DISCUSSION

The lighted and the animated deer crossing signs caused a significant, although small, reduction in the speed of traffic immediately past the sign. The value of this small average reduction in speed in preventing deer-vehicle accidents was not determined in the present study. Several further questions must be answered before a conclusion in this regard can be reached: For what distance behind the sign is the lower speed maintained? Does lower speed indicate greater awareness and cautiousness of the driver, and therefore, increased safety to both the motorist and the deer? Further evaluation of deer crossing signs will attempt to answer these questions.

The present study, however, did reveal that a lighted deer crossing sign is observed by motorists and the warning heeded, at least to a degree. It also appears that the animated sign initiates a greater response on the part of the motorist than the lighted "Deer Xing" sign.

REFERENCE

1. Yeager, L. E. (ed.). Colorado Game Research Review. Big Game Research. Published by Colorado Division of Game, Fish, and Parks, 1969, 35 pp.

NOTE: This report was prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the Federal Highway Administration.

Unusual Prestressed Highway Pavement Built to Serve "TRANSPO 72" Show Near Washington

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Thirty-two hundred feet of prestressed concrete highway pavement was placed during the week of December 1, 1971, on the access road to the Dulles Airport site of TRANSPO 72, the transportation exhibition to be held May 27-June 4, 1972. The A1 Construction Corporation of West Pittston, Pennsylvania, paved the six long prestressed slabs for the general contractor, Shultz Construction Corporation of Reston, Virginia. The concrete was placed with a Maxon spreader and a CMI slipform paver, after which the concrete was hand-finished, dragged with burlap, and textured with a stiff brush.

The wet burlap curing medium was covered with polyethylene and straw to protect the concrete from temperatures that dropped below 20 F during the nights. No problems were encountered other than the normal starting diffi-

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culties and the slow rate of paving that resulted from feeding concrete from ready-mix trucks to the paving train via buckets and conveyor belt.

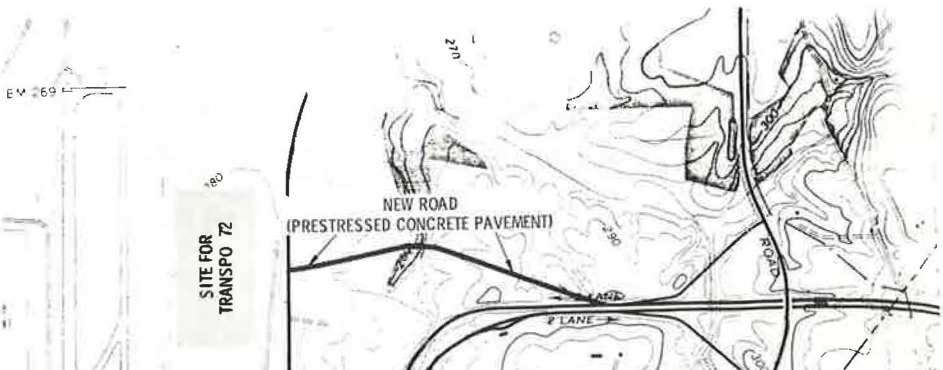
The 2-inch slump concrete contained $7\frac{1}{4}$ sacks per cubic yard of Type II cement. The diabase traprock aggregate all passed a 1-inch sieve. Concrete ingredients were heated to produce placement temperatures over 55 F. Portions of the pavement design were similar to that previously constructed on an interchange ramp pavement in Delaware.

The foundation of the pavement placed at Dulles consists of a 28-foot wide cement-treated (4 percent) subbase, 6 inches thick, that was cured with a bituminous membrane and covered with two layers of 4-mil polyethylene to reduce friction under the slabs.

The six prestressed concrete slabs are 400, 500, 600, 760, 500, and 400 feet long and are 6 inches thick. A full 24-foot width of pavement was placed and a 2-inch deep centerline joint was later sawed. The pavement is the first full-size highway prestressed pavement constructed and incorporates up to $3\frac{1}{2}$ percent grades and $6\frac{1}{2}$-degree horizontal curves with 0.06 foot per foot of superelevation.

One-half inch diameter seven-wire strand (ultimate strength of 270 ksi) was the only longitudinal steel spaced on 2-foot centers and placed $\frac{1}{2}$ inch below middepth. It was supported on No. 3 or 4 transverse reinforcing bars spaced on 30-inch centers. Centerline joint tiebars were No. 4 reinforcing bars 3 feet long and spaced on $2\frac{1}{2}$-foot centers. All strands were post-tensioned to 30,000 pounds (70 percent of ultimate) at the slab ends, bearing against 6-inch steel beams, which remain in place to strengthen the slab ends.

Three of the slabs were constructed by placing the seven-wire strand in $\frac{3}{4}$-inch steel tubing. After post-tensioning the strand, cement grout was injected



Location of roadway at Dulles Airport, near Washington, D.C.

