Vol. 1, Issue 3. 1985.

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TECHNICAL QUARTERLY

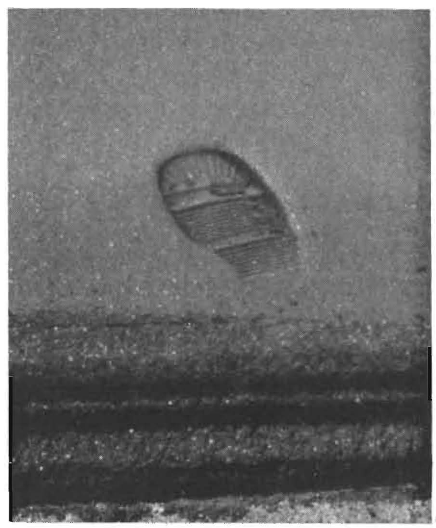
AN EXCHANGE OF IDEAS
Editors:
Richard L. Tyler Kathleen M. Jones

RECOGNITION OF TENDER MIXTURES

The following article is an excerpt from the NCHRP Report 268, **INFLUENCE OF TEMPERATURE SUSCEPTIBILITY ON PAVEMENT CONSTRUCTION AND PERFORMANCE** by J.W. Button, D.N. Little, and B.M. Gallaway of Texas Transportation Institute at A&M University and J.A. Epps of University of Nevada. This report does not constitute a standard, specification or regulation.

During the course of this research [NCHRP 268], it has become apparent that there are two distinctly different types of paving mixtures that are commonly referred to as "tender." One exhibits tenderness *during* construction, which is characterized by being easily overstressed during compaction (i.e., shoving under steel wheel rollers or resisting compaction at normal temperatures). The other mixture is slow setting *after* construction, which is characterized by plastic instability or scuffing during the first few weeks after construction, particularly during periods of hot weather. Frequently, both of these characteristics will be exhibited by the same material.

Tenderness during construction is primarily an aggregate problem (caused by smooth, rounded aggregate, a high percentage of sand-size particles, and/or a low percentage of filler-size particles) which is aggravated by a highly temperature-susceptible asphalt. This mixture must be allowed to cool until the asphalt viscosity increases to a point where sufficient internal friction will prohibit overstressing by the steel wheels of the breakdown roller. Tenderness after construction is an asphalt-cement-related problem (caused by a slow- setting asphalt), which will manifest itself



A mix which was tender during construction.

only if the aggregate type and/or gradation is such that a critical paving mixture is produced. The problem usually disappears within a few weeks.

Tenderness during construction appears to be related to asphalt temperature susceptibility; whereas, tenderness after construction appears to be related to chemical properties of the asphalt cement such as asphaltene content or degree of peptization. A slow-setting mixture will usually show some degree of tenderness

INSIDE...

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Technology Transfer Subsection,
P.O. Box 5051, Austin, TX 78763-5051

during construction, but a mixture that is tender during construction is not necessarily slow setting. A slow-setting mixture is presently more difficult to accommodate than the mixture that is only tender during construction.

Ideally, the field engineer would like to recognize a mixture that will be difficult to compact and/or be slow setting, prior to placing in the field. Two possible approaches are proposed to assist the field engineer in the recognition of tender mixes prior to placement. The first approach uses the collective field experience of engineers to identify those material, mixture, and construction factors that contribute to tender mixes. The second approach uses laboratory tests and associated criteria for identification of mixtures that are likely to be tender during placement. These approaches are discussed as follows.

MATERIAL, MIXTURE, AND CONSTRUCTION FACTORS

Table 1 contains a rating scale to identify the material, mixture, and construction factors that contribute to tender mixes. Important aggregate factors are (1) shape and surface texture of both the coarse and fine aggregate, (2) quantity of sand-size materials, (3) filler or minus No. 200 sieve fraction, and (4) maximum size of aggregate in the mixture. Recognized asphalt properties of importance are (1) asphalt content, (2) asphalt consistency (penetration and/or viscosity), (3) temperature susceptibility, (4) hardening in thin film oven tests, (5) asphaltene content, (6) setting characteristics, and (7) use of asphalt additives such as liquid antistrip agents.

Construction operations also have an impact on the development of tender mixtures. Important factors are (1) mixing temperature, (2) compaction temperature, (3) amount of asphalt hardening during construction, (4) type of air quality control equipment, and (5) moisture content of mix during compaction.

Table 1. Rating scale to identify tender mixtures.

