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TECHNICAL QUARTERLY

AN EXCHANGE OF IDEAS
Editor:
Kathleen M. Jones

HOT WEATHER CONCRETING TIPS

Concreting in hot weather is just a fact of life in Texas. In many districts, the damaging combination of rising ambient temperature, low relative humidity, and wind can occur in spring and fall, as well as in summer. These combined conditions can:

- Increase water demand,
- Increase slump loss,
- Speed up setting,
- Create plastic shrinkage cracking (Fig. 1),
- Reduce freeze-thaw durability,
- Lower ultimate strength.

To cope with these conditions some practical methods and control procedures have been developed over the years. Generally, having a well thought out plan in anticipation of the hot weather conditions is the best precaution against jobsite concreting problems.

Ideal conditions for placing concrete are: an air and concrete temperature of about 60°F; relative humidity of 75 percent or higher; and wind velocity of 5 mph or less. These ideal conditions seldom happen all together; therefore, precautions and protective measures are often necessary [6]. A reasonable step toward developing a plan is to establish under what conditions the plan will take effect.

Texas Specification 420.11 requires that concrete for cast-in-place bridge slabs and top slabs of direct traffic structures be placed when the concrete's temperature is 85°F or less. While paving concrete is not subject to as strict a temperature specification, Item 360.6(3) states that paving concrete must be placed within 30 minutes after mixing or it shall be rejected and disposed of. If, in the opinion of the Engineer, the temperature, wind and/or humidity conditions are such that they would not damage the concrete quality, the specified placing time may be extended to a maximum of 45 minutes. Of course, the higher the ambient temperature, the sooner any freshly placed concrete is liable to start crusting and shrinking, as well as setting. Dry air moving quickly over the surface of fresh concrete increases the problem because it vastly increases the evaporation rate. The lower

FIG. 1: Plastic shrinkage cracking.

INSIDE...

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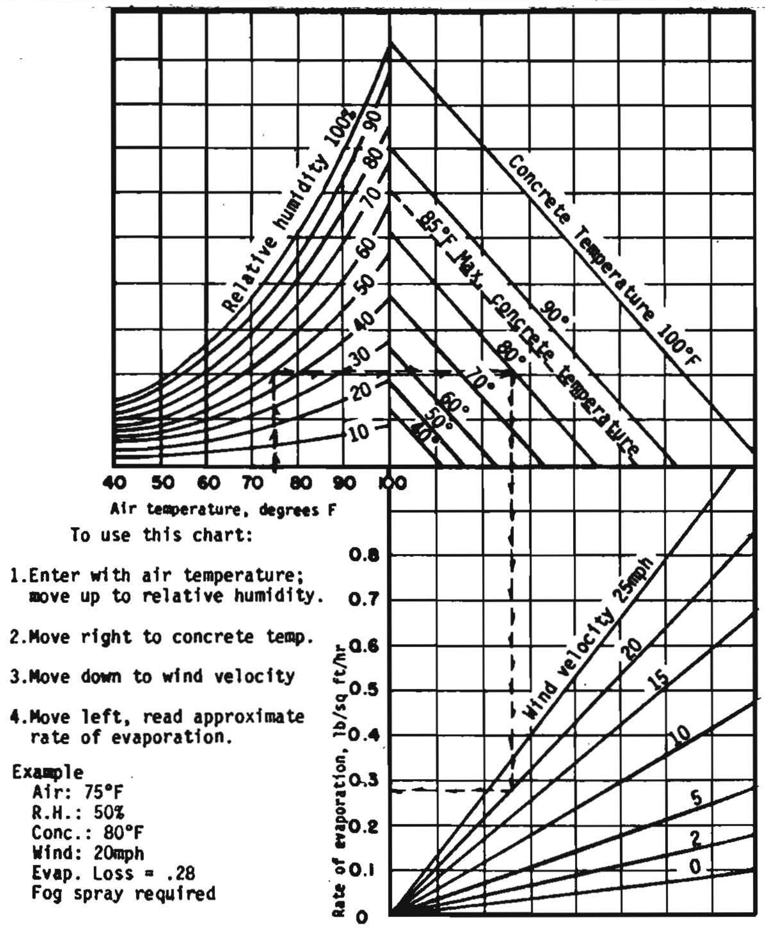

*FIG. 2: Nomograph of the effect of concrete and ambient temperature, relative humidity, and wind velocity on the evaporation rate of surface moisture from concrete (**Concrete Construction Manual**).*

the humidity and the brisker the breeze, the higher the evaporation rate is.

Although the thresholds may vary according to type of concrete, a useful rule of thumb for when to take hot weather precautions might be: when the ambient temperature is in the high eighties and climbing, the fresh concrete temperature is approaching 80°F, the relative humidity is less than 50 percent, and the wind velocity picks up to better than 7 mph [1 p135; 3, p64]. The Department's ***Concrete Construction Manual, Construction Bulletin C-1***, Chapter 4, deals in depth with hot and cold weather problems, and should be referred to for more detail (Fig. 2) [4].

Some details to consider when developing a comprehensive hot weather plan are:

1. Make sure the trial batches are made under the anticipated ambient conditions and construction procedures, as well as with the jobsite materials and any admixtures called for in the design.

2. Offset rapid setting time and increased water demand by: (a) cooling the concrete materials; (b) selecting a retarding/water-reducing admixture; (c) cooling the materials and using a retarding/water-reducing admixture.

(a) Water and aggregate temperatures have more effect than dry cement temperature on fresh concrete. The mixing water can be cooled or chilled. Tanks and pipelines carrying mix water can be buried, insulated, shaded or painted white to keep direct sunlight from transferring heat to the water. Ice can be used, with caution. Enough water must be present as liquid to start hydration, but the amount of water and ice must not exceed the designed water/cement ratio and the ice must all be melted by the time the mixing is finished.

A 15°F temperature reduction in the aggregate will lower the fresh concrete temperature by 10°F [1]. Shade the aggregate or, when relative humidity is low, sprinkle it with water to promote evaporative cooling.

(b) Retarding agents (ASTM 494 Type B), used by themselves, tend to produce concretes that show lower strengths at 1 to 3 days. Therefore, Texas specifications couple the use of retarding agents with water-reducing agents (ASTM 494 Type D), in order to produce higher early strengths [2]. (Water-reducing agents, ASTM 494 Types A or F, without retarder, may be used to produce high strength concrete in favorable weather conditions.)

Remember that special provision to Item 437 states, "**High range** water reducers will be used only to meet special requirements and will require the written approval of the Engineer on each specific project. A satisfactory work plan for control shall be submitted by the contractor for approval and an evaluation of the concrete containing the admixture will be performed by the Engineer." A good outline of minimum details and content for such a work plan, as well as helpful hints for its development, is given in *Admixtures for Concrete*, a paper presented by Gerald Lankes at the Thirty-Second Annual District Laboratory and Engineering Personnel Meeting, 23-24 March 1988, Abilene, Texas (available from D-9 or D-10R Technology Transfer Library).

3. Subgrade, forms, and reinforcing steel should be sprinkled or fogged with cool water before the concrete is placed; however,

avoid soaking the subgrade to the point that there is standing water on it. There should be no puddles on the forms, either.