Aerial view of the prestressed pavement looking west. White polyethylene stands out in highway right-of-way.

Steel tubing (strand enclosed) with grout fittings in place on 2-foot centers over No. 4 reinforcing bars on $2\frac{1}{2}$-foot centers. Concrete blocks are to prevent the wind from lifting the double layer of polyethylene sheeting.

through fittings spaced every 100 feet to lock the strand into the slab and protect it from corrosion. The other three slabs, including the 760-foot long slab, were constructed with polypropylene-sheathed strand that remains ungrouted. The strand receives its corrosion protection from a corrosion-inhibiting grease.

Concrete being spread.

A unique feature of the design is the relatively low prestress in the slabs; at the ends 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.

The transitions between the slabs consist of 8-foot-long joint slabs 6 inches thick, with their transverse edges reinforced with 6-inch I-beams and doweled to the prestressed slabs. The open joints between the I-beams will be filled with foamed-in-place polyurethane to form expansion joints at each end of the joint slabs.

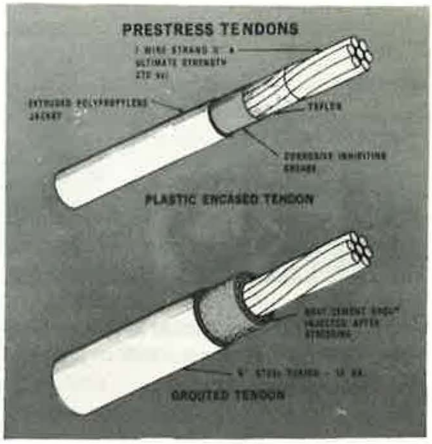
This full-scale highway pavement is a demonstration project of the Federal Highway Administration. It was designed by the Office of Research and constructed under the auspices of the Office of Development and Region 15. Instrumentation was installed to monitor movements, strains, and temperatures. In addition, the Federal Aviation Administration in cooperation with the FHWA and U. S. Corps of Engineers also placed instruments in the two 500-foot-long slabs to measure the effects of simulated aircraft loadings on the pavement.

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.

THE FUTURE OF PRESTRESSED PAVEMENTS

The particular project was too short and too experimental in nature to indicate any economies of scale. If the underlying theory is proved to be correct

Steam rising from the fresh concrete. Air temperature was 35 F, and the concrete temperature was 55 F.



Comparative views of the plastic-encased tendons and grouted tendons.

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. Thickness about 5 to 6 inches will allow decreased 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 four strands of steel per lane width; 0.6-inch diameter seven-wire strands each with an ultimate strength of 58,000 pounds would be spaced on 3-foot centers. Hence, the amount of steel is only $2\frac{1}{4}$ pounds per square yard as compared to 15 to 20 pounds for continuously reinforced concrete pavements.

It is envisioned that paving would proceed as follows:

1. A strong cement-treated subbase is constructed for the length of the project.
2. A bituminous curing membrane is sprayed on.
3. A full width of a double layer of 4-mil polyethelene sheeting is 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-inch diameter seven-wire strand pays out all the necessary strand on rough 3-foot centers across the roadway. A reel contains about a mile of strand.
5. Approximately every 500 feet (length depends on findings from the Dulles experiment) 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 block-out for a 6-inch thick, 24-foot wide roadway would have one side an I-beam, which becomes a permanent end of a slab, and the other side 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 feet apart and would be temporarily connected together with bracing to provide rigidity for handling. The beam and angle would be 5 inches high and 23 feet 8 inches 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 into 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 is 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 from 5-inch to 6-inch pavement thickness. The adjacent concrete is hand-finished and curing is applied.

9. The concrete then is 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 temperatures for several days it is possible to apply full post-tensioning when the concrete reaches 3,000-psi compressive strength (two to three days).

10. A gang of four jacks with 10-inch throws on a mobile cart is lowered into the block-outs at the end of a slab and a jack is positioned on the end of each strand in one lane. They are loaded to pull each strand to 40,000 pounds. Since this load will elongate the strand approximately 40 inches in a 500-foot slab, the jacks (10-inch throw) would have to be regripped several times. The gang is then moved to the adjacent lane and that is 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 to friction. The adjacent lane is also done and the jacks are moved to start on a new slab.

11. With the stressing completed the 24-foot-long angle is removed. A second I-beam 6 inches high is fitted into place adjacent to the one already there and connected via dowels. Extension rods are connected to the strand chucks that are exposed on the opposite side where the angle used to be. The 3-foot length of block-out 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 block-outs are filled and post-tensioned, one small opening between two I-beams is all that remains to accommodate length changes of the slabs. Foamed-in-place polyurethane is used to fill the opening so that debris is rejected.

Overall a very efficient operation can be performed. 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 should be fairly simple because each requires only 1⅓ cubic yards of concrete.

The procedures could be modified slightly to construct with strand that is grouted in place. We envision that the tubing would be in continuous lengths which would be unrolled in the field.