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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

DISTRICT TWENTY'S SIGN MOUNTING BRACKET

Paul Broussard, Signal Maintenance Technician with the Beaumont (District 20) Signal Shop, has devised a sign mounting bracket assembly which is a marked improvement over previous span wire mountings.

Use of the standard sign mounting assembly allowed unrestricted side movement of the sign under windy conditions. This unrestricted movement resulted in frequent collisions between the sign and the adjacent signal head. Over a period of time, damage from the sign and signal collisions required maintenance crews to replace signs and signal visors, often long before the parts were scheduled for replacement.

Mr. Broussard's bracket design overcomes this problem by preventing the side-to-side movement of the sign. In addition, the bracket can be adjusted for mounting signs on a skewed or diagonal span wire application. The bracket parts consist of a standard 3-bolt 5/16-inch cable clamp, a 2½-inch section of 2½-inch aluminum angle, and a 7/16 inch by 1 inch cadmium- or zinc-plated bolt. These are all standard, off-the-shelf inventory items.

The cable clamp is secured to the span wire. The sign is fastened to the inside of the angle bracket on one ex-

FIG. 1: Front view, new bracket assembly (foreground) compared to old.

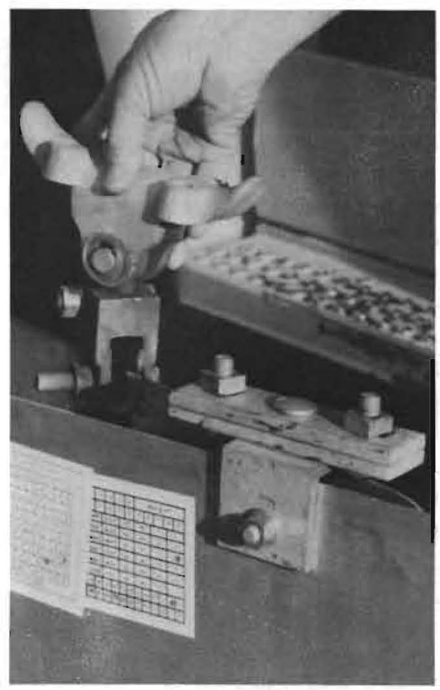

FIG. 2: Back view, new bracket assembly (foreground) compared to old.

INSIDE

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tension, then is mounted by attaching the outside of the other extension to the center of the cable clamp.

Since installation of these brackets Districtwide, the Signal Shop has not had further problems caused by unrestricted side-to-side sign motion. In fact, the *lack* of maintenance now needed for these signs and signal heads has been most noticeable. Another unexpected benefit is that the bracket assembly has not shown the staining problem on the sign face that is common with the previously used type of bracket.

If there are any questions or if more information is needed, please contact Paul Broussard at TEX-AN 855-3275 or (409) 892-7311, Ext. 275.

TIPS FOR CONSOLIDATING PORTLAND CONCRETE

by Kathleen M. Jones
Technology Transfer, D-10R

INTRODUCTION

What factor has a greater effect on concrete compressive strength than any other? Most engineers would say water/cement ratio...as water/cement ratio increases, strength decreases. Duff Abrams showed this in 1919, and Abrams' law is the principle behind most concreting proportioning methods used today. But Abrams ran his tests on fully consolidated concrete. Unless concrete is properly consolidated, voids reduce strength regardless of the water/cement ratio. And, as shown in Figure 1, the effect is significant.

Right after it's placed, concrete contains as much as 20 percent entrapped air. The amount varies with mix type and slump, form size and shape, the amount of reinforcing steel, and the concrete placement method. At a constant water/cement ratio, each percent of air decreases compressive strength by about 3 percent to 5 percent. Consolidation, usually by vibration, increases concrete strength by driving out entrapped air. It also improves bond strength and decreases concrete permeability [4, p563].

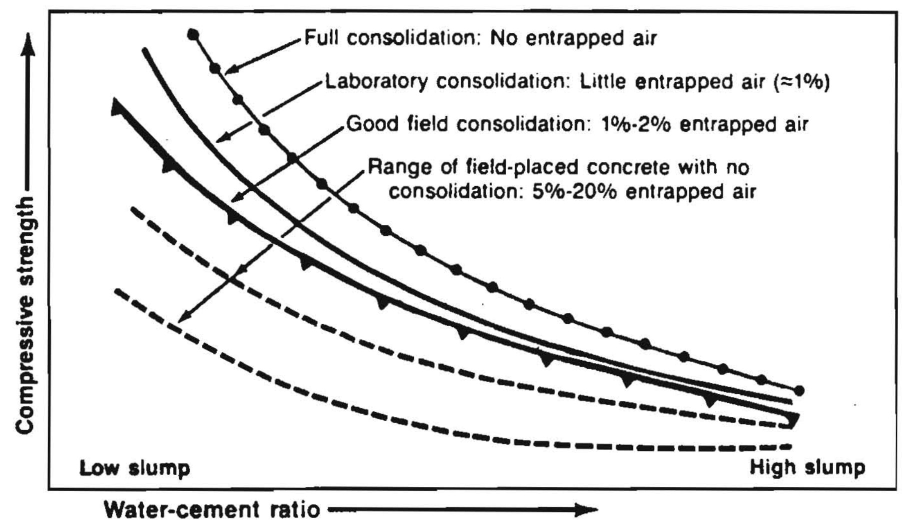

FIGURE 1: Effect of consolidation on compressive strength.

The purpose of this article is to give project managers and inspectors an overview of proper concrete consolidation practice within the Texas Department of Highways and Public Transportation (SDHPT).

Vibration is commonly used to consolidate fresh concrete. It may be applied either internally to the fresh concrete by any of several types of immersible head vibrators, externally to forms by form vibrators, or to the surface by various types of vibratory pans and screeds. Combinations of methods may be used; however, by Texas specification, steel forms are the only type which may be used with a form vibrator. Therefore, precasting yards are where external vibration is most often used. Precast/prestressed concrete items are inspected by Materials and Tests Division (D-9) Field Inspection Section. External vibrators, since they are not much dealt with by most job inspectors, will not be discussed in this article.

Approximately 95 percent of the time on job sites, Department project engineers and inspectors deal with consolidation by internal vibration. Cast-in-place structures are always internally vibrated. According to Item 360.3(10), pavements "...shall be consolidated by approved mechanical vibrators operated ahead of the transverse finishing machine and designed to vibrate the concrete internally and/or from the surface. Unless otherwise shown on the plans, vibrators of the surface-pan type will be used for two-lift placement of concrete and the internal type will be used for full-depth placement...

"Approved hand manipulated mechanical vibrators shall be furnished ...[for] proper consolidation of the concrete along forms, at joints and in areas not covered by mechanically controlled vibrators." [7, p.307]

With respect to internal vibratory consolidation, European counterparts of our inspectors have a somewhat easier job. European inspectors work with vibrator operators who are specially trained in the craft and who serve an apprenticeship of up to eight years before earning the right to be a master craftsman vibrator operator. American contractors often put inexperienced, recent hires to work with hand-held internal vibrators, probably thinking that an inexperienced person operating a vibrator can do little to hurt the quality of the concrete. Unfortunately, this idea is false. The potential durability of a superbly well-proportioned mix, delivered promptly at a site, under ideal weather conditions can be ruined completely by improper vibration. Inspectors, therefore, need to be able to recognize the good technique from the bad, and what the results are. In order to recognize good technique, it is helpful to know how vibration consolidates concrete.