4. Make sure the workforce is sufficiently large and that equipment is in good repair, so that transporting, placing and finishing the concrete can be done as swiftly as is practical. Consider having backup vibrators on the jobsite, so concrete consolidation will not have to stop if an overworked vibrator breaks down.

5. Coordinate closely with the plant so concrete can be discharged as soon as it arrives.

6. When adding withheld water to the concrete at the jobsite, be careful not to exceed the specific *mix design* water, which may well be less than the theoretical maximum amount of water allowed for by Specifications. The successful exercise of this procedure depends on the *accurate* reporting on the batch ticket of either aggregate absorption or free moisture.

7. Use temporary windscreens and sunshades to protect newly placed concrete at joint areas to help minimize cold joints.

8. Have temporary coverings, such as polyethylene sheeting, on hand to protect the concrete if construction delays occur between placing and finishing.

9. Float as soon as the water sheen has left the surface. While the timing sequence of the "finishing train" varies from job to job and cannot be regulated in advance, it is particularly critical during hot weather. Be prepared to continually adjust the timing sequence to produce the best results.

10. Alert the crew to watch for plastic shrinkage (hair) cracking. Make sure they know the inspector to whom evidence of plastic shrinkage cracking should be reported. If the crew is relatively green and has not worked in hot weather conditions before, a brief explanation may be in order of plastic shrinkage cracking (Figs. 3 & 4) and how to identify these short, irregular cracks that occur in freshly placed concrete when water evaporates from the surface much faster than it is coming up to the surface. Pass around a laminated 8 x 10 photo clearly showing plastic shrinkage cracking so they will recognize it.

11. Have a plan worked out to accelerate curing operations should plastic shrinkage cracking start. Close plastic shrinkage cracks that have appeared during finishing by striking each side of the crack with a float and refinishing. Fog spray the refinished area to raise the relative humidity until the specified curing procedure can begin.

12. When water curing is specified, make sure the *curing* water is not significantly colder than the concrete. Otherwise, thermal cracking may occur due to stress from the temperature difference between the concrete and the water.

13. To ensure representative flexural and compressive specimens, test samples must also be protected from excessive moisture loss until they can be placed in a curing tank. This will mean using something more than the standard two layers of burlap or cotton mat kept saturated with water.

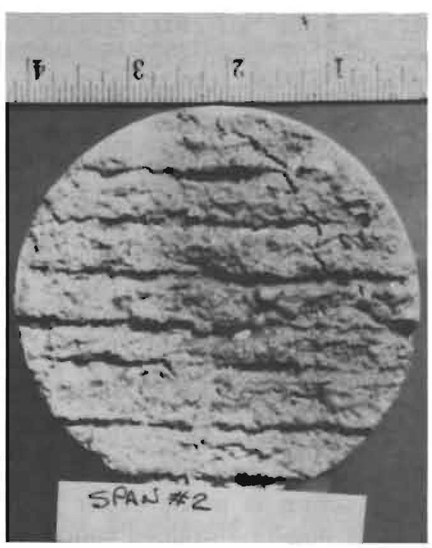

FIG. 3: Core containing plastic shrinkage cracking.

During the middle of summer, especially in the more arid districts, hot weather problems can be controlled more easily if concrete placement is restricted to early morning, evening or nighttime hours. When feasible, this practice results in less plastic shrinkage and thermal cracking in pavements. Shifting the schedule around can be the most economical way of dealing with prolonged hot, dry, windy weather if an unusual or very difficult concrete job is planned.

For more information, contact Mr. Gerald Lankes (D-9): STS 241-7331, (512) 465-7331; James Joslin (D-6): (512) 463-6508, STS 255-6508; or Mr. Berry English (D-5): STS 245-5093, (512) 371-5093. A slide program, ***Hot Weather Concreting***, (TFCONC.3, June 1985) is available from D-9. Additional tips may be found in the D-5 ***Concrete Construction Manual, Construction Bulletin C-1*** [4].

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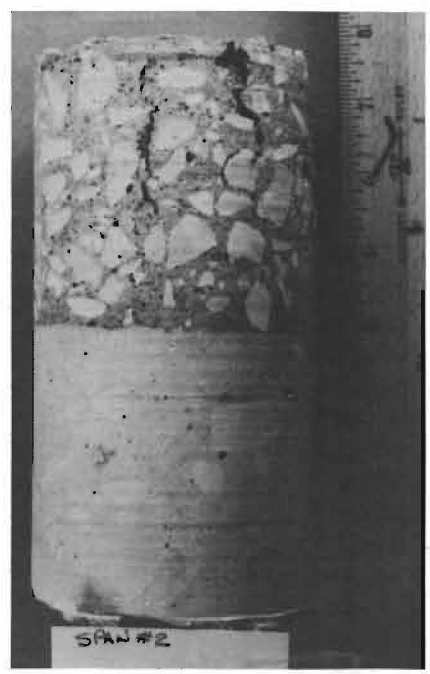

FIG. 4: Side view reveals the depth of damage.

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ACHIEVING MAXIMUM BOND

The use of prestressed concrete panels in bridge deck construction has been a great aid in expediting deck construction and their use seems to be ever increasing. To function properly the deck must rely on bond between the prestressed concrete panels and the cast-in-place concrete placed on them. Every precaution should be taken to obtain maximum bond.

Sometimes panels arrive on the project with a surface coating which in some cases is sufficient to detrimentally affect bond. The source of this coating has not been definitely established. As panels are set they should be inspected for such coatings. It is usually a cream colored, very thin coating which can be easily removed by washing. Sometimes it is quite thick, especially in the low places where accumulations of this substance can occur. Where thicknesses are great, sand blasting may be required to properly clean the panels.

Another potential bond breaker is the accumulation of free water in puddles just ahead of cast-in-place concrete placement. Such water will act as a bond breaker if it is not removed before concrete is placed. Wetting of panels should be far enough in advance of concrete placement so that any excess will have time to drain away. Any remaining free standing water should be either blown or swept away prior to placing concrete. Any free standing water in which concrete is placed will work its way to the surface to produce finishing problems. Panels and other surfaces on which concrete is expected to bond should be clean, approximately saturated surface dry, and free of any standing water when fresh concrete is placed thereon.

From *SDHPT Bridge Tips*, No. 5 (7 January 1986), published by the Bridge Division (D-5) of the Texas State Department of Highways and Public Transportation.

INSPECTION TIPS FOR AIR-ENTRAINED CONCRETE

by Kathleen M. Jones
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WHAT IS AIR-ENTRAINMENT?

Entrained air is a system of nonconnected, extremely small air voids (0.05 mm to 1.25 mm [2]) purposefully put into concrete by the addition of a chemical admixture. Air-entrainment in concrete results in improved freeze-thaw durability, resistance to deicing salt scaling, resistance to sulfate attack, and workability. It also reduces bleeding and segregation. Entrained air should not be confused with entrapped air. Entrapped air bubbles are accidental, large, irregularly spaced voids which are mostly removed by consolidation.

Texas Departmental policy allows air-entraining admixtures to be added during batching, but does not allow the use of air-entraining cements because of their variability. Air-entrainment is often not critical in parts of Texas because freeze-thaw cycles are not an all over climatic concern. However, when air-entrainment is specified in construction plans, it is there for a good reason such as to increase resistance to ground water sulfates or to prevent scaling on a bridge deck. Therefore, air content should be carefully inspected at the appropriate intervals required in the SDHPT ***Construction Manual*** [7] and in accordance with the methods spelled out in the ***Manual of Testing Procedures*** [9].