Material or Mixture Variable	INCREASING TENDERNESS →									
	1	2	3	4	5	6	7	8	9	10
Aggregate										
Shape	Angular			Subangular			Subrounded			Rounded
Texture	Very Rough			Rough			Smooth			Polished
Maximum Size	>3/4-inch		<5/8-inch			<1/2-inch		<3/8-inch		<1/4-inch
−#30 to +#100*	Suitable				Excessive					Large Excess
−#200	>6%		5%		4%			3%		<2%
Asphalt Cement										
Content	Low				Optimum				High	
Viscosity	High				Medium				Low	
Penetration	Low				Medium				High	
Hardening Index	High				Medium				Low	
Temp. Susceptibility	Low				Medium				High	
Setting Characteristic	Fast				Medium				Slow	
Asphaltene Content	>20%				10 to 20%				<10%	
Mixture										
Softening Additives	None				Some				Much	
Moisture Content	<0.5%				1 to 2%				>2.5%	
Construction										
Rolling Temperature	Low				Medium				High	
C-value**	>50				30 - 50				>30	
Ambient Temperature	<70		80				90		>100	

*Suitable quantity depends upon design gradation. Rounded sand-size particles can produce a critical mixture.

**Lund and Wilson ["Evaluation of Asphalt Aging in Hot Mix Plants," Materials and Research Section, Oregon State Highway Division, Oregon Department of Transportation, Salem, Oregon (Aug.1983)] developed a formula to determine the difference in actual change in asphalt viscosity during mixing and placement and that predicted by the rolling thin film oven test (RTFOT):

$$C = \left[\frac{R - A}{B - A}\right](100\%)$$

where:

A = absolute viscosity of the original asphalt at 140 F;
B = absolute viscosity of the RTFOT residue at 140 F; and
R = absolute viscosity of the asphalt recovered from mixture at 140 F.

When C equals 100 percent, RTFOT accurately predicts the actual viscosity increase that occurs in the field. When C is less than 100 percent, less hardening occurred in the field than predicted by RFTOT [sic] and vice versa. The authors [Lund and Wilson] stated that based on field observations of paving projects, no tenderness problems were experienced when C values ranged from 30 to 50 percent, and tenderness problems were always experienced when C values were less than 30 percent.

As discussed previously, all these factors can influence the development of a tender mixture; however, some are more important than others. For example, mixtures that contain angular, rough surface textured aggregates in dense gradations and with proper filler contents rarely exhibit tenderness problems regardless of asphalt properties or construction operations. Mixtures containing subrounded aggregates with smooth surface textures, relatively high sand contents (gap-graded), and low filler contents will often be tender particularly when low viscosity asphalts are used. When the anticipated hot plant hardening of the asphalt is not achieved and when asphalts with low asphaltenes are used, the problem is amplified.

Ideally, a mathematical equation would be developed with the earlier listed material, mixture and construction variables. Each of these variables would be properly "weighted" to indicate its relative influence on tender mix development. A sufficiently large data base was not available to this project such that a reliable equation could be developed. A large and continuous research effort would be needed to develop such an equation. In the interim, the field engineer will have to assign the proper importance of each identified factor (Table 1) based on experience.

LABORATORY TESTS

This research project has investigated a number of laboratory tests to possibly identify tender mixtures. These tests include:

1. Resilient modulus of mixtures.
2. Indirect tensile strength of mixtures.
3. Marshall stability.
4. Hveem stability.
5. Asphalt temperature susceptibility (as defined by several parameters).
6. Asphalt consistency versus time relationship (viscosity and penetration).
7. Asphaltene content.
8. Asphaltene settling test.
9. Gel permeation chromatography (GPC).

Results from the testing programs performed on (1) selected asphalts, (2) mixtures obtained from field projects, and (3) laboratory-prepared mixtures indicate that the resilient modulus and indirect tensile tests performed on mixtures and the asphaltene content of the asphalt cement are the most meaningful tests for identifying potential tender mixtures in the laboratory.

Criteria for each of these tests as developed from project results are presented in Table 2. From the criteria of Table 1, it is suggested that the indirect tensile test and/or the resilient modulus test be performed on laboratory-mixed and laboratory-compacted specimens and the listed criteria be used. The criteria given in Table 1 have been developed for the following specific conditions:

1. Gyratory compaction (modified or standard).
2. Air void content at standard or higher values.
3. Test temperature of 104 or 77 F.
4. Loading rate of 2 in. per minute for indirect tensile test.
5. Load duration of 0.1 sec for resilient modulus test.
6. Sample age of 90 min or 24 hours.

