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SLIP-FORM PAVING WITH MESH AND DOWELS IN ILLINOIS

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A Research Study

By

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SLIP-FORM PAVING WITH MESH AND DOWELS IN ILLINOIS

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The slip-form paver was developed to reduce the cost of portland cement concrete paving through the elimination of form-setting. Experience with the slip-form paving process in Illinois dates back to 1952, at which time a simple, cable-drawn, sled-type device was used in lane-at-time base construction. In time, the self-propelled, full-width pavers came into use.

In the early work that was done in Illinois, some difficulties were experienced in obtaining a smooth surface, reasonably free of excessive bumps and longer undulations. However, improvements in the equipment and in construction procedures eventually reached a stage where the average contractor could be expected to produce a base of uniform thickness and satisfactory edge alignment, meeting a surface-smoothness tolerance of 1/4 inch in ten feet. The use of the slip-form paver in base construction became, and has continued as, standard procedure in Illinois. Portland cement concrete bases are constructed without transverse contraction joints or steel reinforcement, and are surfaced with two or three inches of bituminous concrete before being placed in service to traffic.

In view of the reports received from other parts of the country regarding the improvement of slip-form pavers and the adaptability of the slip-form paving process to surface-course construction, the experimental paving project that is the subject of this paper was undertaken to determine the feasibility and practicability of using the process in conjunction with the inclusion of the standard distributed welded wire fabric and dowels at the transverse joints as normally used by Illinois.

The construction project selected for the experimental work in Illinois is located north and east of Monmouth on Marked Route US 34, and is identified as FA Route 9, Section 103, Project FU-21(8), Warren County.

The project is 4.7 miles in length, and includes 3.4 miles of single pavement and 1.3 miles of dual pavements. Embankment and subbase construction was begun in 1963 and completed in 1964. All paving work was done during 1964. The research work on the project was conducted by the Illinois Division of Highways in cooperation with the U. S. Department of Commerce, Bureau of Public Roads. The construction contractor was Robert A. Black, Inc.

SUBGRADE AND SUBBASE CONSTRUCTION

The experimental project lies in a glaciated area of moderately thick loess, and level to moderately rolling topography. Moderate cuts and fills were required in some locations to establish an acceptable grade line. Embankment and subgrade soils are predominantly in AASHO groups A-6 and A-7-6.

Embankment compaction was accomplished with a three-wheel roller, a tamping roller, and a pneumatic-tired roller. Densities that were obtained met the required 90 percent of standard maximum dry density.

The earth subgrade was prepared to receive a subbase by blading with a Caterpillar No. 12 motor patrol.

Subbases as used in Illinois are of the trench type, constructed 18 inches wider than the pavement at each edge, and installed principally to control pumping. On this particular project, design thicknesses of 4, 6 and 8 inches were used. The 6- and 8-inch thicknesses were constructed of a "dense-graded" crushed stone. The 8-inch thickness was used at only a few locations where less than average support was anticipated. The 4-inch thickness was intended to be a cement-stabilized mixture, in which $3\frac{1}{2}$ percent of cement was added to a "dense-graded" crushed stone; however, the low cement content was not sufficient to provide adequate protection against freezing and thawing when the subbase lay exposed to the elements, except for a curing covering of RC-2 liquid asphalt, through the winter following its construction.

The granular subbase material was laid to the required thickness by a Blaw-Knox pneumatic-tired spreader. A pneumatic-tired roller and a 10-ton tandem roller were used to compact the subbase material to the approximate grade and to the required 95 percent of standard maximum dry density. The subbase was then brought to final grade with a crawler-type subgrading machine operating on a graded track-line. The surface was later smoothed with a light roller. The subgrading machine is shown in Figure 1. Fig 1

PAVEMENT DESIGN

The pavement placed by the slip-form process in Illinois was of the standard design normally placed by the conventional forming process. This pavement is of 10-inch uniform thickness and 24-foot width. Welded wire fabric weighing 78 lb per 100 sq ft is placed at a $2\frac{1}{2}$-inch depth between contraction joints, and between pavement edge and center joint. Transverse contraction joints are spaced at 100-ft intervals and formed by sawing the hardened concrete to a depth of 2 3/4 inches. These joints contain 1 1/4-inch diameter by 18-inch length steel dowel bars spaced on 12-inch centers and placed at mid-depth of the slab. Longitudinal joints are also formed by sawing, and contain No. 5 steel tie bars 30 inches in length and spaced on 30-inch centers, also placed at mid-depth of the slab.