The resistance of 3 to 7 percent air-entrained concrete to freeze-thaw action is much better than that of non-air-entrained concrete. Air-entrained concrete is more durable for several reasons. One reason is that the system of small voids acts as an "escape valve" for water that has reached the freezing point in the capillary channels of the hardened cement paste. The water, expanding as it turns to ice, can fill these voids without causing internal pressure in the concrete. Another reason is that in fresh concrete the air bubbles have a "ball-bearing" effect and act as a lubricant to help spread the concrete paste over the aggregate. This lubrication allows a lower water/cement ratio, better consolidation, and better watertightness, all of which increase durability (Fig. 1) [2].

INSPECTION TIPS

When air-entrainment is required by specifications, the job control tests need to be made at the same time and at the same location as the strength specimens for PCC

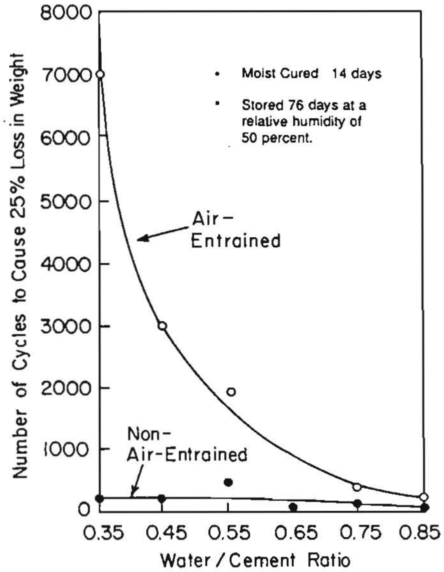

FIG 1: Influence of W/C ratio on freeze-thaw resistance.

pavements and at the point of concrete placement for structures. Only one test per set of strength specimens needs to be witnessed [7]. Test Method Tex-416-A details the three acceptable methods (gravimetric, volumetric, and pressure) for determining air content of concrete [9]. The Chace air indicator must *not* be used as a replacement for any of these tests. It is not reliable enough. (See Research Report 363 or the summary, "Evaluation of Chace Air Indicator," in TQ2-2.) The Chace indicator can only be used as a spot check between regular sampling intervals to get an idea of the *range* (low, medium, or high) of the air content.

Of the three acceptable test methods, the volumetric method is probably the best one for the field. It is the only procedure that can satisfactorily determine the air content of concrete made with any type of aggregate whether it be lightweight, dense, porous, or cellular. Unlike the pressure meter method, the volumetric method does not require individual meter calibration, i.e. finding the initial pressure line. Pressure meters also have problems with leaking air valves, dry or worn pump gaskets, and easily damaged pressure gauges [1]. Volumetric meters have no moving parts, aside from the clamps that seal the base to the upper chamber. The recent development of an anodized aluminum, lightweight volumetric air meter, which is 39 percent lighter than the standard brass version, makes the volumetric method even easier to handle in field tests (Fig.2). For example, the Lightweight-Roller volumetric air meter by Forney weighs 29 pounds empty and lists for $620. A pressure air meter from the same company weighs 39 pounds and lists for $640. Lightweight volumetric meters are approved for use by Materials and Tests Division (D-9). Equipment and Procurement Division (D-4) specifications can be obtained from Mr. Bryan Whitten, STS 255-8893, (512) 463-8893.

Personnel in charge of field testing need to make sure that samples are taken in accordance with Test Method Tex-407-A. This means from the middle portion of truck or batch hauling unit (the middle portion of the load being defined as that portion between 15 and 85 percent) when the air content test is being run in conjunction with making strength specimens. When just slump and air content are being measured, the sample can be taken from the first 15 percent discharged [9].

New personnel should be encouraged to develop good test techniques such as filling the bowl in three layers and carefully rodding each layer 25 times with a hemispherical-tipped rod. The sides of the bowl should be tapped sharply with a rubber mallet after each layer is rodded. The sample must be struck off evenly with the lip of the bowl. The lip's top and sides need to be wiped clean so that a watertight seal can be made.

The ***Supplement to the ASTM Manual of Aggregate and Concrete Testing*** makes some suggestions about the rocking and rolling procedure of a volumetric air meter to increase the accuracy of the test and shorten the rolling time:

1. Use alcohol to bring the water-alcohol level up to the zero mark after the funnel is removed in the initial filling to save time when dealing with air-entrained concrete.
2. Dislodge all the concrete in the base during the first shaking by inverting the device and sloshing the water from side to side. Repeat until you hear the aggregate rolling around in the meter.
3. Do not keep the meter upside down for more than 5 seconds at a time once the aggregate is free or it may get stuck in the neck of the meter.
4. After the aggregate is freed, incline the meter and roll it vigorously for 60 seconds.
5. Return to upright and open the top to add alcohol if the water level is obscured by foam.
6. Roll 60 seconds more. Take a level reading. Repeat until the level changes less than 0.1 percentage points between successive readings [1].

TROUBLESHOOTING

Air content in concrete is affected by many things such as:

FIG 2: Lightweight volumetric air meter.

when the entraining agent was added to the batch, ambient temperature, aggregate size, other admixtures in the concrete, amount of mixing, etc. By and large, a mix with an air content of between 3 and 7 percent should be workable, not stiff, and should look and feel "fatty." A mix with too much entrained air — over 10 percent — will often appear foamy. Some points to consider if the air content does not meet specifications are:

- Is the contractor using an air-entraining admixture that is on the D-9 approved list found on page A-3e of the ***Manual of Procedures?*** [8]
- Is the air entraining agent being batched by itself in the first mix water? Adding it in the first mix water ensures that it has adequate time to disperse. Adding it by itself avoids the problem of having it react with the retarder in the mix water and having solids drop out as a result [6].
- Is the batch plant's piping system in good repair? Low spots or leaks in the line may change the amount of admixture reaching the batcher [3].
- Is the cement contaminated? Masonry cement entrains huge amounts of air. If masonry cement has been shipped accidently or has contaminated trucks or railroad cars, this could be the cause of excessive air content [3].
- Has there been a field change regarding aggregate size? If so, air content should be changed on the specifications because needed air content for adequate durability varies with aggregate size. A change in aggregate source can also change the necessary air-entraining dosage by two or three fold for no known reason [3].
- How long and at what speed has the load been mixing? For low to normal slump concrete, too little mixing or prolonged mixing will reduce the effectiveness of air entraining agents. Extended agitation also results in a loss of entrained air. Air content loss of up to 2 percent has been documented for a period of agitation of about 42 minutes. For high slump concrete, agitation can increase air content with time probably due to an increase in cohesiveness of the fresh concrete [2].
- How high is the temperature? As concrete temperatures increase, water demand goes up and there is less water available to activate the air-entraining agent (AEA). In hot weather, concrete temperatures increase faster. Retarder helps, but even with retarders holding the initial slump constant, some reduction of air-entrainment will occur. The AEA dosage should be increased [2].