If an agency does not have the equipment available to duplicate these conditions, a laboratory testing program should be initiated to define new criteria for their specific capabilities.

Table 2. Criteria for tough and tender mixes.

Type of Samples Tested	Method of Test	Tough Mix	Tender Mix
Modified Compaction of Laboratory Mixtures (~8% air voids)	M_R* @ 104 °F @ 24 hrs	>7,000 psi	<6,000 psi
	T.S.** @ 104 °F @ 24 hrs	>5 psi	<5 psi
Modified Compaction of Field Mixtures (~8-10% air voids)	M_R @ 104 °F @ 24 hrs	>30,000 psi	<20,000 psi
	T.S. @ 104 °F @ 24 hrs	>20 psi	<15 psi
Standard Gyratory Compaction of Remolded Field Cores	M_R @ 104 °F @ 90 min	>130,000 psi	<125,000 psi
	T.S. @ 77 °F @ 90 min	>165 psi	<140 psi

*M_R = Resilient Modulus
**T.S. = Tensile Strength

REQUEST

In our efforts to upgrade the technical library and improve our information searching abilities, we have recently purchased all the volumes of ***Proceedings of the AAPT Technical Sessions*** that are currently in print. Unfortunately, the volumes covering 1940 to 1960 are out of print. We would greatly appreciate the loan or donation of these volumes to the library. *Please contact the editors of **Technical Quarterly (512) 465-7947; TEX-AN 886-7947.***

OOPS!

My apologies to Dan Harrison, who is Maintenance Supervisor of Rocksprings and not the driver of the butane-powered truck as was stated on page 8 of TQ1-2. KMJ

PUBLICATIONS OF INTEREST

PAVING WITH ASPHALT CEMENTS PRODUCED IN THE 1980'S, J.A. Epps, J.W. Button, B.M.Gallaway, NCHRP Report 269, Washington D.C., Dec. 1983, 28pp.

A REPORT ON HIGHWAY SAFETY DEVICES FOR THE TEXAS LEGISLATURE, 69th SESSION, prepared by Texas Transportation Institute for the State Department of Highways and Public Transportation, Jan. 1985, 41pp.

OPERATIONAL AND PERFORMANCE CHARACTERISTICS OF DRUM-MIX PLANTS, H.L.Von Quintus, T.W. Kennedy, J.A. Epps, FHWA-TS-84-212, Washington D.C., Oct. 1984, 198pp.

SOIL REINFORCEMENT AND MOISTURE EFFECTS ON SLOPE STABILITY, Transportation Research Record 965, TRB, Washington, D.C., 1984, 66pp.

JOB SAFETY ANALYSIS

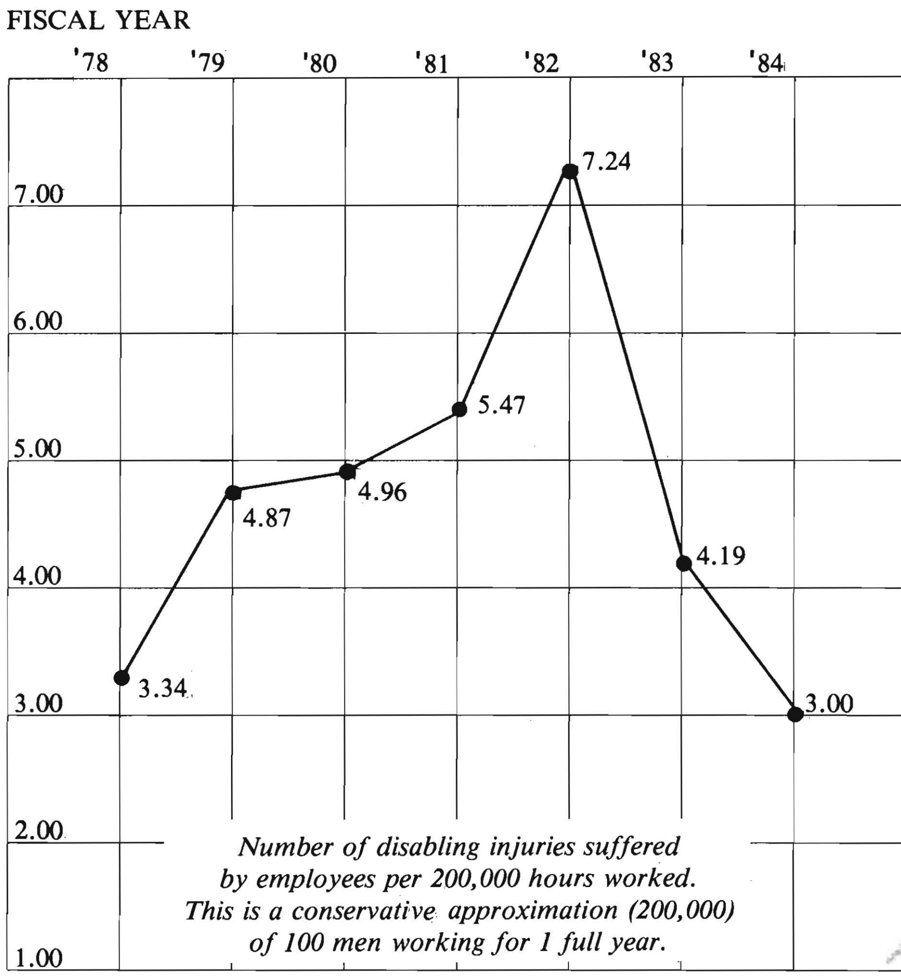
On June 25, 1984, District 12 reported that the Accident Prevention Management program instituted in January 1984 had already shown good results. Lost-time injuries had decreased 40 percent and injury severity had decreased 44 percent. The disabling injury frequency rate declined 29 percent from fiscal year 1983 to fiscal year 1984. The resulting rate of 3.00 is the lowest frequency rate for District 12 since 1977. After more than a year of implementation, the APM program is working well and is well supported by District 12 personnel.