CONCRETE MIXTURE DESIGN

The paving mixture was typical of those used in Illinois. Two sizes of coarse aggregate were combined with sand, cement, water and air-entraining agent to form the mixture. The size A coarse aggregate ranged in size up to $2\frac{1}{2}$ inches for the first half of the project to be constructed; and to 1 3/4 inches for the second half. A typical batch composition is as follow:

Coarse aggregate (size A)	1340 lb
Coarse aggregate (size B)	1300 lb
Fine aggregate	1775 lb
Cement	7.98 bags
Water	34.0 gallons

Slumps of the concrete mixtures on the project ranged between 2 and $2\frac{1}{2}$ inches, and air contents ranged between 5 and $5\frac{1}{2}$ percent.

CONCRETE PLACEMENT

Paving Operation

Two methods of slip-form paving were tried by the contractor on the Illinois project. The initial method, which involved a single-lift process, was unsuccessful because of insufficient drive power of the equipment, and was abandoned after a few hours' trial. The second method, a two-lift process, proved to be successful and was used through the remainder of the project.

The initial and unsuccessful method involved the use of a single Rex slip-form full-width (24-feet) paver. A sled-type attachment was mounted on the front of the paver to set the welded-wire fabric in place at the required 2½-inch depth. The fabric, tie bars, and dowel-bar assemblies were placed on the finished subbase in advance of the paving operation as shown in Figure 2. Fig 2

Concrete was mixed in a traveling mixer operating on the shoulder, and placed between the wings of the paver in front of the strike-off. As the paver moved forward, the fabric was to slide over and into the sled mechanism to the required depth as shown in Figure 3. Fig 3
As stated previously, the driving mechanism of the paver did not have sufficient power to move the paver forward in a satisfactory manner with this arrangement, and it was soon abandoned in favor of a two-layer process.

The two-layer process involved the use of a paving train that included two Rex slip-form pavers operating in tandem (Figure 4). These Fig 4
pavers travel on crawlers, and depend on the smoothness characteristics of the paths they travel along the subbase to provide the required surface smoothness of the pavement. Initially, concrete was supplied to the two pavers by a Koehring 34-E dual-drum mixer. Later, this mixer was supplemented with a Multifoote single-drum mixer.

The lead slip-form paver was used only as a concrete spreader. The hydraulically operated screed of this paver was adjusted to place a $7\frac{1}{2}$-in thickness of concrete, 23 ft 6 in. wide. In the leveling operation, the screed moves forward and backward horizontally a distance of five feet.

At the rear of the lead paver is a device that includes a rotary steel drum for distributing tie bars across the longitudinal joint. Tie bars were inserted on four equally spaced grooves (30-inch spacing) along the circumference of the drum as shown in Figure 5. Fig 5

Dowel-bar basket assemblies were staked in place on the subbase in advance of the paving operation at 100-ft intervals where transverse joints were to be sawed in the hardened concrete.

Sheets of welded-wire fabric reinforcement were carried onto the freshly laid first lift of concrete and placed in position immediately following passage of the lead paver. Four men were required to carry the individual sheets of reinforcement onto the concrete. Initially, some difficulty was experienced in keeping the fabric reinforcement from becoming displaced during the final finishing operation of the second paver. Bending the outermost longitudinal wires of each sheet of fabric to hook onto the preceding sheet remedied the condition. Numerous checks made on the depth of fabric placement as the work proceeded showed the fabric to lie within 1/2 inch of the planned depth of 2 1/2 inches below the pavement surface.