HOW VIBRATION CONSOLIDATES CONCRETE

Internal vibrators:

An internal vibrator head is inserted into fresh concrete. Pressure waves forming at right angles to the more-or-less cylindrical head (Fig. 2) force aggregate particles apart momentarily, reducing internal friction, allowing the cement paste to flow around them. By causing the concrete mix to act as a fluid, vibration enables the mix to level out, to collapse honeycomb formations, and to fill in around reinforcing steel. The pressure wave action also dislodges entrapped air from around reinforcing steel, form faces, and large aggregate particles, letting the air escape to the surface. De-aeration continues even after the initial flattening, so vibration must continue until most of the entrapped air is driven out. Consolidation is not complete until 2 percent or less entrapped air remains.

Fresh concrete damps the pressure waves as they radiate from the vibrator head, limiting their action. The area in which the pressure waves are effectively liquefying the concrete is known as the radius of action. The radius of action is directly proportional to the diameter of the vibrator head; the larger the head, the larger the radius of action, in general. High vibration intensity is also necessary to produce an adequate radius of action. Vibration intensity is dependent on angular acceleration, amplitude, and frequency. Generally, for a given mix, the higher the amplitude, the bigger the radius of action [2, pp309.R-8, 309.R-12]. Be aware that reinforcing steel damps pressure waves drastically, sometimes up to 50 percent of what it would be in non-reinforced concrete [2, p309.R-15]. Inspectors need to pay special attention to size, to vibration times (determined by frequency rates), and to amplitudes, as well as to variations in the mix that might affect consolidation (Fig. 3). Insertion spacing of internal vibrators is also of key importance.

In order to attain complete compaction, vibrators, whether gang-mounted in front of the slipform paver or hand-held, need to be inserted uniformly with radii of action overlapping by a few inches. An insertion spacing of approximately 1½ times the radius of action should provide enough overlap. Immersion vibrators should preferably be inserted as close to vertical as possible. In slabs, vibrators may be sloped.

Surface Vibrators

Surface vibrators consolidate by harmonic motion pressure waves, like internal vibrators; however, the pressure waves are induced at the surface. Therefore, the concrete is consolidated from the top surface down. Most types, like vibrating screeds, also strike off the concrete, which aids in finishing it. These vibrators must have enough amplitude and acceleration, particularly in stiffer mixes, to dislodge air in the bottom of the slab and allow it to move upward to the more fluid core under the pan units.

Because steel dampens pressure waves on reinforced slabs, surface vibration alone cannot provide adequate consolidation in thick slabs. Internal vibration should be used instead of, or in combination with, it [3, p.107].

PROCEDURE FOR CONSOLIDATION

Inspectors should have a good understanding of correct concreting practice so they can bring unusual or bad practice to the attention of the contractor. ***The Concrete Construction Manual: Construction Bulletin C-1*** [5] is the most useful source book for SDHPT concrete inspectors. ***ACI Manual of Concrete Practice*** [2], and ***Design and Control of Concrete Mixtures*** [3] are also good reference works.

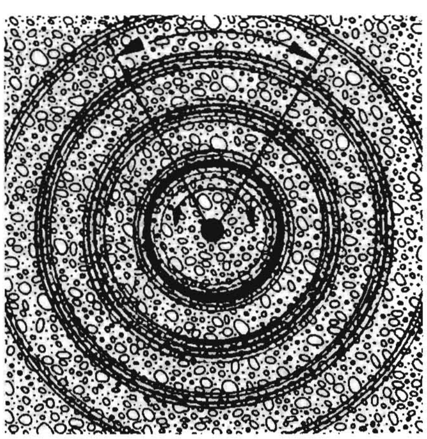

FIG.2: Plan view of pressure waves radiating from a spud vibrator.

FIG.3: Inspecting a spud vibrator.

FIG.4: Using hand-held spud in congested reinforcement area.

FIG. 5: Angling spud in a thin slab.

Hand-held Immersion (Spud) Vibrators: Slabs

Hand-held spud vibrators are used where reinforcing steel is congested (Fig. 4), around construction joints, along form edges, in irregular areas, and in layers of concrete to join them into a monolithic structure. Concrete should be placed as close to final position as possible. Vibrators should be inserted as vertically as possible. In relatively thin pavements, they may slope (Fig. 5). However, they should never be dragged laterally through the fresh concrete.

Consolidation should follow a uniform pattern based on overlapping radii of action and on the compactive effort needed for the particular mix. Adequate vibration can be judged by the appearance of the concrete surface. The signs to watch for are embedding of coarse aggregate, general leveling of the concrete, blending with previously placed and vibrated concrete, very little bubbling of entrapped air escaping from the surface, and glistening of a thin mortar film on the surface and along the junctions with the forms. The tone or pitch of vibrators (other than the motor-in-head type) is also an indicator of consolidation. Usually when a vibrator is immersed in fresh concrete the resistance is great enough that the frequency drops. As the resistance is overcome and the concrete becomes fluid, the frequency increases and becomes constant. A good operator will be aware of the change.

With modern vibrators, operating at an average frequency of 15,000 vpm [4, p565], vibration time is between 5 and 15 seconds. Item 360.3(10) requires not less than 8000 vpm for spud-type vibrators and vibration time of not more than 15 seconds.

Stiff mixes sometimes will not close the hole that the vibrator leaves as it is withdrawn. If this happens, the vibrator can be reinserted a few inches away. If this action does not solve the problem, either the mix consistency or the vibrators need to be changed.

Hand-held Immersion (Spud) Vibrators: Structures

Columns and monolithic structures require special techniques to blend the layers. Layers should be as level as possible and no more than 36 inches thick. Each layer should be placed while the one beneath it is still plastic. The vibrator should penetrate rapidly through the new layer and several inches into the layer beneath. The vibrator should be held vertical and stationary until consolidation appears adequate. Then, it should be withdrawn slowly at the rate of about 3 inches per second. [7, Item 420.11] If the underlying layer has begun to stiffen to the point where the vibrator cannot penetrate it, adequate bonding can still be obtained by systematically and thoroughly vibrating the new layer into contact with the semi-stiffened layer. However, this is an emergency procedure. If layers are stiffening before the next layer can be poured, operations must be speeded up to avoid making cold joints. Cold joints, layers that have not been bonded properly by vibration, weaken the structure and allow water to enter at the seam.

Immersion (Spud) Vibrators on Pavers

For gang-mounted internal vibrators (Fig.6), the rule-of-thumb is the lower the amplitude and the shallower the slab, the closer the spacing should be. The standard spacing on most machines is 24 inches. The location of the outside vibrators is critical to uniform consolidation, especially in slipform paving. The outside vibrator must have the edge-form within its radius of action because surface vibration of concrete is least effective along the edges.

Look for uniformity behind the screed. If mortar streaks occur in the paths of the vibrators when the paving train is traveling at a normal rate of speed, this should be brought to the attention of the contractor; the vibrators may need to be lowered or their angle changed or their frequencies increased or decreased. More vibrators may need to be added. The nonuniformity must be eliminated because it can cause lines of weakness that can develop into lon-

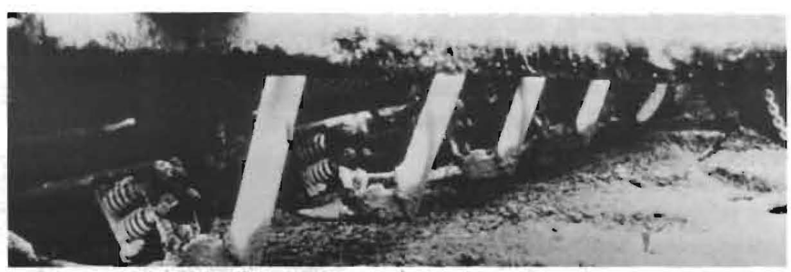

FIG. 6: Gang-mounted spuds on a paver.