Originally, the APM program was presented to District 12 first-line supervisors. Once the supervisors saw the benefits to be gained, they requested that the APM program be presented to their key personnel. Eventually many engineering aides and maintenance crew leaders played an important role in further developing the workshop portion of the APM classes.

The Accident Prevention Management program hinges on Job Safety Analysis (JSA), training, inspections for hazardous physical conditions and thorough accident investigation. JSA is a method used to review a job by breaking it down into steps, identifying hazards inherent to each step, and developing safe procedures to follow in performing those steps. Group discussion by six to ten employees who are experienced in performing the job to be analyzed is the best method for completing a JSA outline. Not only does the completed JSA provide an effective tool for training new employees to be safe and efficient on a particular job, but also it serves as a review of the job's hazards and safe work procedures to the experienced personnel who participated in the group discussion.

The questions asked on the JSA worksheet [Form 1611] are these:

DISABLING INJURY FREQUENCY RATE: DISTRICT 12



What are the
BASIC JOB STEPS ?

Break the job down into basic steps that tell you what is done first, what is done next, and so on. You can do this by (1) observing the job, (2) discussing it with the operator, (3) drawing on your knowledge of the job or (4) a combination of all three. Record the job steps in their normal order of occurrence. Describe what is done, not the details of how it is done. Usually three or four words are sufficient to describe each job step. For example: The job of "replacing a light bulb" may break down into basic steps as follows:

1. Bring and set up ladder
2. Ascend ladder
3. Remove light globe
4. Replace light bulb
5. Replace light globe
6. Descend ladder
7. Remove and store ladder

Make the job step neither too fine nor too broad. They should sound natural. Most jobs can be broken down into 12 or fewer steps. Sometimes the job step may be a major safety precaution, e.g., "Check for gas before entry."

What are the
POTENTIAL ACCIDENTS ?

Ask yourself for each job step

Continued on page 7...

