A prototype prestressed concrete pavement, placed in six lengths that vary from 400 to 760 ft., will provide useful design and construction data for future full-scale highway and airport pavements.

The Federal Highway Administration recently constructed approximately 3200 ft. of 24-ft. wide, 6-in. thick, prestressed concrete pavement at Dulles International Airport (See Fig. 1). The completed pavement will be part of the airport road network serving the 1972 International Transportation Exposition (TRANSPO 72).

This is a prototype pavement constructed under the Research and Development Demonstration Projects Program which was established to demonstrate, by actual example, the practical utilization of research and development results in a way that shows their effectiveness and benefits for general adoption and use. Demonstration Project No. 17—Demonstration of Prestressed Concrete Pavement Construction—has as its objective to show that prestressed portland cement concrete pavement is practical and economically competitive with other types of pavements.

The purpose of the prototype pavement is to test the practicality of the design and construction techniques, to obtain maintenance requirements, to improve design criteria, to gather accurate construction cost data, to create interest by the States, and to provide information for contractors who might possibly bid on subsequent larger projects.

This contract is the first phase of a two-phase demonstration approach. If the design and construction techniques prove practical, and if additional pavement construction is considered economically feasible, a second phase will be initiated to encourage the construction of larger-scale prestressed pave-
ments on major State highway networks but also on an experimental project basis.

Potential advantages in prestressed pavements

Recently, several State highway departments have indicated an interest in design methods and criteria for use in adapting the principles of prestressing to pavement problems. Because of the problems around joints and the cracking of long slabs of conventional concrete pavement, the application of prestressed concrete to highway construction would appear to offer many potential advantages in performance and economy, such as:

1. Transverse joints to accommodate contraction and expansion movements could be spaced several hundred feet apart alleviating the joint problem to a large extent.
2. Thinner pavements should be adequate to support traffic loads when the pavement acts as a continuous slab.
3. Adequate structural joint and drainage design should be economically feasible with the reduced joint pattern.
4. The amount of steel necessary for adequate prestress design will be about 5 lb. per sq. yd. which is less than is used in all but the lightest conventional pavement.

Solution of the problems of joint failure, blowups, and crack maintenance.
could save millions of dollars each year and reduce the hazards to personnel performing maintenance on high-speed highways.

**Design and construction considerations**

The development of valid design criteria and construction methods for prestressed concrete pavements involves a number of problems which must be solved. Among the most important of these are:

1. The prestress which is needed for various slab lengths.
2. The expansion and contraction characteristics of the slabs.
3. The design of joints and drainage systems.
4. The warping characteristics of the slab.
5. The load carrying characteristics of the slab.
6. The development of construction procedures in which conventional paving equipment can be utilized.
7. The effect of pavement-base interface friction characteristics.
8. The development of practical and economical prestressing methods.

**Research objectives**

Earlier research efforts in these areas have established preferred methods of solution to some of the above problems. These methods were utilized and evaluated in the construction of Demonstration Project No. 17. Research on the constructed slab will also help to provide answers to some of the other questions. To observe the behavior of the experimental pavement, and to monitor movements, strains and temperatures, the slabs have been extensively instrumented by the Federal Highway Administration, Office of Research.

A cooperative FHWA-Federal Aviation Administration research study is also being conducted by the U.S. Army Engineer Waterways Experiment Station. Additional instrumentation has been installed for this study. Load testing of the prestressed concrete pavement will be conducted after TRANSPO 72 by the Corps of Engineers using an 18-kip truck axle load and a twin wheel 100-kip aircraft gear load.
Prestressed pavement details

The project consists of six prestressed slabs of various lengths between 400 and 760 ft. built using two different types of prestressing strand enclosures. Three of the slabs were constructed by placing 7-wire strand in ¾-in. steel tubing. After post-tensioning the strand, cement grout was injected through fittings spaced every hundred feet apart to lock the strand into the slab and protect it from corrosion. The other three slabs, including the 760-ft. long slab, are constructed with polypropylene sheathed strand that remains ungrouted. The strand receives its corrosion protection from a corrosion inhibiting grease.