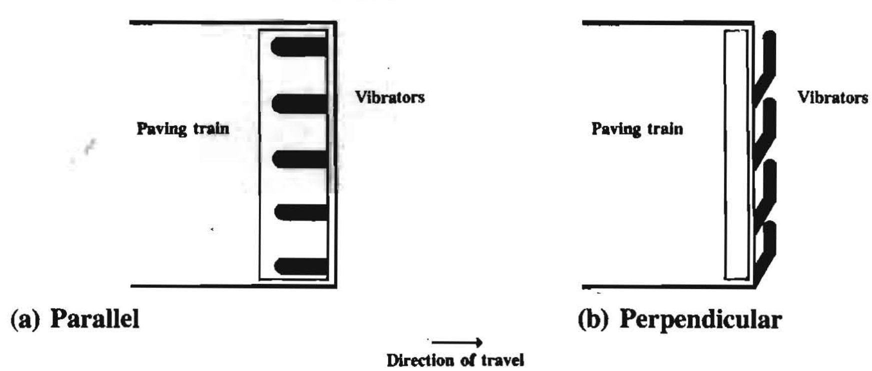

FIG. 7: Mounting configurations.

gitudinal cracks.

Research Report 341-1F, ***Consolidation of Concrete Pavement*** [9], suggests several things to consider about consolidation with internal vibrators on a slipform paver. Two are:

1. **Depth:**

Upward forces produced in concrete above deeply submerged vibrators may counteract the gravitational forces necessary for adequate consolidation of the mix. Dragging the vibrators through the upper portion of CRCP slabs may lead, inherently, to a higher air void content in the vibrators' paths, particularly if the paving speed is rapid. Therefore, consideration should be given to maintaining a sufficient overburden of concrete in front of the paver to be able to raise the vibrators above the desired grade line in order that the vibratory forces will be transmitted downward on the concrete that is being consolidated.

2. **Mounting configuration:**

Two ways of mounting internal vibrators on a paver are parallel to the direction of travel and perpendicular to the direction of travel (Fig. 7). Parallel is the most common mounting. When gang vibrators are mounted parallel to the direction of travel, the concrete will receive varying degrees of vibration across the width of the pavement, depending on where the concrete is relative to the position of the two nearest vibrators and to the rate of travel. Perpendicular mounting of vibrators can counteract the variation across the pavement. However, while this arrangement does show uniform consolidation across the pavement, it does not appear to liquefy the concrete as effectively. Research indicates that the paving speed may need to be reduced by as much as half that of pavers with conventional parallel-mounted vibrators in order to achieve the same level of consolidation. Also, the heads should be mounted at least end-to-end; ideally, they should overlap by almost half the length of the vibrator's head.

Surface Vibration on Pavers

Vibratory pans should be positioned behind the strike-off unit. Operating frequencies are in the range of 3500 to 4200 cycles per minute in air. The contractor must provide a satisfactory tachometer for checking the speed of the vibratory elements [7, Item 360.3(10)]. The forward speed of the paving unit is used to determine optimum frequency. The pan must not have a surcharge built up in front of it, as this will dampen the vibrations. If the paving unit is not equipped with gang-mounted internal vibrators in front, an internal vibrator may be needed to consolidate the concrete along the form edge.

FIG. 8: Uniform roll of material in front of screed.

In vibratory screeds, the position of the bottom affects its performance. A flat screed cuts the concrete surface; a tilted screed tends to "iron-out" or "float-over" it. Tilted screeds may consolidate the concrete more efficiently. Adjustments are made to the screed setting according to the desired finish and the current conditions [6, Index# 321.3.3.b].

Keep the head of material constant in front of, and throughout the length of, the screed (Fig. 8). If alternately large and small amounts of concrete are being carried, the slope of the finishing element will vary, causing a ripple effect in the finished slab [5, 4.8.1 & 4.8.2]

Frequency of the screed affects strike-off capability. Too low a frequency can cause concrete to drag under the screed, especially if the mix is sticky. If the frequency is increased to the specified maximum and the mix still drags, a slight change in the coarse aggregate factor may be necessary [5, 4.8.2.2].

Procedural Problems

The two major procedural problems inspectors see are undervibration and overvibration. Inexperienced, untrained, or hurried operators tend to undervibrate concrete. The most common error is to vibrate the concrete until it flattens and then move on before deaeration can occur. Concrete that is undervibrated is simply not as durable. In general, undervibration can create a number of problems:

1. lower compressive strength than properly consolidated concrete;
2. excessive entrapped air;
3. honeycombing (lack of mortar between coarse aggregate particles, Fig. 9);
4. less bonding to reinforcing steel;
5. sand streaking;
6. higher permeability with respect to moisture with chloride ions; and
7. pour lines between layers in what should be monolithic structures.

Undervibration is far more common than overvibration. When overvibration does occur, it is usually in an excessively wet mix. Careless use of oversized vibrators can also be a cause. Overvibration can be recognized by these signs:

1. almost no coarse aggregate in the surface layer;
2. excessive loss of entrained air;
3. a frothy surface (especially in a wet mix); and
4. sand streaks along form joints.

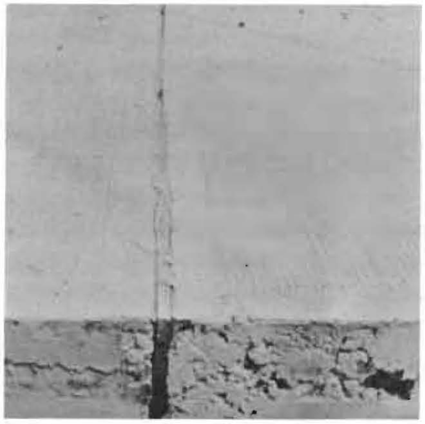

FIG.9: Honeycombing revealed when edge-form was stripped.

Well-proportioned mixes are not easily overvibrated. Be aware, however, that high slump concrete made with high-range water-reducer (superplasticizer) responds very quickly to vibration and can be overvibrated more easily than conventional concrete [8, p11].

TIPS FOR INSPECTORS

for structures or pavements:

1. Do routine checks of vibrator frequency. Check the spare vibrators, too. Construction Bulletin C-1 contains a table (Table 4-1, p4-49) of frequency ranges and other internal vibrator characteristics. If random fluctuations in vibrators' frequencies occur, an inspector may suggest that the air or electric supply be metered (or the meter corrected) to ensure adequate power delivery to the vibrators. The contractor must supply a tachometer suitable for checking the speed of vibratory elements [7, Item 360.3(10)].

2. Observe the crews to see that hand-held internal vibrators are being inserted vertically, held stationary during the vibration time, inserted uniformly according to the radius of action, and not dragged laterally through the fresh concrete.

3. Inspect the concrete for defects caused by undervibration. The presence of honeycombing and entrapped air indicates that one or more of the following changes should be made:

a. Bring the vibrators closer to the form (Fig. 10).

b. Increase the amplitude or frequency of the vibrators.

c. Slow down the paving train.

d. Decrease the vibrator insertion spacing.

e. Increase the size or number of vibrators.

4. Examine the top surface of cores to determine the thickness of the mortar layer above the coarse aggregate. More than ¼ inch of mortar indicates overvibration or overfinishing. Lack of durability is often related to deficiencies, such as removal of entrained air voids and higher-than-designed water/cement ratio, in this critical ¼ inch [8].

5. Record breakdowns, delays, or other unusual happenings. Extra test samples (cylinders, beams cores, etc.) may need to be taken (Fig. 11) in these areas [6, Index# 106.11].