The final 2 1/2-inch course of concrete above the wire fabric sheets and the 3-inch gaps along the pavement edges were placed by a second, more fully equipped, Rex slip-form paver following closely behind the lead paver. This machine spread, consolidated, and finished the concrete in one pass. A metal indicator attached to the paver to follow a stringline off-set from the track line was used to guide the paver as shown in Figure 6. Fig 6

Between spreading and final extrusion, the concrete was consolidated by a surface vibrator mounted on the paver, operating at a frequency of 3500 rpm. The vibrated concrete was tucked into the extrusion meter by means of tamping bars. The extrusion meter is a plate 42 inches wide and 24 feet long adjusted to the crown of the pavement. The tamping bars work slightly below the surface of the concrete to prevent large pieces of aggregate from tearing the completed surface. The vibrators and tamping bars set ahead of the extrusion meter are shown in Figure 7. Fig 7

The concrete surface was given a belt finish by a 2-foot wide oscillating belt mounted immediately behind the extrusion meter.

The second paver included 48 feet of trailing forms of 10-inch depth on each side set 24 feet apart and held together by truss-frame braces. These forms held the concrete in place at the edges a sufficient time for testing of the surface with a 10-foot straightedge and for accomplishing whatever hand-floating operations appeared to be necessary to give a smooth surface. These operations are shown in Figure 8. Fig 8

A wetted burlap drag attached to the last truss-frame brace completed the finishing operation.

Curing of the newly laid pavement was accomplished with the use of impermeable paper placed as soon as the concrete has hardened. The surface of the pavement was wetted immediately before the paper was placed. The curing paper remained in place for a period of not less than 72 hours from the time the surface was covered.

At locations where contraction joints were to be sawed, the curing covering was removed temporarily immediately prior to sawing, and replaced immediately thereafter. Contraction joints were sawed directly over the dowel bar assemblies perpendicular to the pavement surface. Sawing was performed not earlier than 6 hours nor later than 30 hours following paving. Premature cracking occurred at only two locations before sawing was accomplished. Most of the sawing was done the morning following the paving operations. All sawed contraction joints were cleaned, dried and sealed before opening the pavement to traffic.

Manpower and Production

Paving operations, inclusive of batch-truck operation and the curing and joint-sawing operation, required 42 to 46 men while using one mixer, and 52 to 57 men while using two mixers. The average hourly production with one mixer was about 97 feet and about 129 feet with two mixers.

Surface Variations

Illinois specifications require that surface variations do not exceed 1/8 inch in 10 feet when measured in the wheelpaths with a 10-foot straightedge. Grinding is required where variations exceed this amount. Analysis of the data obtained in surface variation measurements on the project indicated an average of about 11 variations over 1/8 inch in 10 feet per wheelpath mile. This value is not inconsistent with values obtained on projects paved by normal procedures in Illinois.

Roughometer Readings

Surface smoothness tests with the Illinois BPR-type roughometer showed an overall section average Roughness Index of 75, which places the pavement at the bottom of the "Very Smooth" category (75 or less) by Illinois standards. This figure is somewhat better than the average for all concrete pavements constructed in Illinois by standard procedures. It is of interest that the Roughness Index readings decreased from the lower 80's to the lower 70's as the paving operations progressed. This improvement is attributed to the experience and skill acquired by the contractor as the work progressed.

Miscellaneous Observations

The maximum vertical grade traveled by the pavers was 4.0 percent. A few locations of low-degree horizontal curvature and slight superelevation were also encountered. In no case did any of these features create problems.

The pavement edges that were formed in the process were considered to be generally satisfactory, although slight slumping was noted at various times. No slump was observed where slump-cone measurements did not exceed 1 1/2 inches. However, the surface of the concrete placed at this consistency did not finish well and appeared to have an open texture, especially where the mixture contained coarse aggregate up to 2 1/2 inches in size. The problem was lessened when a change was made to a coarse aggregate of 1 3/4 inch maximum size. Noticeable slumping of the edges occurred whenever the slump approached 3 inches. At the few locations where excessive settling of the concrete at the edges occurred, a correction was made by staking 2- by 10-in. by 10-ft planks along the side affected.