The pavement was constructed of 6-in. thick, slipformed Class A concrete with Type II cement and a minimum 28-day specified strength of 4000 psi. Prestressing tendons consist of ½-in. diam., 7-wire strand located at 2-ft. centers ¼-in. below mid-depth. These strands have an ultimate strength of 270 ksi; full prestress load was 30 kips or about 0.7 ultimate. Transverse steel consists of either No. 3 or No. 4 bars at 30-in. centers, depending on the section. Details of the roadway and the prestressed concrete slabs are shown in Figs. 2 and 3.

A unique feature of the design is the relatively low prestress in the slabs. At the ends of each slab the compressive stress in the concrete is a mere 200 psi. Previous research has indicated that this may be adequate to prevent any cracking even in the longest slab.

Gaps between the prestressed slabs are 8-ft. long to facilitate use of post-tensioning jacking equipment. Special prefabricated terminals consist of 6-in., 17.25-lb. I-sections against which the strand chucks bear. The joint slabs, which are cast after post-tensioning is completed, are reinforced with two layers of 6 x 6 No. 3 gage wire fabric. To facilitate joint construction and load transfer across the joint (since sleeper slabs have been eliminated), a 6-in., 12.5-lb. I-section forms the ends of the joint slab and 15-in. long dowel bars, 1¼-in. in diameter, are located across the joints at 12-in. centers.

The constructed opening between joint and prestressed slab end I-sections
is approximately 1½-in. depending upon the length of the prestressed slab and the concrete temperature at time of construction. The space between I-beams is filled with a foamed-in-place polyurethane. Expected movement at the joint adjacent to the longest slab is expected to be approximately 1½-in. annually.

The slipformed concrete was hand finished, dragged with burlap and textured with a stiff brush. Concrete ingredients were heated to produce placement temperatures over 55 deg. F. The wet burlap curing medium was covered with polyethylene and straw to protect the concrete from temperatures that reached below 20 deg. F. during the December nights. No problems were encountered other than the normal starting difficulties and the slow rate of paving that resulted from feeding concrete from ready-mix trucks to the paving train via buckets and conveyor belt.

The pavement was placed over a 28-ft. wide cement treated subbase (4 percent cement), 6 in. thick, that was cured with a bituminous membrane and covered with two layers of 4 mil polyethylene to reduce friction under the slabs. Since the pavement was placed for the full 24-ft. width, a conventional centerline longitudinal joint was sawed to a depth of 2 in. No. 4 tiebars are 36-in. long on 30-in. centers. Details of the prototype prestressed pavement described in this section are shown in Figs. 4 through 9.

**Stressing procedures**

Prestress was applied in one-third increments until the full load of 30 kips was placed on each tendon. The first third was applied when the concrete reached a compressive strength of 1000 psi (less than 24 hours after placement), the second third at 2000 psi (generally...
Fig. 5. Bonded tendons in this slab are placed in steel tubing. Note the fittings for pumping in grout after the tendons are stressed and anchored less than 36 hours) and the full load at 3000 psi.

Several tendons were stressed at the same time. Starting in the mid-portion, alternate tendons were stressed, with the outer tendons jacked last. Prestressing was done by hydraulic jacks, using the terminal I-beam to jack against. The prestress operation stretched the tendons approximately 8-in. for every 100 ft. of slab length.

Fig. 6. I-beam end plate for prestressed slab serves as a bearing plate for strand anchors and supports dowels across the expansion joint.

Fig. 7. The 8-ft. space between ends of prestressed slabs is concreted after the slabs are cast and stressed.
Future considerations for prestressed pavements

This particular project was too short and too experimental in nature to indicate any economies of scale. If the underlying theory is proven to be correct in this project, it is hoped that projects several miles in length can be built utilizing specialized equipment which could show significant savings. The following operations can be used to reduce costs, delays and manpower requirements:

1. Thicknesses about 5 to 6 in. will allow increased paving speeds or additional width to be placed for a given quantity of concrete.
2. It may be possible to eliminate all transverse steel except tiebars.
3. It should be possible to use only 4 strands of steel per lane width. 0.6-in. diam. 7-wire strands, each with an ultimate strength of 58 kips would be spaced on 3 ft. centers. Hence the amount of steel is only 2½ lb. per sq. yd. as compared to 15 to 20 lb. per sq. yd. for continuously reinforced concrete pavements.