Tips for structures:

1. In walls and columns, look for sand streaking, as well as honeycombing, when forms are removed. Harsh, wet, poorly graded mixes are prone to

FIG.10: Vibrating along form to prevent honeycombing.

sand streaking; concrete dropped through reinforcing steel is sometimes the cause. Depositing concrete in thick lifts and then undervibrating it can also cause sand streaking, as can leaky forms. Determine the cause, then remedy it.

2. Check for pour lines. If they are not the result of a delay which caused the underlying layer to stiffen to the point where a vibrator could not penetrate, recommend to the contractor that vibrators be lowered further in the next set of pours.

Tips for pavements:

1. Check that the vibrator spacing is no more than 24 inches on gang-mounted vibrators that are parallel to the paving train's direction of travel.

2. When internal vibrators are gang-mounted perpendicular to the paving train's direction of travel and the concrete slump is less than 1½ inches, monitor the consolidation with more than usual caution, particularly if the internal vibration is not followed up by surface vibration. Research indicates that the paving train speed for this configuration must be slower than for parallel or the concrete will not have time to liquefy and to consolidate properly. [9, p84].

3. Constantly watch for nonuniformity behind gang-mounted vibrators. Be aware that changes in weather, in mix consistency, in rate of progress, etc. may require changes in position or even in characteristics of the vibrators.

4. If test cores reveal inconsistent consolidation across the width of a pavement, the void content (in the hardened concrete) found exactly between the paths of two vibrators is the critical factor in determining if there needs to be a change in vibrator spacing. If void content is unacceptable in these areas, but acceptable in cores taken from near the center of any vibrator path, this situation should be called to the attention of the contractor. He may wish to reduce the spacing of the vibrators or slow the forward speed of the paver to give the vibrators more time to act. This is more a problem of parallel-mounted vibrators than of perpendicular ones [9].

FIG.11: Casting extra beams at point of difficulty.

Quality assurance is a major part of any type of inspection. When the job is inspection of freshly placed concrete for pavements and structures, consolidation is a major concern. Without proper consolidation, the potential durability of a well-proportioned mix can be ruined. Inspectors need to recognize good consolidation practice. They also must recognize the signs of bad consolidation practice, and what the causes might be in order to communicate effectively with the project engineer and contractor.

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A LOOK AT PRIVATIZATION

by Mohanan Achen
Civil Engineering Student
University of Texas at Austin

INTRODUCTION

Much of the transportation infrastructure in the country is in bad condition. Numerous incidents involving failure of our basic transportation structures have occurred over the past few years. The bridge collapse at Schoharie Creek, New York, is a good case in point. Currently, the federal government administers and maintains most of the transportation infrastructure. Inadequate government supervision and deferred maintenance are factors in the deterioration.

Deferred maintenance is an unfortunate product of the political process itself. Many interests are lobbying for government funding. Highway projects, which are politically unattractive compared to other courses, are repeatedly shortchanged. Government supervision is also burdened by a massive web of rules and regulations which slows down the government machinery considerably. The government procurement process is a good example of being a victim of these rules and regulations. A combination of discriminatory political influence and the huge bureaucratic process results in the delay of essential highway maintenance to the detriment of transportation.

The present trend of advocating less federal government involvement has resulted in more responsibility being shifted to the local and state governments. Federal funding for highway and transit services have been reduced. From 1974 to 1982, highway maintenance costs increased by 122 percent while general highway revenues increased by only 92 percent [1, p1]. Highway funding for the interstate system terminates in 1991 [2]. In the face of these problems, privatization has been turned to as a means of safeguarding the welfare of our highway system.

PRIVATIZATION

Privatization refers to the transfer of ownership of public assets from the government to the private sector in varying degrees. Joint public-private partnerships are popular, especially in the field of transit services. The types of projects that are best suited for privatization are:

* Service-oriented projects which require manpower and equipment.

* New construction projects — not

Continued on page... 13

QUALITY CONTROL DATA BASE READY FOR DISTRICT USE

*from **Organization and Analysis of 1987 HMAC Field Construction Data**, Research Report 1197-1F (Preliminary Draft), by Maghsoud Tahmoressi and Thomas W. Kennedy, Center for Transportation Research, University of Texas, Oct. 1988. Excerpted by Kathleen M. Jones.*

INTRODUCTION

A hot mixed asphalt concrete field construction data base has been developed that has several practical district applications. The data base, a result of Research Project 1197: ***Organization and Analysis of 1987 HMAC Field Construction Data***, contains actual construction records from eighteen districts. These construction records were obtained by an SDHPT survey conducted to establish current HMAC properties in field construction. The field construction data base, as it now exists, can be used to analyze several important parameters that affect the quality of HMAC pavements in present and in future construction. It can provide a foundation for automating quality control aspects of HMAC construction, as well as for judging the success of any new specification in improving the quality of HMAC.

The Center for Transportation Research organized and analyzed the data, which was collected from June to October 1987. The data, received from 72 HMAC jobs, reflected 92 different mixes. Most classes of highways such as Interstate, US highways, and FM roads, were represented. Of the 92 mixtures, 63 were type D, 9 were type B, 12 were type C, 1 was type A, and 7 were type G. Information concerning various aspects of the construction process such as compaction equipment, mixture temperature data, mixing plant information, and handling equipment were requested on a miscellaneous data sheet. Other requested data included information on mix design, relative density of laboratory-compacted specimens, asphalt content, and gradation. Most districts included the daily construction record, Form 404, as well, which includes Hveem stability and total production for each day. A summary of the analysis of this specific set of data is given in "Chapter 3" of Research Report 1197-1F and on the videotape of "Session 4: Materials" from the ***Sixty-Second Annual Highway and Transportation Short Course***, and will not be repeated here.

```
* ************************************************************************************ *
* DISTRICT:       23 DISTRICT:LAMPASAS          HIGHWAY: US 190                         *
*    TYPE: D          COURSE: SURFACE                                                   *
* PROJECT: C231-1-24                            CONTROL: 231-1-24                       *
* ************************************************************************************ *
*                                                                                       *
* GENERAL INFORMATION                                                                   *
*                                                                                       *
* THICKNESS  1-1.5   OLD ACP        ROLLERS:  WEIGHT   SPEED    #PASS IN  TRAIN         *
* UNDERLAIN LAYER:  FLEX BASE                  (TON)   (MPH)          POSITION          *
* MIX DISCHARGE TEMP  335 F          3-WHEEL                                            *
* TEMP @ 1st PASS:    320 F         VIBRATORY   10.6    1-2         3        1          *
* TEMP @ 2nd PASS:  200-275 F       PNEUMATIC    9.5    1-2         3        2          *
* EXISTING PVT.:    SMOOTH&WARPED   VIBRATORY    9.1    1-2         2        3          *
* PLANT:            BATCH                                                               *
* PILE CAP,            137                                                              *
* SILO CAP.,TON:                                                                        *
* NO. OF BINS:      4(HOT),4(COLD)                                                      *
*                                                                                       *
*                          VIBRATORY ROLLER INFORMATION                                 *
*                                                                                       *
*                   VIBRAT.  VIBRAT.  AMPLITUDE         FREQ     NO. OF                 *
*                   FORWARD  BACK.    (IN.)             (CPS)    VIB. DRUMS             *
*                                                                                       *
*                       X        X      0.022            37          2                  *
*                                                                                       *
*                                                                                       *
*                                                                                       *
* HAULING & LOADING EQIPMENT:                   MAX. THEORETICAL DENSITY                *
*                                                                                       *
* BOBTAIL  SEMI-    BOBTAIL/W  FLOW-             RICE                 Gt                *
*          TRAILER  TRAILER     BOY             (227-F)              (207-F)            *
*    X                                             X                                    *
*                                                                                       *
* DENSITY MEASUREMENT TECHNIQUE                 DAY OF DENSITY TEST                     *
*                                                                                       *
* CORES    NUCLEAR  IN WHEEL BETWEEN            SAME DAY              NEXT DAY          *
*                   PATH     W. PATH            PLACED                OR LATER          *
*    X        X        X        X                                        X              *
*                                                                                       *
* ************************************************************************************ *
```

FIG.1: Level 1 miscellaneous construction data (sample output).

