Arizona's Experience with Slip-Form Paving

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Arizona's first, and highly successful, use of the slip-form concrete paver had several noteworthy features. Profilograph readings averaged 2.5 in./mi; one ½-mi section indicated a value of 1.1 in./mi by the Hveem profilograph—the smoothest riding concrete pavement in the state. The width of the Guntert-Zimmerman machine was changed to pave both 24- and 35-ft wide roadways. Polyethylene strip was used for all longitudinal joints; in one test section it was unsuccessfully used for the skewed, transverse contraction joint. A central plant setup, using dump trucks as concrete haul units, was established.

•THE ARIZONA HIGHWAY DEPARTMENT awarded a contract in May 1963 for the construction of 6.1 mi of I-17, north of Phoenix, on a total bid of $5,056,448.90. The contract called for portland cement concrete paving, using standard forming as called for in the standard specifications. All of the paving was to be a 9-in. nonreinforced section on two roadways consisting of 3.6 mi of 36-ft wide pavement and 2.5 mi of 24-ft pavement.

In December 1963, the contractor requested the highway department to approve a change to a slip-form paving method. A cost analysis submitted reflected a $0.075/sq yd reduction in price for slip-form paving using polyethylene strips for the longitudinal and transverse joints. Sawing was to be eliminated completely. The change order, which included a central plant setup using dump trucks as concrete haul units was approved. Approval was also given to subcontract the paving to a company using a Guntert-Zimmerman paver and joint-laying machine. Work was started on Feb. 3, 1964, and was completed on April 17, 1964.

The base material on which the concrete paving was placed was specification aggregate base with the following grading: 100 percent passing 1-in. sieve; 95 to 100 percent passing ¾-in. sieve; 45 to 75 percent passing ¼-in. sieve; and 0 to 12 percent passing No. 200 sieve. The base was processed and laid with motor graders and compacted with a 16-ton pneumatic roller. Steel spikes were then placed at 50-ft intervals on each side, 4 ft beyond the pavement edge and to the elevation of the top of the base. The contractor then set stakes 16 in. above this grade at 25-ft intervals and piano wire was stretched taut between stakes on each side. The sensing units for controlling the machine followed these wires. The contractor set blue tops as grade stakes for the top of the finished aggregate base by using a string line stretched across the road from wire to wire. A LeTourneau-Westinghouse blade, Model 777, with a 14-ft moldboard was used to fine-grade the AB. A 25-ft wheelbase land plane was used for final finishing before rolling with a Galion tandem roller. A state crew checked the grade by stretching a nylon string from wire to wire. These tests were made on 25-ft stations at three points across the roadway.

Location of the concrete batch plant and the central mixer allowed by the change order resulted in a maximum haul of 6.5 mi and a minimum haul of 1.5 mi. A console-controlled plant combining five batches of 1.7-cu yd into an 8.5-cu yd mixer was used. A minimum mixing time of 55 sec was set.

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Standard gradation (square openings) for the coarse aggregates used in the paving was as follows:

Passing $2\frac{1}{2}$ in., 100 percent;
Passing 2 in., 95 to 100 percent;
Passing 1 in., 35 to 70 percent;
Passing $\frac{1}{2}$ in., 10 to 30 percent; and
Passing No. 4 sieve, 0 to 5 percent.

Gradation for the fine aggregate was as follows:

Passing $\frac{3}{8}$-in. sieve, 100 percent;
Passing No. 4 sieve, 95 to 100 percent;
Passing No. 16 sieve, 45 to 80 percent;
Passing No. 50 sieve, 10 to 30 percent; and
Passing No. 100 sieve, 2 to 10 percent.

The aggregate was produced at Union Sand and Rock Plant in the Salt River.

Specifications called for the concrete to be placed within 30 min after water was added at the mixer. Slump control was maintained by utilizing radio contact between the paver and the batch plant and through the use of the Kelly ball test on each truck load of concrete. Correlations between the standard slump cone test and the Kelly ball were continually made and recorded. It was found that a $\frac{3}{4}$- to 1-in. slump was ideal for the operation. The low-slump concrete was hauled to the paving site in dump trucks with filleted corners in the dump beds to prevent concrete from hanging in them.