SUMMARY

Entrained air is a system of tiny, nonconnected bubbles evenly distributed thoughout the cement paste. Air-entrained concrete is specified for improved freeze-thaw durability, improved workability, resistance to scaling, and resistance to sulfate attack. It isn't a needless requirement. It is part of the inspector's job to see that concrete of the appropriate air content is delivered by the contractor. The volumetric air meter is probably the best apparatus for field testing air content. It is the only method capable of testing lightweight, cellular, or porous aggregate concrete. Many factors can affect air content; some have been presented above. For more information, please call Mr. Gerald Lankes (D-9): STS 241-7331, (512) 465-7331; or Dr. Ramon Carrasquillo (CTR): (512) 471-4585.

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ARTERIAL FLYOVERS INCREASE HIGHWAY CAPACITY

From ***Increased Capacity of Highways and Arterials Through the Use of Flyovers and Grade Separation Ramps: Arterial Flyovers****, Research Report 376-1, by Carlos Bonilla and Thomas Urbanik, II. Excerpted by Mohanan Achen.*

Flyovers are two-or-more lane grade separation structures on an existing arterial that overpass cross streets. Flyovers are a viable cost effective option to increase the capacity of congested arterial intersections and reduce bottlenecks at these intersections when other methods have been exhausted. The flyover concept has not been widely considered because of the difficulty in evaluating the feasibility of flyovers at any intersection. However, Report 376-1 gives methodology, case studies, and suggested warrants for flyover feasibility. It gives construction costs and consideration for two types of flyovers. The two types of flyovers are:

(1) Conventional flyovers

Conventional flyovers are highway-type overpasses used to solve arterial congestion. They have been in existence since the 1950's. The average construction period is about 23 months. They can increase intersection capacity by as much as 140 to 300 percent and reduce accidents by about 33 percent. They do not influence manufacturing land values at intersections, but do adversely affect land values of commercially zoned property.

(2) Prefabricated flyovers

The superstructure consists of prefabricated modular components and can be assembled in a short period of 4 to 6 months. Their initial costs are greater than conventional flyovers. However, their short construction period, the minimal impact on adjacent properties and the minimal delay and diversion of traffic have increased the popularity of prefabricated flyovers, especially in France and in Germany. A French study suggested that permanent flyovers should only be considered if there is a 30 percent capacity reserve or more to accommodate future traffic growth. Report 376-1 concludes that in Texas cases the conventional flyover will usually be less costly than the prefabricated ones.

BENEFITS

With unlimited right-of-way, there would be no need for a flyover. Within a limited right-of-way, flyovers dramatically reduce delay, the number of stops, and improve safety. Fifty percent reductions in delay periods have been obtained from the construction of flyovers. Delay savings in excess of 300,000 vehicle hours have resulted from the use of flyovers. Flyovers reduce the conflict points for through traffic, lower the number of stops, and maintain a more uniform traffic flow. The French observed that prefabricated flyovers reduced accidents by 25 percent within 3 months of opening a flyover to traffic. In 1966, it was discovered that reduced accidents at flyover intersections did not affect the number of accidents at nearby intersections. It was also discovered in 1975 that 88 percent of the accidents that occurred at major intersections, like right angle collisions, oblique collisions, and side swipes, could have been prevented with grade separation. Report 376-1 points out a strong relationship between the benefits of a flyover and the average approach volume at a congested arterial intersection. An important fact derived from this relationship is that based on a benefit-cost ratio exceeding one, a simple arterial flyover may be justified for a congested intersection with an average approach volume of 50,000 vehicles per day. $6.5 million worth of benefits can be expected at a flyover location where the total volume from four approaches equals 50,000 vehicles per day. A simple conventional flyover is estimated at about $5.0 million, including delay and diversion during construction.

IMPACTS

Flyovers greatly influence property access and local vehicle circulation. Generally, the access to properties beside the arterial, located near congested intersections, is negatively affected by a flyover. Flyovers create a physical barrier that prohibits left turns to and from the arterial 900 feet or more from the cross street in each direction. This negative impact should not necessarily deter the construction of a flyover. Access impacts are influenced by:

(i) Number of driveways along the arterial within the influence of the flyover;
(ii) Existence of a cross street within the influence of the flyover;
(iii) Time of day and intensity of traffic using driveways and cross streets;
(iv) Optional access to the affected parcels;
(v) Existing left turns or restrictions.

FLYOVER CHARACTERISTICS

Flyover design characteristics are determined by the unique traffic needs and environment of individual intersections. A California study suggested that the advantages of a flyover are maximized when:

(i) through movements are dominant;
(ii) turning movements are comparatively low;
(iii) turning lanes are not reduced.

The five design considerations are right-of-way, structure length, structure width, at-grade treat-

continued on page 12. . .

A TOOL FOR ACP QUALITY CONTROL?

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Quality control is an important issue, not only in highway construction, but also in all other construction industries. The concrete floor slab industry, for instance, requires very tight control to get fine tolerance necessary for floor acceptance. Six years ago, the Edward W. Face Company of Norfolk, Virginia, developed an instrument for the concrete slab industry that provided precision profile measurements at a greater speed and accuracy than traditional rod and level. The instrument (Fig. 1) is called the Dipstick for 'Digital Incremental Profiler'. Transport Canada began using it successfully a few years ago to measure bridge deck tolerances. Now the Texas State Department of Highways and Public Transportation is looking into it as a good candidate for quality control of hot-mixed asphalt concrete pavements, as well as bridge decks. A preliminary evaluation of the Dipstick was done at the Center for Transportation Research (CTR) at the University of Texas under Research Project 1167. The results were so encouraging that the device will be included with various other types of pavement evaluation equipment in a set of tests and experiments to be done jointly by CTR and the Pavement Evaluation Section (D-10E) late in the summer.

The Dipstick is a compact, easy-to-handle instrument. Like rod and level, it measures the difference between elevation points along a survey line; however, it can be operated by a single person who does not have to be a licensed surveyor. The instrument is not operator-sensitive, is simple to use, and can be learned in about five minutes. The operator walks the Dipstick down a chalkline snapped on the wheelpath (or other area to be measured) by alternately pivoting the device about each leg. The difference in elevation between its two legs is determined by the machine, using an internal pendulum. Since the legs are on a 1-foot center, interval markings do not need to be made.

FIG. 1: The Dipstick.

FIG. 2: Carl Bertrand (CTR). assembles the Dipstick.

The prototype automated version under consideration consists of a 1-foot x 4-inch x 4-inch instrument box, a removable TRS-80 PC-2 18K computer, and a take-down handle (Fig. 2). On the box are two adjustable legs with metal ball-and-socket feet spaced on a 1-foot center. These legs are the means for sensing the point-to-point elevations. Above each sensor, on the top of the box, are LCD readouts (Fig. 3) of the current measurement which can be used for making manual records. The readouts are accurate to within plus or minus 0.001 inches. The internal pendulum is unbalanced as the Dipstick is rotated by the operator. The unbalance signals the PC-2 computer to stop taking readings until the pendulum balances again. The sequence takes about 4 seconds per measurement.

The PC-2 captures the data and calculates the difference between the elevation of its two legs. The printout gives, among other things, point number, point elevation relative to mean elevation, F-Number for flatness, local 3-point curvature in inches, and International Roughness Index (overall and to any specific point). International Roughness Index (IRI) is the world standard for quantifying pavement roughness. It has been adopted by the FHWA as the standard measurement for SHRP test pavement reporting.