The purpose of this article is to familiarize people with the data base and make them aware of possible practical applications.

ORGANIZATION OF THE DATA BASE

The entire data base is contained on floppy disks. It is IBM compatible and runs in dBASE III Plus with Lotus 1,2,3 and Microsoft Chart. Lotus 1,2,3 is a spread sheet software which can perform limited statistical analyses and can perform complex data reductions. dBASE III Plus is a powerful, well-known data base software which is used

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

to manage the data. (General questions about dBASE III Plus can be directed to Charlie Yates of the Automation Division, D-19.) Microsoft Chart is used to perform plotting tasks.

To simplify data management, the data were categorized in three levels. Level 1 files consist of all the information received from the districts for specific projects. A separate computer file was created for each project's Level 1 data. Each Level 1 data file is separated into two segments. The initial segment contains all qualitative information regarding construction activities, as well as a description of the project (Fig. 1), from the miscellaneous data sheet. The second segment of these files includes relative density, nuclear density, asphalt content, and air temperature data, all extracted from daily construction records (Form 404) and input for each working day. Descriptive statistics are calculated for each project at this level. Each of these two segments has a header which identifies the project by district, county, highway, mixture type and course, and project code and control. Level 1 gradation data contains extracted gradations from Form 404, design gradations, and gradations of a 0.45 power curve corresponding to the maximum aggregate size (Fig. 2).

Separate computer files contain Level 2 data. Level 2 project files were created by adding several parameters to Level 1 files to enable the user to perform analysis on specific projects. Like Level 1, Level 2 is also divided into two major segments. The first segment includes daily relative core density based on Rice specific gravity, laboratory density based on maximum theoretical specific gravity, mat thickness, production quantity, air voids, voids in mineral aggregate (VMA), Hveem stability, and percentage of voids filled. The second segment includes relative core densities based on laboratory-compacted specimen density and relative densities based on maximum theoretical density from design and extracted asphalt contents. Descriptive statistics are provided for each parameter.

Level 1 and Level 2 gradation data are included in the same computer files for ease of operations. The Level 2 portion of the gradation files includes: average extracted gradation, design gradation, the difference between design and extracted gradation for each sieve, gradation for a 0.45 power gradation curve, and the average extracted gradation for each sieve. Also, the sum of the differences between a 0.45 power curve and an extracted gradation in several regions of the gradation chart is given (Fig. 3).

The Level 3 data base is generated from the descriptive statistics in Level 2 project files. In this level, the data base is created using dBASE III Plus software. The data base consists of more than 160 fields. Each field contains one parameter regarding a specific project. More than 40 fields are used to describe construction details. These fields generally contain quantitative data which include averages, standard deviations, maximums, minimums, and counts for each of the parameters.

PRACTICAL APPLICATIONS

The Level 3 data base, in particular, is set up to provide the user with specific information. For example, the user may request to have the relative core density for all projects which had a compaction temperature of less than 250°F, had a mat thickness less than 2 inches, and had used a vibratory roller weighing 5 tons with a forward speed of 3 to 5 mph. The data base program searches through all available data and locates all projects which meet the prescribed conditions. The results are displayed. The results can either be printed on an on-line printer or saved for future work. If further analysis of the data is required, the displayed results can be transported to Lotus 1,2,3 where it can be graphically represented and analyzed. In this way engineers and project managers, knowing what equipment and materials will likely be used, can check what results were obtained in previous similar jobs. In some cases, the data base may identify probable or potential problems with an upcoming ACP placement, giving time to plan a way around the problem areas before the problems can occur. The data base allows the user easy access to the experience of other districts that might be using similar materials and construction techniques as well. Patterns of recurring problems may be discovered and their causes explored by process of eliminating variables. The value of this construction and materials data base will be increased greatly when pavement performance information can be added after several years of service.

The dBASE III Plus program also provides a format for a district or residency to input and study their own future construction data. Daily construction records (Form 404) can easily

```
* ************************************************************************************** *
* DISTRICT:      23 DISTRICT:LAMPASAS              HIGHWAY: US 190                       *
*   TYPE: D          COURSE: SURFACE                                                     *
* PROJECT: C231-1-24                               CONTROL: 231-1-24                     *
* ************************************************************************************** *
```

GRADATION INFORMATION

SIEVE	0.45 LINE	DESIGN GRAD. 1D	1	2	3	4	5	6	7
+1/2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1/2-3/8	0.0	7.2	5.5	4.9	5.6	6.5	4.4	7.0	7.4
3/8-#4	26.9	31.3	33.4	35.7	35.0	35.6	33.4	33.2	34.2
#4-#10	23.6	27.3	26.6	26.1	25.5	24.4	27.0	26.4	23.5
+# 10	50.5	65.8	65.5	66.7	66.1	66.5	64.8	66.6	65.1
#10-#40	25.0	10.6	9.0	7.8	6.9	8.6	8.8	8.8	9.5
#40-#80	7.8	13.7	8.3	11.8	8.7	9.3	7.4	8.7	9.6
#80-#200	5.5	7.5	12.2	8.9	13.1	11.3	12.4	10.6	10.1
-#200	11.2	2.4	5.0	4.8	5.2	4.3	6.6	5.3	5.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

FIG. 2: Level 1 gradation data for 7 extractions.

```
****************************************************************************************
*        DISTRICT:       23 DISTRICT:   LAMPASAS          HIGHWAY: US 190              *
*          TYPE: D               COURSE: SURFACE                                       *
*        PROJECT: C231-1-24                               CONTROL: 231-1-24            *
****************************************************************************************
```

GRADATION INFORMATION EXTRACTED GRADATIONS

SIEVE	0.45 LINE	DESIGN GRAD. 1D	AVG. EXT. GRADATION	SIEVES FOR % PASS.	AVG. EXT. % PASS.	DES. GRAD % PASS	DES-EXT	.45 LINE % PASSING	.45 LINE - AVG. EXT	SUM IN REGIONS	SUM OF ABS. VALUES
+1/2	0.0	0.0	0.0	1/2	100.0	100.0	0.0				
1/2-3/8	0.0	7.2	5.7	3/8	94.3	92.8	-1.5	100	5.7	5.7	5.7
3/8-#4	26.9	31.3	33.4	4	60.9	61.5	0.6	73.1	12.2		
#4-#10	23.6	27.3	26.9	10	34.1	34.2	0.1	49.5	15.4		
+# 10	50.5	65.8	65.9							27.6	27.6
#10-#40	25.0	10.6	9.2	40	24.9	23.6	-1.3	24.5	-0.4		
#40-#80	7.8	13.7	8.0	80	16.9	9.9	-7.0	16.7	-0.2	-0.6	0.6
#80-#200	5.5	7.5	12.3	200	4.6	2.4	-2.2	11.2	6.6	6.6	6.6
-#200	11.2	2.4	4.6						TOTAL:	39.3	40.5
	100.0	100.0	100.0			SUM =	-11.3				

FIG.3: Level 2 gradation data .

be entered directly and electronically stored. This in itself would be a great step toward automating quality control aspects of HMAC construction. Districts could document the effect of new specifications by comparing the results of old jobs to the results of new jobs, where most other parameters were similar. The effects of the new specifications in different districts could be aggregated and analyzed to judge the success of the various specifications.

Other possibilities for this data base and data bases which may be created with this program format will come to light as districts experiment.