DISTRICT SPECIALS

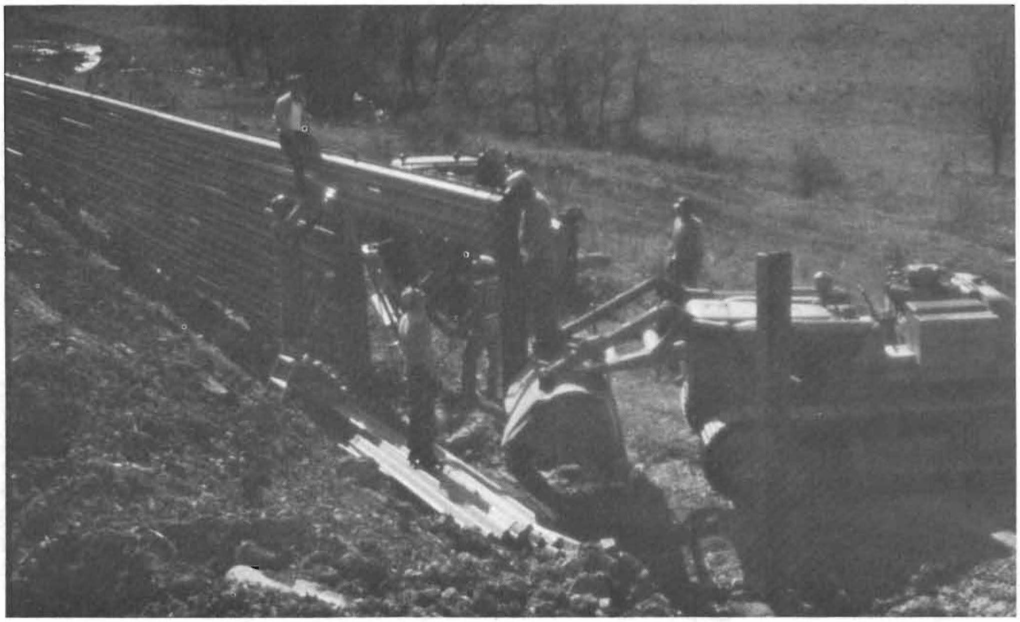
Part of Technology Transfer's job is to track down, catalogue and make available innovations and implementable ideas from all sorts of sources that make people's work faster, safer or easier. In District shops and Residencies all over Texas, there are any number of unsung creative talents who are sources of these innovations. A lot of you have come up with some very ingenious solutions to commonplace problems or have fabricated tools and equipment that save money, time and effort; but you think, "It's no big deal, anyone would have thought of that," or "Everyone knows that." Please don't assume that "everybody knows that" about something you do in your District. Not everyone everywhere is as inventive as you are. There's always somebody who hasn't heard and might like or need to know.

TECHNICAL QUARTERLY'S staff is actively collecting innovations and ideas from the Districts. These ideas and innovations are being logged on to diskette and can be sorted by District, by name of contributor and by subject to form a catalogue. The catalogue will be available to anyone who requests it (as soon as we have something of sufficient size compiled to be called a catalogue). That's where you come in: call us; write to us; buttonhole us at maintenance and research conferences; talk to us when we're in your area filming or researching a story. Also, it doesn't matter if two or more Districts present similar techniques or ideas, since we want to know what's happening where, even identical items will be logged. The more responses we get, the better off we all are in terms of spreading ideas around.

If you're not sure what types of ideas or innovations we might be interested in, here are four from among the many we collected at the Maintenance Conference in Tyler (District 10) on 9-10 April 1985 as they are entered in brief form on diskette:

02 Davis, Bill E.
(817) 292-6510
837-6221

Old steel guard rails are salvaged and straightened a bit to be used with I beam or posts placed vertically in five foot intervals as pile sheeting to strengthen a slide area.



10 Graff, Joe S.
(214) 593-0111
836-2209

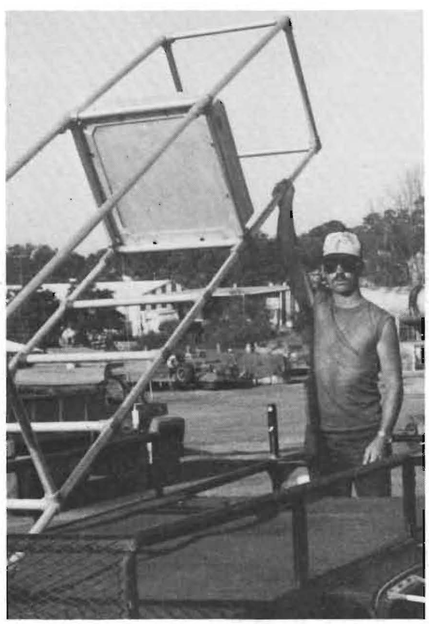
Slide shows and video tapes have proven very useful in developing good working relationships with various maintenance contractors. Pre-bid conferences are held where video tapes, films or slides of the type of job (mowing, bridge joint cleaning, etc.) are shown to potential contractors so they will better understand what DHT expects of them. Bidding procedures are also explained for the benefit of contractors who have not worked with DHT before. Approximately eight such pre-bid conferences have been held in the last three years.

09 Grady, James
(817) 772-3150

To avoid blocking lane traffic when reloading from an asphalt tanker, Mr. Grady modified a hydro-static Roscoe 1350 gallon asphalt distributor to be front-end loading, rather than side loading. He did this by attaching a 3-inch pipe to original side loading pipe and running the 3-inch pipe around to the front. The pipe is fitted with quick couplings. There is an air valve at the front of the pipe to cut the flow of asphalt. The modification was made to the 13-year old distributor over a year ago and has been satisfactory.