Transverse construction joints were formed at the end of each day's operation by means of a header board with holes for dowel bars. Dowel bars 1 1/4 inches in diameter by 18 inches long, and spaced on 12-inch centers were installed through the header boards. To facilitate positioning of the paver for the next day's operations, 3/4- by 10-in boards were inserted along the side of the last 20 feet of trailing forms. This caused a slight reduction in pavement width in the vicinity of the construction joints.

In a few locations it was necessary to provide a longitudinal construction joint with tie bars where local roads were to intersect the main pavement. This was accomplished by inserting bent tie bars with cardboard sleeves at the required spacing as the paver moved along. In these few instances, the tie bars were located on top of the wire fabric reinforcement. The alternative of driving the tie bars into the concrete edges after the paver had passed caused slumping to occur and was abandoned.

FINDINGS

It was evident from the work on this project that, with the exercise of reasonable control, the slip-form paving process can produce pavement that is true to line and grade, of specified thickness, and of satisfactory surface smoothness.

It was also evident that the slip-form process is applicable where welded wire fabric and doweled, sawed transverse joints are included in the construction.

A comparison of the costs of the slip-form process with the costs of conventional paving was not a part of this study; however, it was evident that the slip-form process offers the opportunity for some reduction in cost by the omission of form-setting, without adding appreciable cost elsewhere.

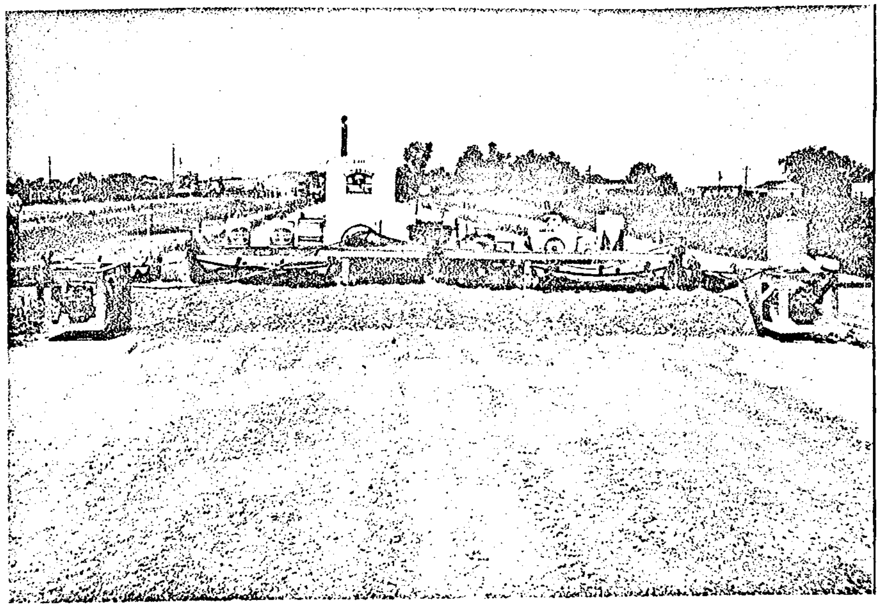

Figure 1. Subgrading machine.