The paving train consisted of four pieces of equipment: the paver, a 4-in. tubular float, a burlap drag, and a curing compound application machine. It was planned to place all joints with a polyethylene ribbon. After several days of unsuccessful attempts to place the transverse joint with this new machine, it was taken off the job and the standard procedure was used. This called for steel control joints every 60 ft with sawed joints at 15-ft intervals. These transverse joints were skewed 2 ft in 12. The steel joint material was 12-gage metal, $2\frac{1}{4}$ in. wide by 12 ft long.

The Guntert-Zimmerman slip-form paver used on these projects was used first on the 24-ft wide sections and changed on the job to finish up with the 36-ft wide sections of concrete pavement. The tubular float, burlap drag, and curing compound machine were also converted. The receiving hopper at the front of the machine was equipped with sliding gates to allow the dump truck to back into the paver while in motion. The concrete was dumped into the receiving hopper in two locations in order to load the paver uniformly. Internal vibrators followed by a horizontal tubular surface vibrator, all operating at 5,000 cycles/min, consolidated the concrete. The speed of the vibrator could be varied, depending on the consistency of the concrete. Behind the surface vibrator was the main 7-ft wide pan float. Next was an auger to distribute the concrete further, followed by a Clary screed. Behind the Clary was a second pan float, $3\frac{1}{2}$ ft wide, followed by a final pan float, 18 in. wide. No trailing forms were used in this operation.

The speed of the paver varied from 9 to 12 ft/min, but due to the limited production of the concrete plant the machine was forced to wait for concrete. Control systems were all automatic, working from elevation sensing units mounted on all four corners and an alignment sensing unit located on either of the front corners. The operator only stopped and started the slip-form paver and regulated the speed of it and the vibrators.

Hydraulic rams automatically installed the transverse tie bars every 30 in. at a depth of $4\frac{1}{2}$ in. These tied together the 12-ft lanes of pavement. The longitudinal joint was placed automatically by a device fastened to the rear of the slip-form paver. The 2-in. polyethylene ribbon was fed out from a holding reel.

The 4-in. tubular aluminum float was used to obtain final surface smoothness and was pulled back and forth longitudinally across the pavement by two finishers. An edging tool was used to true up and finish the edge. Occasional edge settlements were formed and concrete was brought from the paver to bring the edge to grade.

The desired nonskid surface was attained by a burlap drag which straddled the pavement on wheels and was pulled behind the finishing after excess surface moisture evaporated and before the concrete hardened. A self-propelled curing compound applicator also straddled the pavement and applied white-pigmented compound at the rate of 1 gal/150 sq ft of surface. The rate of application was checked at the emptying of each 55-gal drum.

The transverse joints were made by a gang saw consisting of 24 and 12 units having a total of 6 blades; each blade made a 6-ft cut. The sawing was done when the concrete was approximately 24 hr old.

Concrete test beams and cylinders were made from concrete taken from the receiving hopper of the slip-form machine. Slump and air-content tests were made periodically from this concrete. Six flexure strength beams per shift were fabricated and cured with curing compound. These were tested at 7 days at the project laboratory. Six cylinders were made each shift and buried at the point of fabrication for 24-hr curing. Four were then forwarded to the central laboratory for testing, two at 7 days and two at 28 days. The remaining two were retained at the field office for checks.

The change order required that the finished concrete pavement have a profile index, as measured with a Hveem profilograph, not to exceed a rate of 7 in./mi in any $\frac{1}{10}$-mi section. In addition, the standard specification requirement that any variation from a 10-ft straightedge of more than $\frac{1}{8}$ in. shall be corrected or removed was also in effect. An average of readings on the 24-ft wide section, which was the first placed, showed a profilograph average of 1.9 in./mi. The average for the 36-ft wide section was 2.9 in./mi. The entire 6.1 mi of pavement averaged out at a rate of 2.5 in./mi. The best $\frac{1}{2}$-mi section was on the 24-ft southbound roadway with an average rate of 1.1 in./mi.

We are well pleased with the results of this first slip-form paving job. The riding surface on these two projects is better than we have ever been able to obtain by form paving. The price advantage of the change orders of Bentson's two projects will be about $13,000.00. Supplemental specifications, covering slip-form paving with central mixing and dump truck transporting, have been prepeared and will become a part of our standard specifications when revised in 1965. Our bidding schedules will allow contractors an option between the conventional forms and the slip-form method on all future concrete pavement.