Highway Department personnel can obtain copies of the data base and program or the program alone by contacting Mr. Paul Krugler (D-9), (512) 465-7603, TEX-AN 241-7603. Non-department requests should be directed to the D-10R Technology Transfer Library, (512) 465-7644, TEX-AN 241-7644, P.O. Box 5051, Austin, TX 78763-5051.

UNIVERSITY OF TEXAS' INVOLVEMENT IN THE SHRP ASPHALT PROGRAM

by Thomas W. Kennedy,
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INTRODUCTION

In the Spring of 1987, the United States Congress passed legislation which provided $150 million (U.S.) over five years for the Strategic Highway Research Program (SHRP). SHRP is the largest, most ambitious highway research effort ever undertaken in the United States. Developed under the leadership and guidance of the American Association of State Highway and Transportation Officials (AASHTO), the Transportation Research Board (TRB), and the Federal Highway Administration (FHWA), it is a long term, major undertaking to research high risk areas with potential payoffs, within the highway construction field [1 & 2].

A large portion of that effort is performance-based research involving asphalt cements and asphalt-aggregate mixtures, including modifiers. Fifty million dollars will be expended in this area to identify and describe those properties that will assure improved pavement performance. The end product will be an economical performance-based specification for asphalt and an asphalt-aggregate mixture analysis system to facilitate mixture designs.

WORK PLAN DEVELOPMENT

The initial work plan [2] for the asphalt research addressed the fundamental chemical and physical properties of asphalt cement and their relationship to asphalt mixture performance. Specific research topics to be considered were adhesion, steric hardening, absorption, aging, and oxidation. From this initial work, contracting plans were prepared combining similar research topics. The resulting research contracts are as follows:

Contract #	Title
A-001	"Improved Asphaltic Materials, Experiment Design, Coordination and Control of Materials."
A-002A	"Binder Characterization and Evaluation."
A-002B	"Novel Approaches for Investigating Asphalt Binders."
A-002C	"Nuclear Magnetic Resonance Investigation of Asphalt."
A-003A	"Performance-Related Testing and Measuring of Asphalt-Aggregate Interactions and Mixtures."

A-003B "Fundamental Properties of Asphalt-Aggregate Interaction Including Adhesion and Absorption."

A-004 "Asphalt Modification Practices and Modifiers."

A-005 "Performance Models and Validation of Test Results."

A-006 "Performance-Based Specifications for an Asphalt-Aggregate Mixture Analysis System (AAMAS)."

A-IIR "Independent Innovative Research on Asphalt."

CURRENT STATUS OF ASPHALT CONTRACTS

Six contracts (A-001, A-002A, A-002B, A-002C, A-003A, A-003B) have been awarded, as of December 1, 1988. The University of Texas at Austin was awarded the A-001, "Improved Asphaltic Materials, Experiment Design, Coordination, and Control of Materials," contract. UT has subcontracts with the Asphalt Institute, Nittany Management Engineers, Matrecon, and Mr. James Scherocman.

The A-002 contract was awarded to Western Research Institute, Laramie, Wyoming. Contract A-002B has been awarded to Montana State University. The University of California at Berkeley was awarded contract A-003A, and A-003B was awarded to the National Center for Asphalt Technology (NCAAT) at Auburn University. SHRP is currently negotiating with a potential A-004 contractor. Contracts A-005 and A-006 are scheduled to be awarded in 1989 and 1990, respectively.

A satellite program entitled, "Independent Innovative Research in Asphalt," (A-IIR), was initiated recently (Fall 1988) and will continue into 1989. This effort is intended to maximize innovation by encouraging scientists from many disciplines to become involved. Hopefully, this "fresh" look at testing and evaluation systems will spawn innovative approaches. Contracts of a moderate size, $80,000 to $250,000, with a potential for high payoff, but with possible high risk, will be awarded. This program is specifically targeted at the research areas covered by contracts A-002, A-003A, and A-003B. Findings from these smaller contracts will immediately be implemented into the mainstream of this research through the coordination efforts of the SHRP staff and the A-001 contractor (UT). To date, four potential contractors are negotiating for A-IIR contracts.

The A-001 contract awarded to UT is the technical assistance and management support hub. It provides the SHRP staff with the means for execution, coordination, and implementation of the whole Asphalt Research Programs. To coordinate the various complex asphalt research activities of SHRP, the contract is divided into four major areas: 1) Project Coordination; 2) Project Experiment Design; 3) Development and Evaluation; and 4) Implementation.

PROJECT COORDINATION

The asphalt research contracts as specified by SHRP must, by their interdependence, interact in such a way that significant, positive or adverse findings in any contract can be transmitted to others in order to determine their impact. The plans and activities of each contractor will be monitored on a regular basis to ensure that the projects are on schedule, are following the contract research plan, and are producing results which can be analyzed and related to other contracts.

The Critical Path Method (CPM) has been selected as the most comprehensive means of monitoring and coordinating progress. A commercially available software package is being used and the latest A-001 and A-002A work plans are being loaded for program testing and verification.

Additional coordination activities of the University of Texas as the Technical Assistance Contractor involves interfacing with the Long Term Pavement Performance contract with the Texas Research and Development Foundation (P001), and Maintenance Effectiveness (H101) contract with Texas A&M University so that all related activities are considered. Also, several other asphalt-related research projects funded by the National Cooperative Highway Research Program (NCHRP) are currently being conducted. These research findings will be incorporated into the appropriate SHRP research activities.

The University of Texas, as the Technical Assistance Contractor, provides a full-time engineer in the Washington, D.C. area to complement the SHRP staff. An asphalt chemist is also provided under subcontract with the Asphalt Institute as additional support. These staff members aid in the preparation of program announcements, review proposals, and provide general technical guidance, as required by the SHRP staff.

PROJECT DESIGN

An overall experimental plan has been developed to coordinate the innovative and diverse simultaneous activity. The experimental design outlines a systematic methodology so that individual research efforts can be evaluated as part of the whole. Also provided in the experimental plan is a structured data base so that results can be easily made known and implemented.

Control of Materials

A Materials Reference Library is being established for use by the asphalt research program. It provides climate-controlled storage for the large amounts of asphalt and aggregates needed. Thirty asphalts, eleven aggregates, and as yet an undetermined number of asphalt modifiers will be sampled and stored in Austin, Texas. Asphalt will be sampled and stored in 5-gallon, epoxy-lined pails. Aggregate will be sampled and stored in 55-gallon, high-density polyethylene drums.

Initially, eight core asphalts are to be obtained (Fig. 1). These eight asphalts will be included in each researcher's program. The remaining 22 asphalts will be identified and sampled at a later date. The asphalt grade most commonly produced at each refinery is being sampled. Softer grades suitable for modifying are being sampled from a select number of refineries. To date, six core asphalts and three additional ones have been sampled. This represents 15,000 gallons of asphalt stored at the Reference Library.

