COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT, KENTUCKY 40601

Eugene Goss
COMMISSIONER OF HIGHWAYS

February 20, 1970

MEMORANDUM TO: A. O. Neiser, State Highway Engineer
Chairman, Research Committee

SUBJECT: Research Report; "Slip-Form Paving;"
KYHPR-64-5; HPR-1(5), Part II

The slip-form method of constructing portland cement concrete pavements originated in the midwest. In anticipation of eventual use of the method in Kentucky, KYHPR-64-5 was proposed and authorized for the purpose of observing and recording construction experiences and quality of work on a project-by-project basis. The specific objectives were to provide research support when or if needed in the field and to develop information leading to the refinement and standardization of specifications.

Fortunately, the need for research overview has proven to be minimal; and it now seems unnecessary to continue the study. Therefore, the summary report forwarded herewith may be regarded as formally concluding the study.

Respectfully submitted,

Jas. H. Havens
Director of Research

JHH:cel
Attachment
cc's: Research Committee

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Assistant State Highway Engineer, Construction
Assistant State Highway Engineer, Operations
Assistant State Highway Engineer, Staff Services
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Associate Dean for Continuing Education, College of Engineering
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Research Report

SLIP-FORM PAVING

KYHPR-64-5, HPR-1(5), PART II

FINAL REPORT

by

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DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

in cooperation with the
US DEPARTMENT OF TRANSPORTATION
Federal Highway Administration
Bureau of Public Roads

February 1970

INTRODUCTION

The proper placement, consolidation, and finishing of low-slump concrete without the aid of pre-erected side forms has been widely acclaimed as an economical and effective procedure in the construction of portland cement concrete pavements. This construction procedure, commonly referred to as slip-form paving, depends upon the ability of low-slump concrete to remain in place after consolidation and removal of forms.

Slip-form pavers differ from conventional pavers in that no fixed side forms are required inasmuch as the slip-form paver has side forms that advance with the machine. Concrete is merely deposited on the prepared subgrade in front of the machine, which strikes off and consolidates the concrete. The slab is then shaped by an extrusion plate and given an initial floating. The slab is given another floating and then dragged with a burlap drag. All that remains to be done is curing the concrete and sawing the joints. A slip-form paver replaces several pieces of equipment that are normally required for conventional paving. Not only is a reduction in capital investment brought about by the use of slip-form pavers, but a savings is also realized in the accompanying reduction of labor. Savings from 20 to 45 cents per square yard have been reported by other states.

To investigate the feasibility of slip-form paving, a small pilot unit capable of placing a continuous layer of concrete 18 inches wide and 3 inches thick was built and tested in Iowa in 1947. The following year, a larger unit capable of placing a layer of concrete 3 feet wide and 6 inches thick was constructed and tested. In 1949, a unit considered at that time to be a full scale model was built and used to pave an experimental road in Iowa. That paver placed a continuous strip of concrete 10 feet wide and 6 inches thick.

After the successful performance of these pilot models, the slip-form paver was commercialized and crawler tracks, vibrators, and finishing belts were incorporated into the basic design. The first commercial unit was used during 1955; since that time, numerous manufacturers have entered the field; and continued improvements have led to the successful use of slip-form pavers in many states. The slip-form process was introduced in Kentucky in 1965 when two highways were widened with a crude slip-form paver. It was not until 1967 that a full-width pavement was constructed by the slip-form process. To date, approximately 100 miles of roadway have been paved by this method. This report documents the procedures, performance, and history of those projects.

In May 1965, a slip-form paver (Figure 1) was used to place a strip of concrete, 4 feet wide, to widen the eastbound and westbound lanes of the Lexington-Versailles Road. Concrete was deposited in the machine from dump trucks and conveyed to the area to be widened. Two stationary vibrators seated the concrete in place, and an extrusion plate with two small vibrators compacted and leveled the surface to the desired elevation. A plow attached to the paver was used to place a buttress of soil beside the vertical edge of the freshly placed concrete. Due to the short length of the form (10 feet) one finisher with a trowel was the only workman operating between the forms. The surface after the forms had passed was rough and contained a large number of depressions (Figure 2), which were hand-filled. Bull floats and a hand trowel (Figure 3) were used to finish the surface, causing the sides of the pavement to slump slightly. The contractor attempted to limit slump to 1 1/2 inches; however, slumps up to 5 inches were obtained at times. In such instances, the contractor inserted 1 x 6-inch boards for forms (Figure 4). The mix consisted of No. 36 crushed limestone, 36 percent concrete sand, and 5 to 6 percent entrained air. All concrete was cured with wet burlap, and the transverse joints were sawed.