It is envisioned that paving a large-scale project would proceed as follows:

1. A strong cement treated subbase

Fig. 8. Hydraulic jacks stress each strand to 30 kips to provide 200 psi prestress in the pavement
would be constructed for the length of the project.

2. A bituminous curing membrane would be sprayed on.

3. A full width of a double layer of 4 mil polyethylene sheeting would be rolled out with a specially built piece of equipment. Both layers must be tacked down at the edges to prevent wind damage.

4. A specially designed trailer carrying reels of encased 0.6-in. diam., 7-wire strand pays out all the necessary strand on rough 3 ft. centers across the roadway. A reel contains about a mile of strand.

5. Approximately every 500 ft. (length depends on findings from Dulles) the strand is cut and moved aside slightly.

6. A preassembled structural steel block-out is staked in place. The strand ends are threaded through holes in the steel forms and temporary strand anchors installed. A typical blockout for a 6-in. thick 24-ft. wide roadway would consist of one side being an I-beam which becomes a permanent end of a slab. The other side would be a temporary steel angle that would be removed after the concrete had hardened and had been stressed. The beam and angle would be about 3 ft. apart and would be temporarily connected together with bracing to provide rigidity for handling. The beam and angle would be 5 in. high and 23 ft. 8 in. long to provide clearance for the paving equipment to pass easily.

7. The concrete is then slipformed into place. Special holding devices into which the strands can be inserted and removed are used to position the steel strands in
the extruded concrete. The machine is unlocked from the strand at a joint and locked on to strands at the beginning of the next slab.

8. Tiebars are depressed into the concrete with a wheel type device and a plastic parting strip installed to form a longitudinal joint. After the finishing machine passes, metal caps are placed on the top of the I-beam and the angle to build them up to the 6 in. pavement thickness. The adjacent concrete is hand finished and curing applied.

9. The concrete is then allowed to gain strength. If the pavement is expected to shrink or contract it may be necessary to apply more than one step of post-tensioning to prevent tensile cracks from occurring. If the concrete remains at close to its placement temperature for several days it is possible to apply full post-tensioning when the concrete reaches 3000 psi compressive strength (2 to 3 days).

10. A gang of four jacks with 10-in. throw is lowered from a mobile cart into the blockouts at the end of a slab and a jack is positioned on the end of each strand in one lane. Each strand is then pulled to 40 kips. Since this load will elongate the strand approximately 40 in. in a 500 ft. slab, the jacks would have to be regripped several times. The gang would then be moved to the adjacent lane and that completed. Next the jacks are moved to the other end of the slab and the strands are pulled just a few inches to bring that end to full force since about 20 percent of the force from the other end was lost due to friction. The adjacent lane is also done and the jacks moved to start on a new slab.

11. With the stressing completed, the 24 ft. long angle is removed. A second I-beam 6 in. high is fitted into place adjacent to the one already there and connected via dowels. Extension rods are connected to the strand chucks which are exposed on the opposite side where the angle used to be. The 3-ft. length of blockout is then concreted and after it gains adequate strength is post-tensioned against the main slab with torque nuts on the ends of the extension rods.

12. After the blockouts are filled and post-tensioned only one small opening between the two I-beams is all that remains to accommodate length changes of the slabs. Foamed-in-place polyurethane is used to fill the opening.

Overall a very efficient operation can be effected. The two major areas of concern are getting well consolidated concrete at the joints and in determining the time for tensioning. The tensioning operation is relatively simple and poses no problems. Filling the gaps with concrete will require some care but it should be fairly simple since each requires only about 1½ cu. yd. of concrete.

Other agencies are encouraged to place additional slabs in order to improve paving techniques and to develop additional design criteria. The FHWA is developing specifications for constructing additional sections and these will be available upon request.

Discussion of this paper is invited. Please forward your discussion to PCI Headquarters by July 1 to permit publication in the July-August 1972 issue of the PCI JOURNAL.