19 Thompson, Charles K.
(214) 843-2527

Where bucket trucks are in short supply, signals and tall signs may be more safely serviced by the use of a "deer stand" cage bolted to the cab of the 1½-ton truck. The stand, made of lightweight, tubular aluminum and expanded metal mesh, swivels on two lag bolts and is pinned in place by two more when raised. It is light enough to be handled by one person. Nine of these cages are in service on District 19's sign trucks. Billy Nash is credited with having built the prototype.



Any one of the thumbnail-sketched innovations or techniques could be expanded into a full-scale article similar to the article in TQ 1-2 on culvert repair, if there is enough interest.

JOB SAFETY ANALYSIS *Continued*

what accidents could occur to the person doing the job step. Get your answers by either (1) observing the job, (2) discussing it with others, (3) recalling past accidents or (4) a combination of all three. Ask: Can he be struck by or contacted by anything? Can he strike against or contact anything? Can he be caught in, on or between anything? Can he fall? Can he strain or overexert himself? Can he be exposed to gas, fumes, radiation, etc?

Record potential accidents by combining one of the accident type abbreviations below with the agent of contact. For example, "struck by cranehook" is recorded "SB-crane hook." Number each potential accident.

SB = Struck by
(CB) = Contacted by
SA = Struck against
CW = Contact with
CI = Caught in
CO = Caught on
CB = Caught between
F = Fall
SO = Strain/overexertion
E = Exposure

If you prefer, explain hazards and potential accidents more fully. Draw a line to indicate where the entries for one job step end and the next begin.

Observing a job to analyze it for potential hazards.

What is the
SAFE JOB PROCEDURE ?

For each potential accident, ask yourself what should the person do or not do to avoid the accident. Get your answers by either (1) observing the job for leads, (2) discussing the job with others who are experienced therein, (3) drawing on your own experience or (4) a combination of all three.

Describe specific precautions in concrete detail. Give each recommended precaution the same number as was given the potential accident (center column) to which it applies. Avoid generalities like "Be alert," "Be careful," and "Take caution." Use simple do or don't statements, e.g., "Lock out main power switch." "Stand clear of lift before signaling," or "Check wrench grip before exerting full force." If necessary, explain how as well as what to do. Amount of detail is a matter of judgment.

Also, question the basic job method. Is there an entirely different way to do the job that is better and safe? If a repair or service job, can anything be done to increase the life of the job?

Try to develop some cost reduction ideas. Question the material, e.g. better materials, less costly materials, easier to work materials? Question the equipment, e.g., more efficient tools, power tools, tools less subject to damage? Question personnel required, e.g., too many, too few, different type personnel? If it is a repetitive maintenance repair job, can anything be done to reduce the frequency with which the job has to be done?

Along with JSA and initial training, inspections for hazardous physical conditions are an essential part of the APM program. These inspections should occur on a scheduled basis, usually monthly, to insure that re-occurring hazards are kept under control. These inspec-

The cause of an accident must be determined.

tions are excellent opportunities to further involve selected employees in the overall administration of the program.

Accident investigation is the other major part of the APM program. The purpose of the investigation is not to lay blame, but to find out what happened. The actual cause of today's accident is the potential cause of tomorrow's accident. If the actual cause of an accident is not determined, there is little way to prevent the same type of accident from happening again. Division-20 feels that it is important that, if an employee is injured in an accident, the employee's supervisor should perform the accident investigation to reinforce the idea that accidents will not be overlooked. After accident investigations are completed using Form 1598, the appropriate JSA should be reviewed to make sure it points out the accident-causing hazard by its self and has detailed procedures to follow to avoid the hazard.

