Operations
**Perform Complete Cost Analysis*

ANALYSIS PROCEDURE

The traffic analysis procedure involves four basic items: normal demand volumes, estimated capacity through work zone, length of work zone, and the percentage of trucks. The hourly demand volumes are compared to the capacities, and the vehicle delay quantities are determined. Computer models such as QUEWZ3 are available to assist in this calculation. Road user costs are then computed for the uncongested condition for the length of the work zone and for the estimated delays during congestion. These costs are adjusted for the proportion of trucks in the traffic stream.

*From FHWA **Construction Costs and Safety Impacts of Work Zone Traffic Control Strategies**. Technical Summary FHWA-RD-89-210 (December 1989).*

BIOREMEDIATION OF ORGANIC CONTAMINANTS

Sometimes the Georgia DOT must purchase property for roadway project development even though the project is contaminated, and then the DOT is responsible for cleaning up the site. Typically, the contaminant is a fuel or other organic material.

Bioremediation is a clean-up method involving the use of microorganisms that consume organic material. A small scale bioremediation experiment [Georgia DOT Research Project 9007] is being conducted in which a container (3 feet high by 12 feet diameter) of typical sand clay soil was contaminated with one percent by weight of diesel fuel. A well was constructed at one end of the container and a limestone infiltration bed was constructed at the other end. Water is pumped out of the well into a drum where oxygen and nutrients are added (Fig. 1). The water is then pumped to the infiltration bed. This water movement is designed to simulate natural groundwater action.

The pH and dissolved oxygen level in the well water is measured daily. According to literature, microbes degrade organic material optimally under aerobic conditions and neutral pH. An aeration rod was put in the drum and hydrogen peroxide was added periodically to maintain aerobic conditions. Limestone and potassium hydroxide were added periodically to raise the pH.

Soil samples were removed from the container and analyzed for microbial activity by CO_2 measurement and plate counts. After addition of fertilizer to the soil samples, the CO_2 produced by the microbes increased from 2 to 6 times. The plate counts also increased. Based on this increase in microbial activity, fertilizer was added to the test site.

A soil sample was analyzed for total petroleum hydrocarbons one month after the addition of diesel fuel. The hydrocarbon level was 8120 ppm.

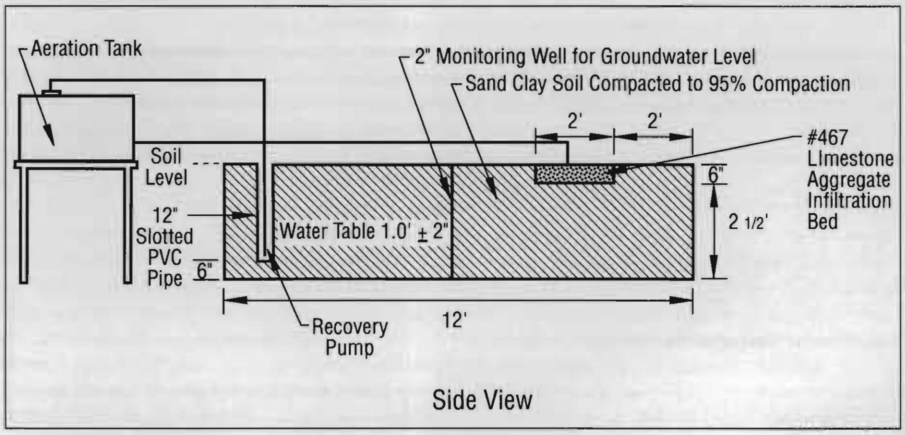


FIGURE 1: Schematic of Georgia DOT's bioremediation container.

(Original level was 10,000 ppm.) Fertilizer was added two weeks later. Two months after the petroleum hydrocarbon level was 600 ppm. Since the beginning of the study there has been a reduction of hydrocarbons in the soil of 94 percent. The report will be available in December 1991.

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