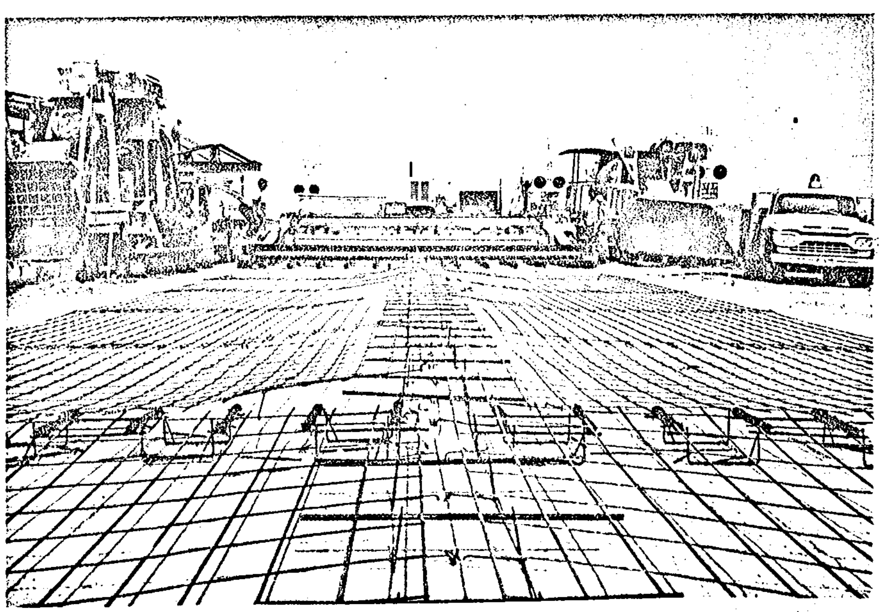

Figure 2. Wire fabric, tie bars and dowel assemblies used in unsuccessful single-lift process.

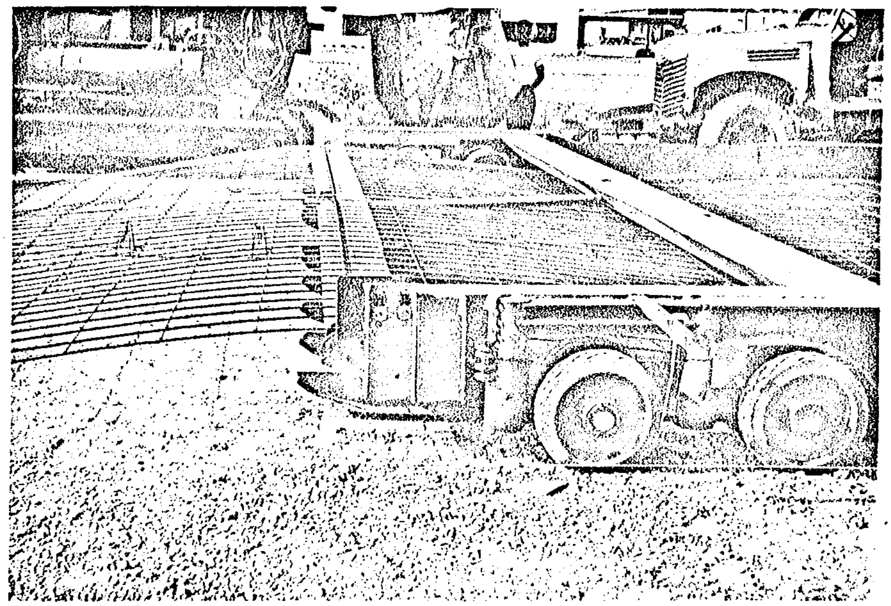

Figure 3. Sled attachment on Rex slip-form paver used in unsuccessful single-lift process.