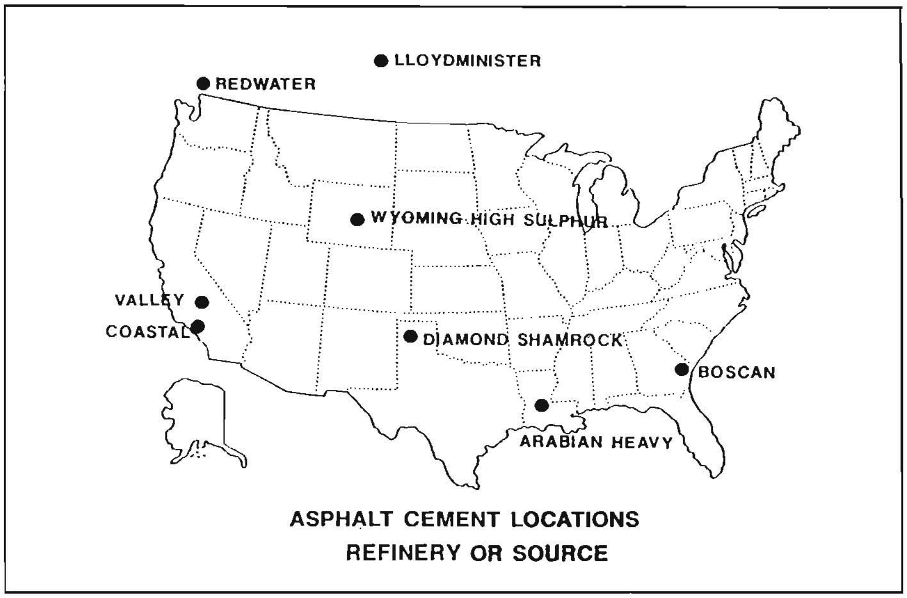

FIGURE 1: Initial asphalts selected.

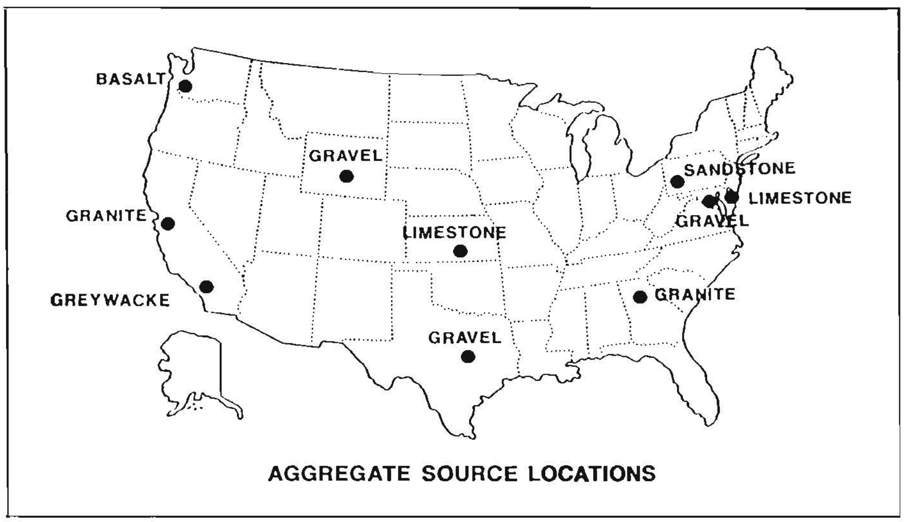

FIGURE 2: Aggregate sources selected.

For each aggregate type (Fig. 2), approximately 15 tons of AASHTO sizes No.476 and No.8 are being obtained. Five aggregates, representing 150 tons, have been stored already.

Each material is tested, so that the library materials can be "fingerprinted." Among the tests conducted are: 1) Asphalt; penetration, ductility, viscosity, rolling thin film oven test, elemental analysis, separation procedure; 2) Aggregate; porosity, L.A. abrasion, absorption, specific gravity, CKE, particle index, gradation, soundness, petrographic analysis, and chemical analysis. Expectations are that the individual researchers will request asphalts and aggregates with specific characteristics in order to validate or extend their findings. These tests will also aid in the final selection process for the remaining 22 asphalts.

Approximately 1000 to 1500 gallons of each asphalt cement and 30 tons of each aggregate will be available to researchers. Thus, each researcher can be assured of testing material which represents a distinct production period with minimal inherent variation, while the various research projects are working with the same asphalts and asphalt aggregate mixtures.

Experimental design

The term "Experimental Design," as used in this article, designates the overall statistically based plan for evaluating and correlating each work element, not the control of individual experiments.

The experimental design portion of the UT contract is subcontracted to Nittany Management Engineers and Consultants, State College, Pennsylvania. They have provided a team of statisticians in charge of developing a partial factorial design involving the "core" asphalts and aggregates to ensure meaningful interrelationships between the various contracts. The statisticians also will interact with each contracted research team explaining the experimental design approach and providing guidelines for each asphalt contract to ensure a project standard of statistical validity.

Data base development

A state-of-the-art system for handling the type and amount of data that will be generated within the Asphalt Research Program is being designed under the UT contract. The data will be categorized into two levels: the raw data and information calculated from the raw data. Flexibility will be built into the system to allow for future expansion.

Interaction with the other asphalt contractors is on-going, supplying the data base management design team with examples of data input, including nomenclature. A commercially available data base management system is being used as a starting point for this effort.

DEVELOPMENT AND EVALUATION

Health and Safety

Health and safety concerns have been raised recently about working with asphalt cement at various stages from refinery to hot mix placement. Some laboratory studies have suggested that asphalt cements are not only toxic, but carcinogenic as well. In addition, some well-intentioned researchers have grouped asphalts with coal tar materials in their evaluations, which clouds the issue.

Documenting all known studies which have considered the health and safety aspects of using paving asphalts is one of the tasks under this third major division of the UT contract. No new research is proposed. The current work plan entails a detailed literature review, an assessment of the information by an expert task group made up of prominent physicians and scientists, and the preparation of a concise final report. So far, 138 articles related to health and safety of individuals handling asphalt have been identified.

Development of Performance-Related Binder Specifications and Their Economic Impact.

This part of the evaluation relies on information from the Western Research Institute contract, the UC Berkeley contract, the Auburn University contract, and the as-yet-unawarded A-004 contract. It is scheduled for years 3 and 4 of the contract.

Survey of Available Asphalts and Current Refinery Practices.

The oil crisis and embargo in the 1970s upset traditional crude sources and caused changes in refinery practices by making the extraction of light fractions from asphalt residues profitable. In addition, the oil embargo stimulated the production of asphalt by new and different refining processes. This survey is taking place because of the general belief that North American specifications for paving grade asphalt do not always ensure satisfactory performance when applied to changing or unknown crude oil sources and new refinery techniques.

The industry-wide survey is being conducted by the Asphalt Institute, under subcontract to UT. The intent is to establish the range of methods, equipment, and crude oil sources currently employed in the production of paving asphalts. The survey is organized to achieve comprehensive knowledge of relationships between the properties of asphalts and production factors. Equal consideration is being given to both crude oil sources and refinery practices.

A detailed questionnaire, designed for ease of statistical evaluation and compatibility with the overall experiment design, has been sent to each primary paving asphalt refiner in the U.S.A. and Canada. Additionally, a questionnaire on transportation, storage and handling of paving asphalts after they have left the refinery is being sent out to asphalt paving contractors. This effort will be coordinated with the sampling of refinery and terminal tanks to determine what changes, if any, take place in the typical paving asphalt from refinery to storage tank at a hot mix plant.

Several production facilities (either refineries or terminals) will be chosen for periodic sampling and testing throughout the course of the research. This testing should reveal the extent of "normal" variation to be expected in asphalt properties from a given source due to short-term changes in crude sources, refinery operations, and seasonal product demand.

Sixty U.S. refineries and 23 Canadian ones have already responded to the survey. Of these, 45 refineries use the vacuum distillation process and 13 employ the vacuum distillation and solvent process. The remaining refineries use atmospheric distillation or vacuum distillation and solvent refining with air blowing. Twenty-seven million tons of asphalt were produced in the U.S. and Canada in 1987. This survey represents 22.5 million tons of production, or 85 percent of the U.S./Canadian production.

IMPLEMENTATION

Implementation involves three specific areas: 1) preparation of status reports; 2) presentation of findings at various meetings; 3) preparation of workshop materials, seminars, and handbooks. Implementation can not wait until the entire project is over; it is a full time effort and begins the day of contract execution.