In June 1965, a 15-foot slip-form paver was used in widening an 18-foot pavement on US 51 between Bardwell and Wickliffe (Figures 5 and 6). The existing pavement consisted of portland cement concrete with a 3-inch bituminous overlay and was widened 2 feet 3 inches on each side. Concrete was deposited from ready-mix trucks onto the subgrade and then vibrated into place. A 6-foot extrusion plate equipped with a vibrator was used for compacting and finishing (Figure 7). A plow (Figure 6) attached to the paver

Figure 1. Front View of Slip-Form Paver Used for Pavement Widening on Lexington-Versailles Road, May 1965.

Figure 2. Close-up View of Slip-Form Paver on Lexington-Versailles Road.
Note Vertical Edge of Low-Slump Concrete.

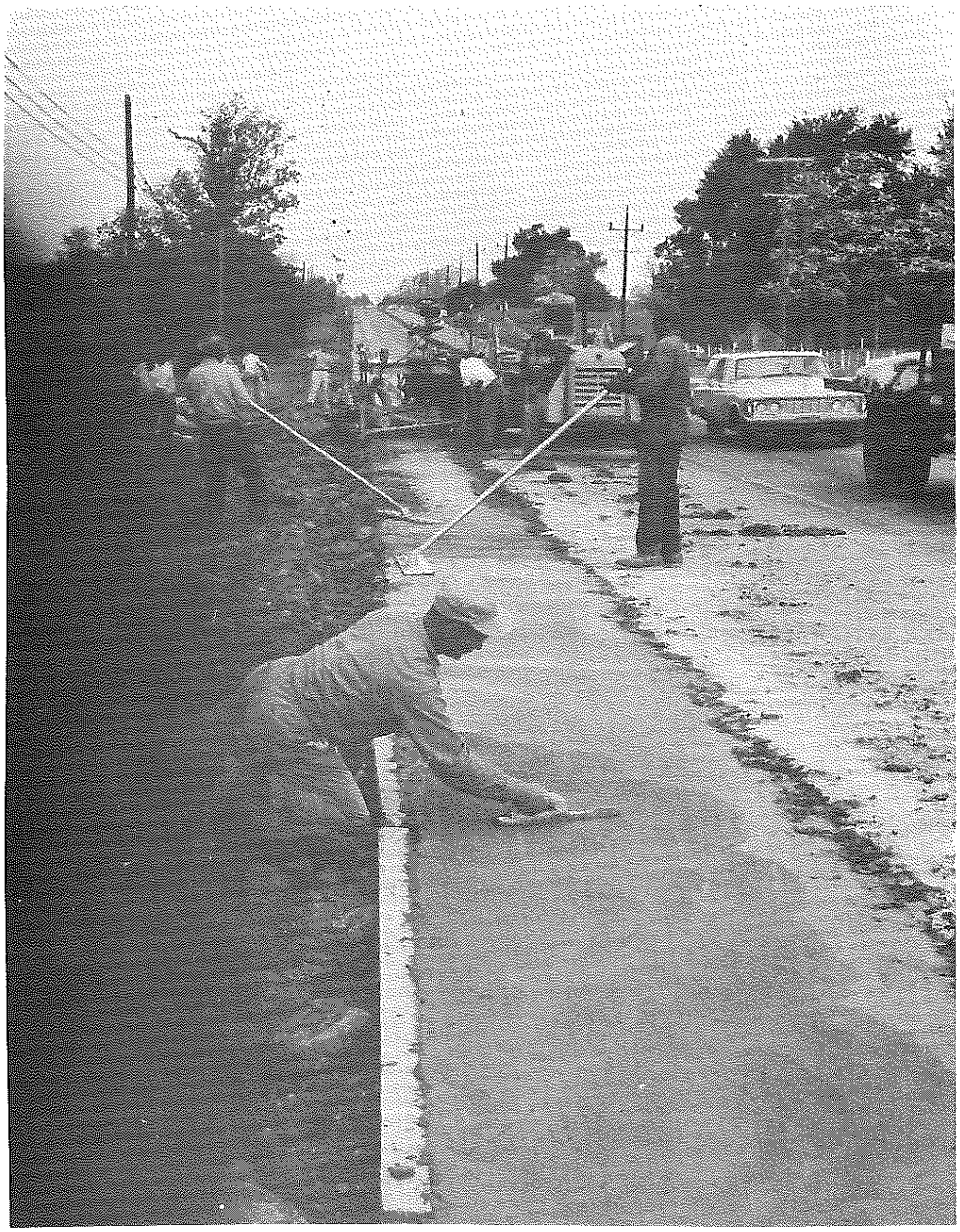


Figure 3. Finishing of Concrete on Widened Pavement on Lexington-Versailles Road.