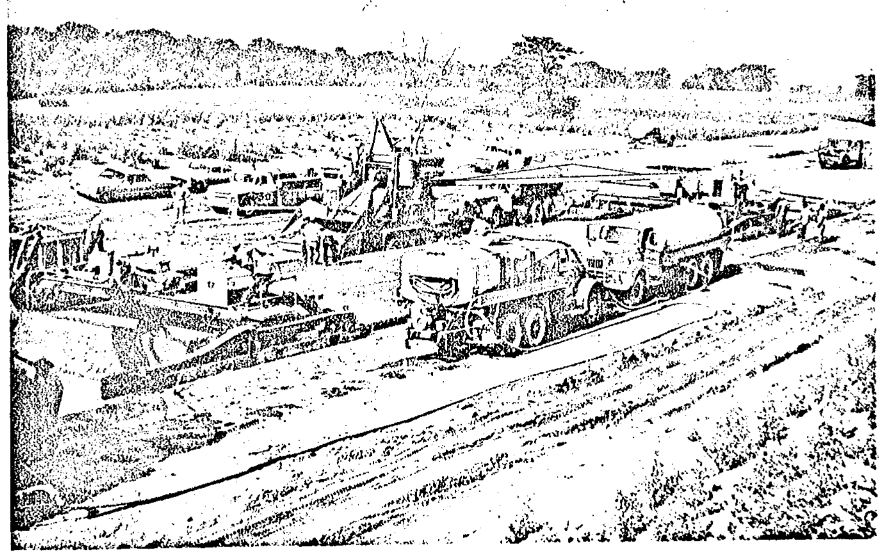

Figure 4. Rex slip-form paving train.

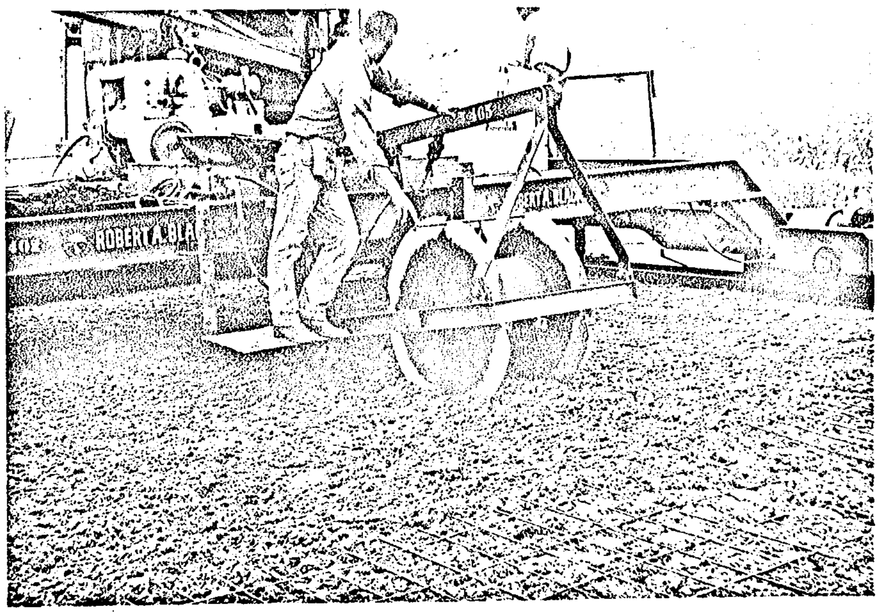

Figure 5. Tie bar placer of lead paver.

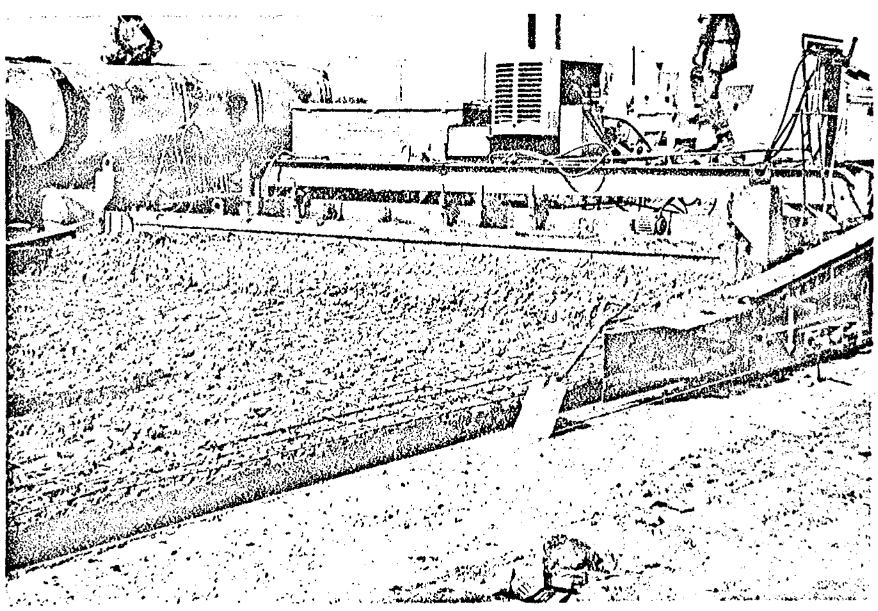

Figure 6. Second Rex slip-form paver.