Presentations to various groups about SHRP asphalt research are going on to stimulate interest and to inform people of current activities. Additionally, quarterly activity reports and reports documenting significant findings will be prepared as the research progresses. Study and review materials, seminars, workshops, handouts, and workbooks are in various stages of planning, though obviously the implementation effort will be concentrated in the fifth year, once major research findings are available.

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A LOOK AT PRIVATIZATION

Continued from pg. 7

burdened by existing public asset transfers or leases.

* Projects with track record technology — the private firm concerned may be responsible for the development of the new technology concerned [3, p35].

Private ownership of highways is a rare phenomenon. Throughout the world, governments have shouldered the responsibility of building highways and maintaining them. The economic theory of perfect competition argues against private ownership of highways. There are several economic imperfections in the highway market. These imperfections are:

(a) Users of highways, which are essentially built for public service, cannot be charged a fee based on highway quality because no one can be restricted from using the highway.

(b) Highways are not perfectly competitive because geographic uniqueness does not permit one highway to be a perfect substitute for another one.

(c) The highway builder cannot account for externalities which are costs or benefits that cannot be traded on the market [3, p35].

These imperfections, however, do not rule out private participation in highway building. Government needs do play a supervisory role because of the economic imperfections in the highway market. Because governments must maintain unprofitable routes which will not be serviced by the private sector, the infusion of private capital would be welcome relief in a period of bloating federal deficits and fiscal austerity measures. Private capital can comprise 20 to 30 percent of the equity concerned [3, p35]. Privatization could foster a more flexible, rational and businesslike management approach.

BENEFITS OF PRIVATIZATION

The privatization concept is attractive because of four main reasons:

(a) More revenues can be obtained without increasing taxes. This can be achieved by converting previously non-toll roads to toll roads; or by increasing the tolls charged on existing toll roads.

(b) Efficiency of highway usage will be increased. Current highway prices (usage-sensitive excise taxes and user fees plus tolls) are far below the economic efficient level on congested highways. Tolling highways would change travel patterns or highway usage, especially if higher rates are applied during peak hours.

(c) Production efficiency of highway maintenance might be improved. Private companies, being boom-or-bust organizations unlike the federal government, have profit maximization incentives to minimize production costs. Private highway companies would be at least as efficient as the government in providing maintenance services. The substantial administrative costs, involved in privatizing highways, would be offset by the tremendous savings produced by privatizing the road. Governmental participation in a privatization project is justified if savings in the range of 5 to 20 percent can be obtained [3. p35].

(d) Since highway revenues for a private owner are proportional to the number of highway users, the private highway owner has more incentive to provide quality highway service [3, p35].

For a successful public/private partnership, three important ingredients are required [1, p1]. First, there must be a willingness on the part of both partners to seek out joint opportunities. Second, the public partner should have prior knowledge, before bringing in a private partner, that the potential demand for service in a geographic location will probably be heavy enough to warrant privatization. Third, there must be desirable economic and/or developmental opportunities at and around those geographic locations. Privately owned facilities offer two major attractions to investors: a large, steady pretext cash flow and large depreciation write-offs [5, pp102-106]. Public/private partnerships spread financial responsibilities and provide opportunities for business expansion. These partnerships meet private section profit goals and public sector service goals.

PRIVATE SECTOR PARTICIPATION IN TEXAS

The private sector participation in highways would be advantageous in Texas considering the vast network of roadways in the state: 73,181 miles of state-maintained road (D-10 "Road Mileage Monthly Summary, 9/30/88,") and approximately 200,000 miles maintained by other government entities [4, p35]. The financial strain, caused by increasing highway expansion and continued urbanization, has forced the state to look towards the private sector. At least seven nontraditional financing mechanisms have been created in Texas.

1. Transportation Corporations

Transportation corporations are non-profit, tax-exempt corporations that can accept property and funding donations, primarily to assemble right-of-way for highway transportation projects. These corporations, which are formed by private property owners, can also assist in the planning and design of transportation facilities. Preliminary alignment studies have been done with donated funds. The corporation is governed by a board of at least three directors who are appointed by the SDHPT Commission. Six transportation corporations have been created since 1984, with length of roadways ranging from 7 to 155 miles [4, p35]. The first corporation, Grand Parkway Association, has been fairly successful in obtaining lands for the $600 million, 155-mile Grand Parkway project [4, p35].

2. Road Utility District (RUD)

A RUD, acting as an official subdivision of the state, is a legal entity which is empowered to construct, to acquire, or to improve major arterials or feeder roads. The RUD projects are to be financed by an ad valorem tax on property within the district. The RUD may be dissolved upon completion of the roadway improvements project and full payment for the project. Because of the full cooperation needed among landowners, RUD concept is most suitable for a few landowners. The major advantage of a RUD is that the burden on the private developer to pay the full cost of roadway improvements is reduced. Funding is obtained through tax-free bonds and a special ad valorem tax. One RUD in Denton County has been approved by SDHPT Commission.

3. Municipality Utility Districts (MUD)

MUDs, which were originally meant to fund drainage-related developments, have been granted the same powers as Road Utility Districts (RUD). This new legislation is wise, considering that the districts already have taxation powers. MUDs can generate a more comprehensive development plan which encompasses transportation, drainage, navigation and other natural resource developments. MUDs are still in the planning stages.

4. County Road Districts (CRD)

These special districts levy an additional tax for roadway improvements within a district. CRDs are authorized and governed by the elected County Commissioner's Court of the county in which the district lies. The first CRD was established in Southwest Travis County Road District One in 1984 [4, p35]. CRDs are more popular than

RUDs because they do not require 100 percent landowner approval or the establishment of a separate governing body [4, p35]. They can also be used for any type of roadway.

5. Tollways

The private sector and local governments have been interested in the development of toll roads. A good example is the Harris County Toll Road Authority, which received $900 million in bonds in September 1983 [4, p35]. Most toll facilities in Texas are operated by the Texas Turnpike Authority. Direct private sector involvement in Texas tollways is currently limited to the operation of several toll bridges and a ferry across the Texas/Mexico border.

6. Developer Fees

A developer of a new project is held responsible for the new traffic demands generated by his project. The developer has to finance roadway improvements by paying a developer fee. Dallas and one of its suburbs, Farmers Branch, have enforced traffic impact fees for new developments in the amount of $0.50 for each square foot [4, p35]. The City of Austin requires the issuance of a letter of credit for a specified amount on the basis of the estimated traffic impacts.

7. Negotiated Improvements and Donations

Developers in major Texas cities negotiate with city transportation or planning staff to provide needed roadway improvements in the area of new developments. Developers in several Texas cities and counties have donated land for right-of-way. $122.5 million of right-of-way needed to construct State Highway 151 was donated by the private sector through local government. Fort Worth officials recently offered $6.3 million worth of right-of-way towards construction of State Highway 121 [4, p35].

CONCLUSION

The privatization process has many barriers to overcome. One barrier is simply bureaucratic inertia. There is in-place legislation to deal with, like Section 129, Title 23 [5, pp102-106]. This piece of legislation forces the state to reimburse the federal government the cost of constructing a federally aided road if the state intends to impose a toll on that particular road. There are specific problems in relation to the private financing mechanism existing or being implemented in Texas. Developers are hampered by their inability to deduct local taxes from income taxes. The strategy of relying on property value increases to fund roadway projects may backfire. Despite the obvious disadvantages, privatization is a viable option to be pursued. Private innovation and capital can definitely enhance the quality of our highways.

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The information contained herein is experimental in nature and is published for the development of new ideas and technology only. Any discrepancies with official views or policies of the TSDHPT should be discussed with the appropriate Austin Division prior to implementation of the procedures.

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