Before measurements are started, the Dipstick's feet must be leveled. The Dipstick is placed on a hard, fairly level surface. Circles are drawn on the surface around the footpads of the legs. The LCD

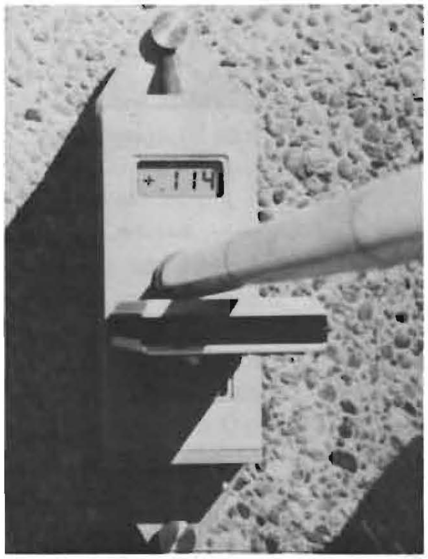

FIG. 3: The LCD display.

readings for both display panels are noted. The Dipstick is then lifted and rotated 180° and the footpads are placed within the circles. The LCD displays should be within 0.003 inch of the initial readings. If the readings are not within 0.003 inch, the legs must be adjusted until a set of readings within 0.003 inch is obtained.

The operator runs through a short, menu-driven start-up program on the PC-2 computer. When the computer signals that it is ready, the operator places the rear foot of the Dipstick on the start point and presses the start-reading function key. The operator holds the Dipstick steady until the computer captures the data. The operator then rotates the Dipstick around its foremost foot to the next point (Fig. 4). The LCD screen blanks and a series of beeps are produced by the computer. The Dipstick is ready for another elevation after the new display appears and the number is stable. Operators should keep an eye on the numbers that come up on the display screens. Because the machine is accurate to within a thousandth of an inch, two readings which are exactly the same at two successive points should be manually noted as a false reading. This does not occur frequently.

FIG. 4: Operating the Dipstick.

Operator error can be determined by 'closing the loop' (Fig. 5). The isosceles triangles at the loop ends need to be in whole feet because the Dipstick can not take a partial reading. The readings taken in the triangles are canceled out and the absolute values of the difference of the two long sides are compared. Error is usually negligible, particularly considering that the machine is accurate to the thousandth of an inch, whereas the best rod and level is accurate only to the thousandth of a foot. The calculated operator error on one of the initial CTR tests was 0.002 percent for the 199 readings it took to close the loop. The difference in elevation between the first and last reading was 0.003 inches. Another test site showed an operator error of 0.0045 percent over 416 readings.

Initial testing in Texas was done at three sites at Balcones Research Center (BRC) and at one site at Oakmont and 37th Street in Austin. Two sites at BRC were 300 feet long. Each of these two sites had 100 feet of PCC pavement and 200 feet of ACP on different types of subbase. These test pavements had originally been used in

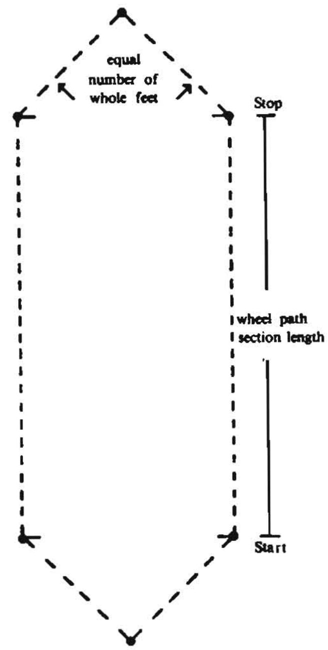

FIG. 5: Closing the loop.

a study for the Attorney General's Office on the damage done by overloaded trucks. The ACP pavements were rutted in varying degrees. The third BRC site was 970 feet of ACP pavement on a 2 percent grade. This section, designated as roadway "D," was chosen because of its gradual grade and relative smoothness. The Oakmont and 37th Street section was 200 feet in length. This section showed severe elevation changes for drainage purposes. A rod and level survey was conducted. Right and left wheelpaths of the westbound traffic lane were marked, as were start and stop locations.

As a control for the Dipstick, a crew of two did a rod and level survey at 2-foot intervals on the wheelpaths of the BRC test sections. It took the crew 7 hours to perform the survey, 6 hours to generate the reports and 4 hours to draw the profile of the roadway. It took one person approximately 3 hours to survey the three BRC sections using the Dipstick. The computer printout of selected results, including IRI calculations and a profile plot, was obtained in a matter of minutes. The plot, of the profile in the form that the existing program runs is difficult to compare directly to the rod and level profile plot. A raw data ASCII file, which can be transported to any software like Lotus or Cricketgraph, is being added to make direct comparison easy. Even so, the Dipstick saves at least 5 work hours, while reducing the crew to one.

The results of the Dipstick readings and rod and level survey on the BRC overloaded truck path are fairly close (Fig. 6). The Dipstick was run in the same direction as the rod and level survey, and one operator took the measurements. Note the apparent software error in the graphing program used to generate the graph: It appears that the starting point is actually less than 0.0 feet distance. For some reason, the Dipstick reading went up in elevation instead of down as represented by the rod and level plot. This initial difference was maintained through the first 94 feet. As the Dipstick began to climb the grade, the difference began to increase. This cumulative error was probably due to the foot being rotated and slipping slightly backward down the grade. The profiles from the two instruments are very similar as far as the peaks and valleys are concerned. The difference in elevation is 2.06 inches over the 296-foot distance. This calculates into approximately a .69 percent average cumulative error over the 296 readings.

The Dipstick's few drawbacks are all fairly minor. Aside from needing a raw data ASCII file, the software, as it stands, is computer- and printer-dependent. It needs to be made significantly more user friendly. The Dipstick's pitch sensitivity needs to be reduced for highway field use. This could help eliminate false readings. The footpads need to be rubberized or redesigned to prevent them from slipping backwards on grades. This would reduce cumulative error. Some automatic method needs to be devised of revealing, without going to printout, exactly how many measurements have been taken in the middle of a run.

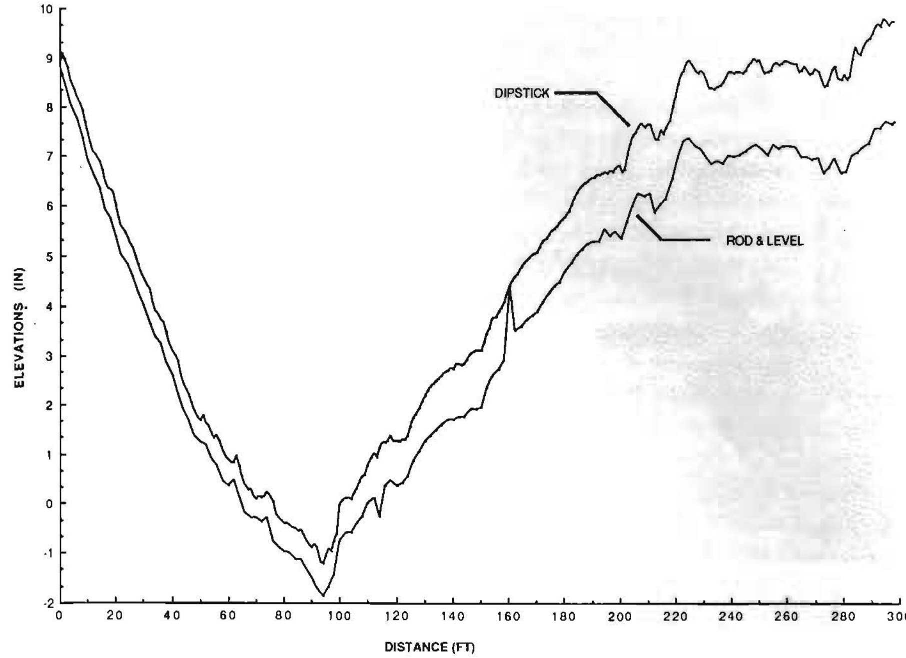

FIG. 6: BRC overloaded truck path comparison of rod and level to Dipstick.