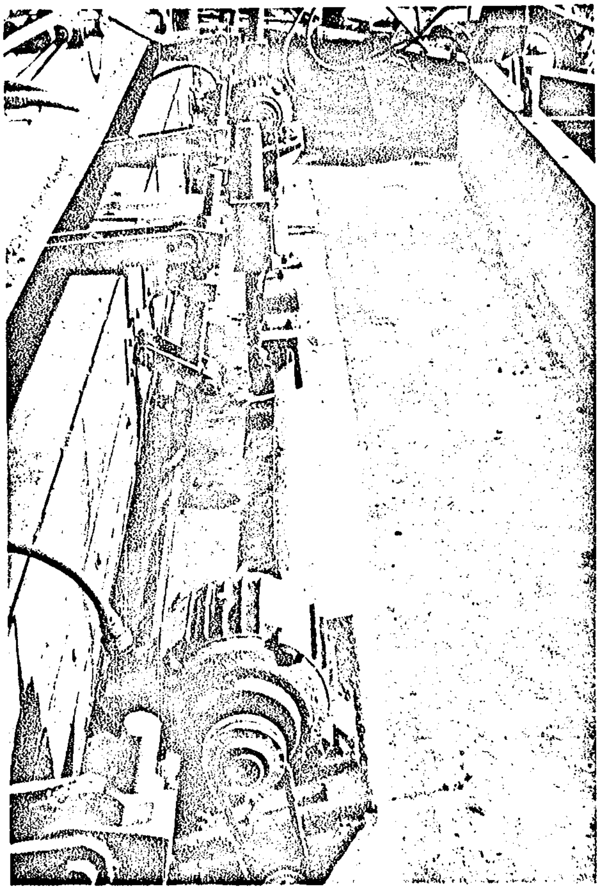

Figure 7. Tamping bars and surface vibrators.

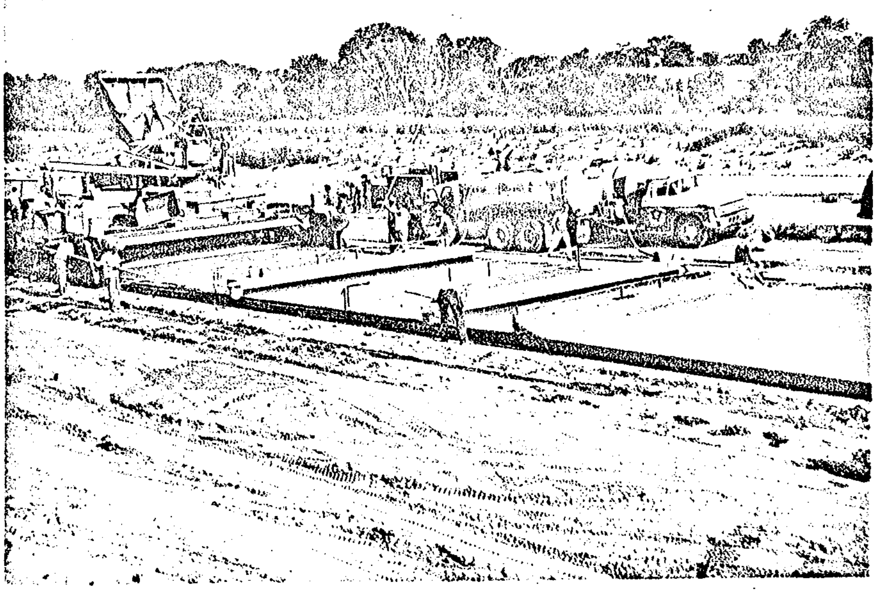

Figure 8. Finishing operations behind second paver.