The Accident Prevention Management program can be extremely effective in the reduction in numbers and severity of accidents and injuries, but only to the degree that it is wholeheartedly carried out, particularly by the senior ranking management. The Job Safety Analysis Worksheet (Form 1611) and the Accident Investigation Report (Form 1598) are now being stocked at the warehouses. *If further information is desired, contact Bill England, Division-20, SDHPT, Camp Hubbard, P.O.Box 5055, Austin, TX 78763-5055, phone 465-7590; TEX-AN 886-7590.*

REQUESTS FOR INFORMATION

One of the many topics discussed at the Area III Research Committee meeting in Houston on 16-17 April 1985, was the problem of earth slope failures (Studies 3-8-85-435 and 3-8-85-436). Many Districts are altogether too well aware of what a significant problem slope failure can be. Dr. Stephen G. Wright of Center for Transportation Research has done extensive research into slope failure for a number of years, on Project 435, 436 and their predecessors. At the end of his lecture at Area III, Dr. Wright pointed out that more information on actual slides was needed to provide a good data base for accurate prediction of slide-prone slopes. As it stands now, there are a number of unanswered questions that cause inconsistencies between the hypothetical prediction of slide-prone slopes and the actuality of earth slope failures. The more accurate the ability to predict what types of soils will be prone to slide under what type of conditions on what would otherwise be an acceptable slope gradient, the better future designs will be, and the less time Maintenance will have to spend repairing failed slopes.

To help gather the information, he has prepared a ***GUIDE FOR REPORTING OF EARTH SLOPE FAILURES.*** This guide is for use in collecting information from slides (slope failures) in embankments, excavated ("cut") slopes and natural slopes; the guide is not intended to cover failures of embankments or excavated slopes which involve a significant portion of the foundation beneath the level of the toe of the slope. The information collected and covered by this guide can be used (1) as a data base for future design, and (2) to back-calculate shear strengths. The guide is presented in two parts. The first part consists of several pages of general instruction; the second part consists of a one-page *Documentation Report,* which is used to summarize the data for each individual slide. District participation would be greatly appreciated.

The guide, with its easily filled-out earth slide documentation form, is available from:

Dr. S.G. Wright, Center for Transportation Research, University of Texas, Austin, TX 78712, (512) 471-4929; TEX-AN 821-4929.

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District 17's Floyd Siptak would like to know if there are any dump trucks around with built-in interior compartments in the cab for the storage of various items such as lunch boxes, boots and flags. If these items are stored in outer toolboxes, they are difficult to keep clean, especially during pothole patching operations; if they are left loose inside the cab, they can be a safety hazard in the event of an accident. Of course, eight inch PVC pipe cut to flag length and stored behind the seat solves the problem for the flags, but not the boots or lunch boxes.

Anyone who has a workable cab modification or knowledge of factory-made equipment that would provide a safe, clean place for the crew's gear, please contact the editors of **TQ** *or Floyd Siptak, Maintenance Construction Supervisor, P.O.Box 832, Navasota, TX 77868, (409) 825-3446.*

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REQUESTS FOR INFORMATION

Practical "How To" books, based on Texas' experience, dealing with widespread asphalt hot-mix problems will be the final result of three recently approved Research Projects. The Projects are being done at the Center for Transportation Research. The well known Dr. Thomas W. Kennedy is supervising the three projects which are numbered 3-9-85-366, 3-9-85-441, and 3-9-86-468.

Project 366, ***Segregation in Asphalt Mixtures Produced in Drum-Mix Plants***, is a field study. Project personnel will conduct on-site investigations, in cooperation with the Districts and D-9, of jobs with segregation problems. The findings and recommendations for each field investigation will be summarized and sent to the Districts as a brief technical memorandum. Based on the results of the investigations, a report suited for field use and related to the proper procedures and equipment required for the satisfactory operation of drum mixers will be prepared with emphasis on segregation. *All Districts are encouraged to notify Dr. T.W. Kennedy, Center for Transportation Research, University of Texas, Austin, TX 78712, (512) 471-4325; TEX-AN 821-4325 or Paul E. Krugler, Supervising Bituminous Engineer, D-9, SDHPT, Austin, TX 78763, (512) 465-7603; TEX-AN 886-7603.*

Project 441, ***Field Evaluations of Anti-Stripping Additives***, needs to have 10 experimental project sites for five years. Each site will have one anti-stripping agent and one control section per job. The test and control sections are to be bid into the contract to avoid problems. An attempt will be made to include different aggregates and asphalts in various traffic and climatic regions of the state. Jobs using rhyolite or lightweight aggregate this summer will be of particular interest. CTR will monitor the test and control sections to see if the predictions match the long term results for the anti-stripping agents. This field information will foster improvements in test methods, the establishment of realistic specification values, and the possible need for additional tests. All information will be evaluated and distributed in a series of reports related to testing and effectiveness of various treatments. *Districts interested in participating, please contact Dr. T.W. Kennedy, Center for Transportation Research, University of Texas, Austin, TX 78712, (512) 471-4325; TEX-AN 821-4325 or Donald L. O'Conner, Materials and Tests Chemical Engineer, D-9, SDHPT, Austin TX 78763, (512) 465-7352; TEX-AN 886-7352.*