The drawbacks are far outweighed by its potential as a quality control and calibration device. Unlike the California profilograph or the SD profilometer, the Dipstick measures profile directly (Class 1 profiler), like a rod and level. As a Class 1 profiler, it can be used to calibrate test sections for the profilograph and profilometer much faster and with less labor than rod and level. Although it is less expensive than a profilograph, it is not as fast and will probably not replace profilograph as the simplest method of ride quality control for PCC pavements. As for asphalt pavements, the Dipstick can be used on ACP immediately after compaction (the profilograph does not work well on ACP and the profilometer would have to wait until the mat cooled). For quality control of structure surfaces, it may prove very useful as well. It has six years of field testing in an industry that requires closer tolerances than highway work. It produces ASTM F-numbers for flatness of PCC surfaces (ASTM 1155). These F-numbers represent values from a series of bell curves which are correlated to construction methods and slab performance. (F-numbers have not been determined for PCC pavements, as yet.)

Facts from the CTR preliminary evaluation indicate that the initial $12,000 cost of the automatic Dipstick could be recouped after eight to twelve uses. The instrument is not operator-sensitive and is simple to use. All in all, it may well prove a valuable tool that every District can afford to have. More information can be obtained on the Dipstick preliminary evaluation from Carl Bertrand's (CTR) technical memo to the Project 1167 staff, *Evaluation of the Dipstick*, dated 27 April 1988. Copies of this memo are available from the ***TQ*** editor, Kathleen Jones: STS 241-7947, (512) 465-7947. Future issues of the ***TQ*** will carry the results of the D-10E/CTR series of summer tests and experiments planned for a host of pavement evaluation devices.

INTERPERSONAL COMMUNICATION SKILLS

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Being an effective communicator seems to be based on certain interpersonal components such as: an adequate self concept; the ability to be a good listener; the skill of expressing one's thoughts and ideas clearly; being able to cope with one's emotions, particularly angry feelings, and expressing them in a constructive way; and the willingness to disclose oneself to others truthfully and freely. The skills described in this handout are intended to improve both human relationships and the communication process. Attempts to improve communication must stem from desire to improve interpersonal relationships and to achieve mutual understanding. The skills are neither new nor unique and many people sometimes use them spontaneously when interacting with others. By themselves the skills do not assure increased clarity of communication. In fact if they are used inappropriately, they can arouse antagonism in the other person and obstruct communication. If, however, interpersonal interaction is based upon a genuine desire to understand the other as a person, these communication skills provide ways of overcoming many of the problems inherent in the communication process.

ACTIVE LISTENING

Active listening is most noticeable by its absence. When group members carry on more than one conversation at a time, interrupt one another, and jump from one subject to another, you can be sure people are not listening to one another. The consequences of the failure, particularly in the work situation, are that vital information is lost and ideas are not properly explored, leading to hasty and poor selection of alternatives. The failure of people to listen to one another is also very time consuming because we tend to repeat ourselves until we feel we've been heard.

Listening as a skill is something we do most poorly. Studies at Florida State University, Michigan State University and the University of Minnesota demonstrate that the average person remembers only 50 percent of what he/she has heard immediately after hearing it. Two months later, only 25 percent is remembered. The difficulty of effective listening stems from the fact that we think far faster than we speak. The average rate of speech for most Americans is 125 words per minute while the brain can process the language of our thoughts at an extremely high speed. Consequently, since the words we listen to arrive slowly, our brain has surplus time for other things. These other things include thinking of an argument to the speaker's position, constructing a question that can't be answered, looking for hidden motives, evaluating the speaker, or generally paying attention to something other than what the speaker is saying.

Active listening is an attempt to understand the speaker from the speaker's point of view. In doing this the listener is required to pick up and remember much more of what is being said. In addition, the speaker has little or no need to defend or protect, and will in turn be more likely to listen.

Four activities contribute to active listening: 1) anticipate where the conversation is leading, 2) objectively weigh the evidence being presented, 3) periodically review and summarize what is being said, and 4) pay attention to non-verbal behavior as well as the verbal. A key factor in poor communication is that tendency to critically judge and evaluate the speaker and his/her expressions. As a result the listener indulges in selective listening and is likely to force the speaker to justify, rationalize, defend or protect his/her position. Active listening requires that we assume the other person has useful ideas, information, or points of view and we listen carefully and attempt to understand adequately what the person's point of view is.

PARAPHRASING

Paraphrasing is a way of checking with the other person to be sure that you understand their idea or suggestion as it was intended. Any means of revealing your understanding of the other person's comment constitutes a paraphrase. The objective is to provide information to the other person so he/she can determine whether you understand the message as intended. You can have another person clarify what he/she means by asking what was meant or by saying "I don't understand." However, when you paraphrase you show what your present understanding is and thus enable the person to address clarification to the specificity and understanding you have revealed. Before you agree or disagree with a remark, you should make sure that the remark you are responding to is really the message the other is sending.

An additional benefit of paraphrasing is that it lets the other person know that you are interested in him/her. It is evident that you want to understand what is meant if you can satisfy the other that you really do understand the point. The other person will probably be more willing to attempt to understand your views, too. Paraphrasing increases the accuracy of communication and thus the degree of mutual or shared understanding. The act of paraphrasing itself conveys feeling—your interest in the other, your concern to see how he/she views things.

To develop your skills in understanding others, try different ways of conveying your interests in understanding what they mean and revealing what their statements mean to you. Find out what kind of responses are helpful ways of paraphrasing for you.

PERCEPTION CHECKING

Another basic skill for understanding another person is checking with them to make sure you understand their feelings. This skill complements paraphrasing in that it focuses on the emotive aspects of a message rather than ideas. To check your perception of the other's feelings, you describe what you perceive to be their feelings. This description should tentatively identify the other's feelings without expressing approval or disapproval of the feelings and without attempting to interpret or explain the causes of the feelings. Checking the feelings of another conveys a message of how I understand your feelings. Am I accurate?

Your perception of another person's feelings often results from what you are feeling or are afraid of or are wishing for rather than from the other person's words, tones, gestures, facial expressions, etc. Our inferences about other people's feelings can be and often are inaccurate. Thus, it is important to check them out. Perception checking responses conveys that you want to understand the other as a person, and that means understanding feelings.

Note that a perception check identifies the other's feeling in some way—disappointed, pushed out of line, etc.—and does not express disapproval or approval of the feelings; it merely conveys that this is how you understand his/her feelings and raises the question of whether or not your interpretation is accurate.

DESCRIBING OWN FEELINGS

Describing your own feelings helps the other person understand how you feel so that he/she can respond to you with greater efficacy. Although feelings are expressed in many different ways, usually people make no attempt to describe or identify directly the feelings themselves. When you express your feelings, the other person must try to infer your emotional state from a variety of cues. Since these cues are often ambiguous or even contradictory, the likelihood of misperception is great. When you directly describe your own feelings, however, the chances of misinterpretation and resultant action based on false assumptions are decreased.

In describing your own feelings, you should make clear what feelings you are experiencing by naming or identifying them. The statement should refer to I, Me, or My and specify some kind of feeling by name, simile, or figure of speech. The aim in describing your own feelings is to provide the other with accurate information about your emotional state, not an effort to coerce the other into changing annoying actions so that you will not feel as you do.

ARTERIAL FLYOVERS *continued from page 7. . .*

ments and geometrics.

(1) Right-Of-Way

Limited lateral (safety) clearances are a major constraint in determining lane width, capacity and safety. Trade-offs between uniform roadway geometrics, which are expected by motorists, and maximum number of lanes within available right-of-way can result in marginal safety clearances, low type (desirable minimum) clearances, or high type clearances that include safety shoulders. (Refer to Table 1.) Marginal clearances are not recommended except as temporary measures.

(2) Structure Length

The profile of a flyover is determined by the design speed, the required vertical clearance above the cross street and the span over the cross street. The vertical clearance should be 16.5 feet with a minimum value of 14 feet.

TABLE 1: Minimum right-of-way for urban arterial flyovers. (feet)

	Two Lane	Four Lane	Six Lane
Marginal	76	98	--
Low Type	100	120	140
High Type	120	144	168

(3) Structure Width

The structure width is mainly determined by the number of lanes, lane width and lateral clearances. The ideal lane width would be 12 feet. Structural requirements for three different types of flyovers are:

(i) Marginal safety clearance flyover — 10- to 11-foot lanes and a maximum of one foot of lateral clearance;

(ii) Low type flyover — 11- to 12-foot lanes, 3-foot shoulders, maximum design speed 45 mph;

(iii) High type flyover — 12-foot lanes, 8- to 10-foot shoulders, speed limits the same as the rest of the facility, opposing traffic separated by a guardrail or barrier wall.

(4) At-Grade Treatments

The at-grade transition, dividing through traffic and turning traffic, must be logical, simple and safe to follow. The at-grade intersection should be treated as a wide intersection rather than as a diamond interchange. The design speed of the arterial should determine the degree of tapering. A minimum paved lane width of 19 feet is recommended between both face-of-curbs to permit passing of a stalled vehicle and to make allowance for enough single-unit trucks or buses in the central design. When arterial lanes are dropped, advance warning of the upcoming flyover should be made.

(5) Intersection Geometrics

The number of entry lanes at the intersection should clear the intersection within each cycle. A 100-foot clear span for a flyover enables the use of eight 12-foot lanes on the cross street. The flyover structure requires some lateral displacement of arterial left turn lanes to prevent overlapping paths and closer turning lanes for simultaneous left turns (Fig. 1). Four solutions to the simultaneous left turn problem are:

(i) Lengthen the mainspan using a very long radius curve;
(ii) Use lead-lag signal phasing to prohibit simultaneous left turns;
(iii) Allow vehicles to turn prior to entering the intersection;
(iv) Provide left turn lanes under the structure — an expensive option (Fig. 2).

The delay savings accrued from the use of simultaneous left turns, because of time savings, may surpass the extra expense of the modified structure and make it cost effective.

COST

In general, flyover construction costs (Table 2) can be divided into five different categories. They are:

(i) The structure proper — the most expensive and the most time consuming to estimate;
(ii) At-grade improvements;
(iii) The intersection signals, signs and illumination;
(iv) Utility relocation;
(v) Traffic handling during construction.

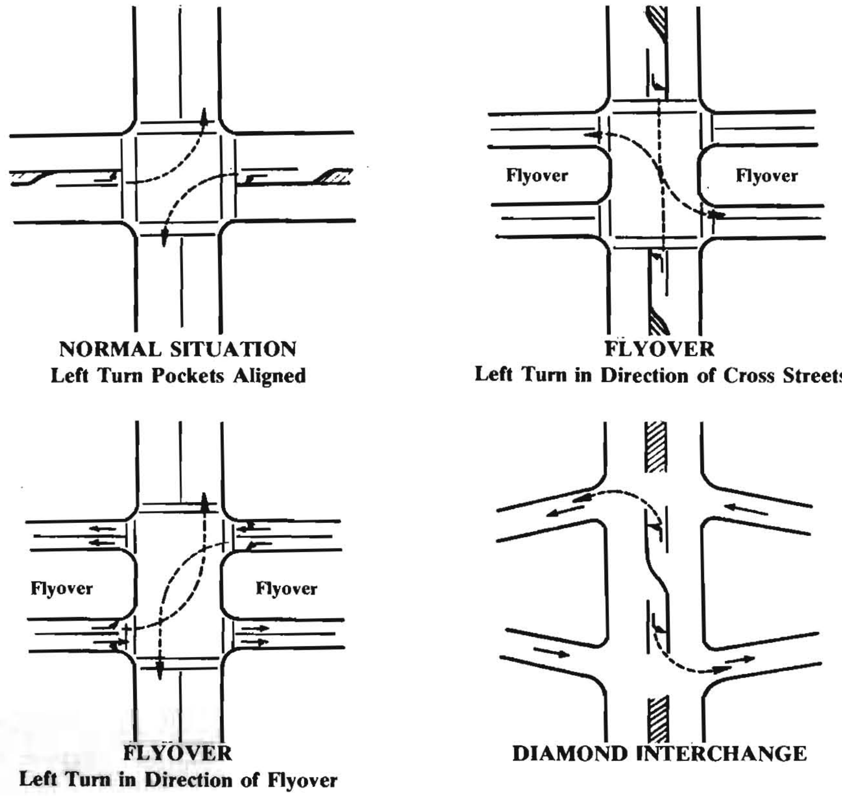

FIGURE 1: Conflicts of simultaneous left turns.