Project personnel for 468, ***Field Evaluation to Obtain Density in Asphalt Mixtures***, need to examine hot-mix jobs where achieving density has been a problem. Dr. Kennedy and his team will work with the various Districts and contractors of the jobs to determine and classify the problems and suggest solutions. The data gathered will help establish field and mix design techniques which will allow satisfactory density to be achieved. A field manual will be the end result. *Districts wishing to participate, please contact Dr. T.W. Kennedy, Center for Transportation Research, University of Texas, Austin, TX 78712, (512) 471-4325; TEX-AN 821-4325 or Paul E. Krugler, Supervising Bituminous Engineer, D-9, SDHPT, Austin, TX 78763, (512) 465-7603; TEX-AN 886-7603.*

REFINING EQUIPMENT DEVELOPMENT

Distillation, the key process available to the refiners of crude oil, had its origin in the distillation of alcoholic spirits, using a batch operated retort or still. Figure 1, dated 1550, indicates its use was carried over to processing wood tars or crude petroleum (76). The early (1860/65) USA crude oil refinery units were an adaptation of this, using a cast iron vertical retort, with a condenser called a "worm"... These units were copied directly from the equipment previously used in producing coal oil, through the destructive distillation of coal and other bitumens as described by Gesner in his 1865 Treatise on the subject (7). Four such retorts of 25 to 30 barrel capacity, installed in what was considered a well designed "lay out," could refine approximately 50 bbl. of crude per day. The cost of the complete plant is given as $ 11, 230.00.

Fig. 1. Batch Distillation of Crude and Bitumens, 1550 (Courtesy E.J. Brill).

7. William Gesner, *A Practical Treatise on Coal, Petroleum and Other Distilled Oils.* Bailliere Bros., 1865; Reprint, Augustus M. Kelley, 1968.

76. R.J. Forbes, *Bitumen and Petroleum in Antiquity. Netherlands: E.J. Brill, 1936, p.33.*

L.C. Krchma, D.W. Gagle, "A U.S.A. History of Asphalt Refined from Crude Oil and its Distribution," ***Proceedings of the Association of Asphalt Paving Technologists Historical Session;*** *43A (1974):25.*

COMMUTING IN THE 1980's

Through the Cooperative Research Program with the Texas DHT, the Texas Transportation Institute has been involved in extensive evaluations of high occupancy vehicle facilities throughout Texas. Park-and-Ride studies were first performed in the Dallas area in 1979 and extended to the Houston and San Antonio Metropolitan areas in 1980. In 1982, TTI undertook investigations of Park-and-Go and Park-and-Pool facilities in and around the Dallas/Fort Worth region. This study, entitled, ***Park-and-Pool in Rural, Nonurbanized Areas*** by R.L. Peterson and R. Sato, presents the result of an investigation of Park-and-Pool activity in rural ares throughout Texas and compares the results with prior research findings. The following chart is a summary of estimated annual benefits per Park-and-Pool user by lot location as found in this study:

Measure of Benefit:	Benefits per Commuter Using a:		
	Rural Lot	Urban Fringe Lot	Urban Lot
Annual VMT Reduction			
Low estimate (mean)	9,341 miles	8,531 miles	5,896 miles
High Estimate (mean)	12,636 miles	11,537 miles	8,162 miles
Annual Fuel Savings			
Low Estimate (mean)	588 gallons	587 gallons	371 gallons
Low Estimate (mean)	795 gallons	726 gallons	514 gallons

TECHNICAL QUARTERLY: AN EXCHANGE OF IDEAS

Articles, techniques or ideas about any facet of highways or public transportation are welcomed. If you have a new way to handle an old problem, a helpful hint for making better use of a standard procedure or product or new application of a common item, send it to us. It doesn't have to be an earthshaker to be useful and appreciated.

If you have an idea to share, a comment to make or materials to request, use the tear sheet in this issue or call Kathleen Jones at (512) 465-7947 or TEX-AN 886-7947.

TECHNICAL QUARTERLY
State Department of Highways and Public Transportation, Transportation Planning Div. (D-10R), Technology Transfer, Bldg.1/Flr.5, P.O. Box 5051, Austin, TX 78763-5051

Name ______________________

Dist/Div ______________________

Address ______________________

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Phone (   ) ______________

☐ Requesting information on ____

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☐ Ideas or comments __________

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(We'll call you to get the details).

☐ Question ______________

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