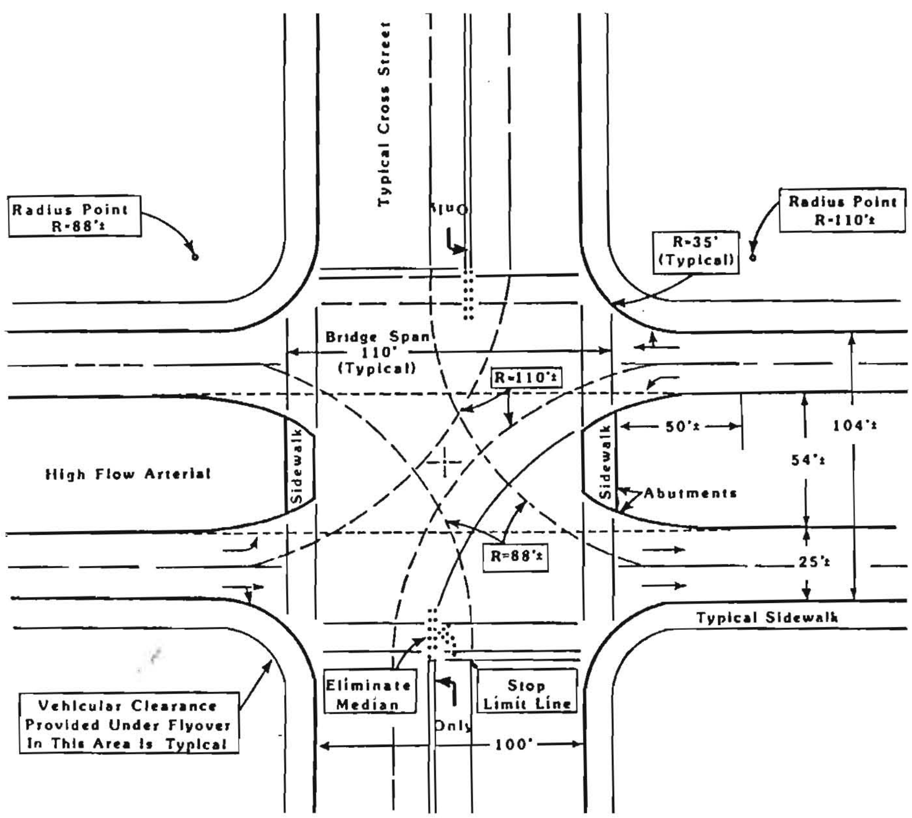

FIGURE 2: Optional solution for simultaneous left turns. *Source: JEF Engineering, 1982.*

TABLE 2: Direct construction costs of typical flyovers.

(1985 million dollars)

Construction	Type[1]	Lanes		
		2	4	6
Conventional	Low	1.62	2.17	2.72
	High	4.19	5.19	6.20
Prefabricated	Low	2.85	4.49	6.13
	High	6.23	8.49	10.75

[1]Low means designed for 35 mph and with limited right shoulders; high means designed for 60 mph and with full right shoulders and an 8-foot median provided with CMB.

TABLE 3: Immediate rate of return.

(First Year Life)

Case	Conventional	Rank	Prefabricated	Rank
1	0.39	4	NA	--
2	0.30	5	0.21	3
3	0.52	2	0.20	4
4	0.53	1	0.58	1
5	0.45	3	0.30	2
6	0.19	6	0.14	5
7	0.16	7	0.10	6

The structure costs include the intersection bridge, retained and/or viaduct type ramps, barrier walls, and portland cement concrete running surfaces. The at-grade improvements to the intersections and utilities and the traffic handling costs vary significantly and are included in the indirect costs. Motor and vehicle operating costs are assumed to increase by 25 percent during construction because of lane closures, and because of the reduction in geometric standards in the absence of a detailed control plan.

Prefabricated structures are 50% to 125% more capital intensive than the conventional ones. Utility relocations are estimated at one quarter, and traffic handling at one half, the cost of conventional flyovers.

In terms of immediate rate of return (first year benefits divided by construction costs), prefabricated flyovers do not appear to have an edge over conventional flyovers. According to the 376-1 test cases, conventional flyovers have immediate return rates which, in the better cases, will break even in about two years (Table 3). Only one of the prefabricated flyovers shows an immediate return rate of above .5, which means that it would break even in about two years. The rest would take longer, since the next highest is .3.

SUGGESTED WARRANTS

A set of warrants to justify development of a flyover has been proposed. If the conditions of these warrants are met, a flyover is justified based on function and on economics.

1. The intersection is a bottleneck on an arterial and conventional traffic engineering measures, such as prohibiting turning movements, cannot resolve the capacity problems.
2. A minimum of four arterial through lanes already exists and maximum use of the intersection right-of-way has been made. The sum of critical lane volumes approaches or exceeds 1200 vehicles per hour.
3. It is very expensive and/or contrary to the arterial objectives to obtain additional right-of-way.
4. Impact on access to adjacent properties and minor streets limited to right-turn-only movements is not severe. No traffic crossing the arterial should be allowed closer than 200 feet from the flyover's touchdowns.
5. The accident rate (accidents per vehicle entering the intersection) is significantly higher than rates on nearby intersections of the same arterial. Conventional traffic engineering measures cannot resolve this problem.
6. Benefit/Cost ratio is greater than three based on the method incorporated in this report or as approved by the SDHPT. Ratios above one may be justified but a detailed analysis should be conducted to include all benefits and costs.

A screening method for flyovers and a detailed analysis method using PASSER II Model are outlined in Report 376-1. SDHPT uses a standard multiplier of 1.2 to account for mobilization, engineering and contingency costs. $2.0 million is a safe estimate for planning purposes. For prefabricated flyovers, utilities are estimated at one fourth and traffic handling at one half of the conventional structure. The prefabricated structure is 50 to 125 percent more capital intensive than the conventional structure. Maintenance costs for prefabricated flyovers may be higher. In general, conventional flyovers appear to be less expensive.

SIGNIFICANT BENEFITS WITH CTI SYSTEMS

Central Tire Inflation (CTI) systems are mechanical systems which allow truck drivers to vary tire pressures over a wide range while the truck is moving. By using CTI systems to lower tire pressures over low-speed, low-volume roads, considerable savings could be realized in the construction and maintenance costs of these roads. The U.S.D.A. Forest Service conducted a Proof-of-Concept Test with logging trucks which confirmed the lower tire pressure concept. The Forest Service then contracted an independent consulting firm to determine the benefits gained from using lower tire pressures. The study concluded the following benefits:

- Use of CTI Systems is technically and economically feasible.
- Significant savings can be expected in construction and maintenance of unsurfaced and aggregate surfaced roads.
- Significant reduction in tire damage.
- Significant reduction in impact-related breaking of truck parts.
- Potential reduction in tire wear.
- Potential reduction in fuel consumption.
- Potential reduction in personal injury and fatigue due to road impacts.

Two test programs, one in the Boise National Forest in Idaho and the other in Alabama, were conducted under the following similar conditions:

- Logging loads were hauled with tires at commonly used pressures (90-110 psi) and low pressures (20-45 psi).
- Road surface, equipment repairs, and driver fatigue and comfort were key considerations.

The following are general conclusions from the tests:

- Low-pressure tires have a definite healing effect on the road surface. Improvements include the densification and smoothing of ruts and washboards.
- Vehicle speed increases when a lower tire pressure is used over rough roads.
- Vehicles with low pressure tires can operate in wet conditions that would normally prohibit truck travel due to potential road damage or the inability of the trucks to negotiate the road.
- Impacts on truck and cargo are significantly reduced thereby resulting in few repairs and less down time.
- Driver comfort and control are greatly improved with the lower tire pressures on rough roads.
- Damage to tires is significantly less at the lower pressures.

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Although tests are still being conducted, all the evidence indicates that CTI Systems and lower tire pressures on rough low-speed, low-volume roads offer significant benefits. It is apparent that this concept is the beginning of a new era in low-volume road transportation.

Modified by *Wyoming T2 Tips* 3 (November 1987): 4 from "The Use of Central Tire Inflation Systems on Low-Volume Roads" by Edward Stuart III, Ed Gililland, and Leonard Della-Moretta. Vol. 1, pp. 164-168, ***Fourth International Conference on Low-Volume Roads, Transportation Research Record - 1106***, Washington, D.C., 1987.

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