Figure 4. Use of Conventional Forms in Areas Where High-Slump Concrete Was Encountered.

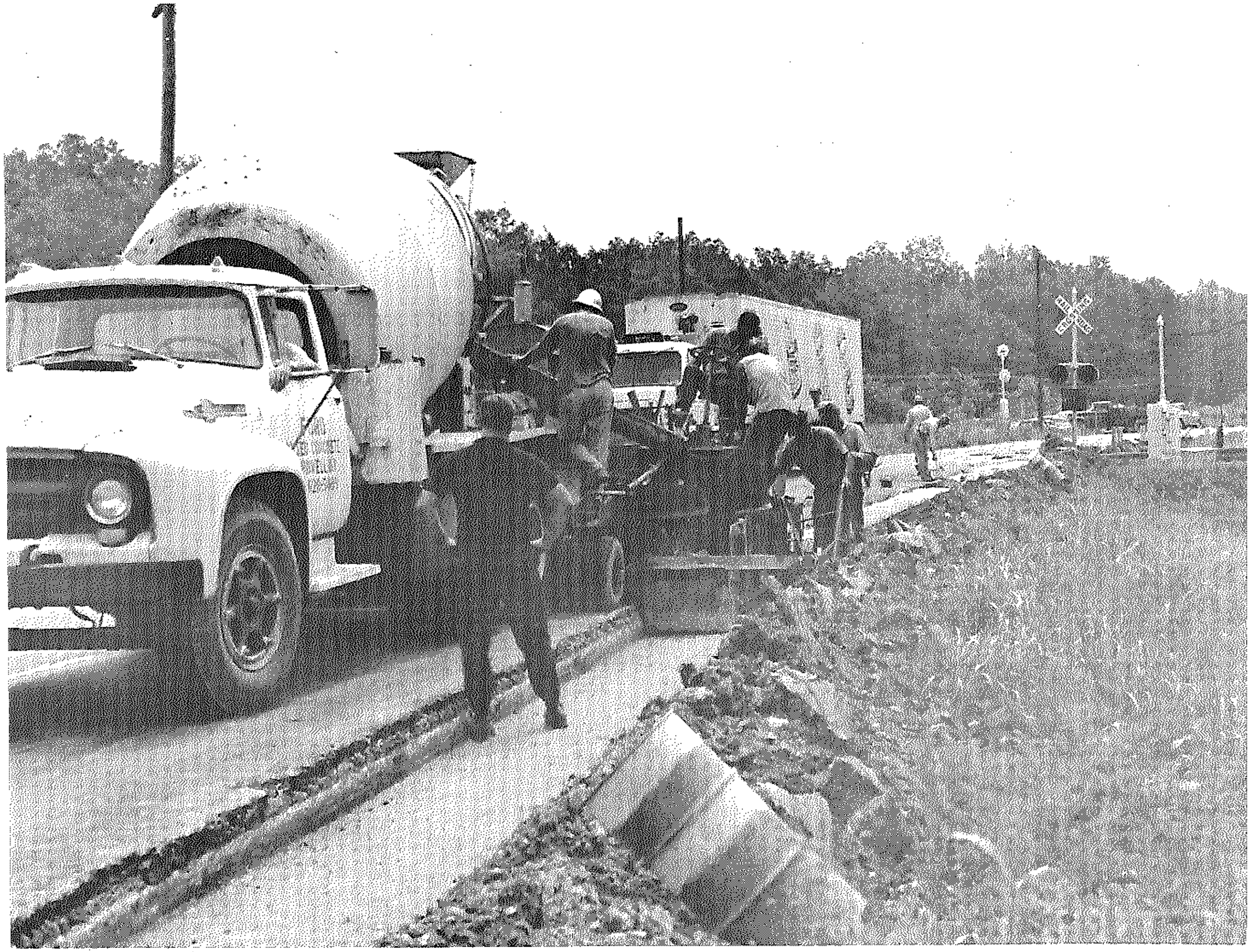


Figure 5. Slip-Form Paver Used for Pavement Widening on US 51 between Bardwell and Wickliffe, June 1965.

Figure 6. Close-Up View of Slip-Form Paver, US 51. Note Hand Plow.

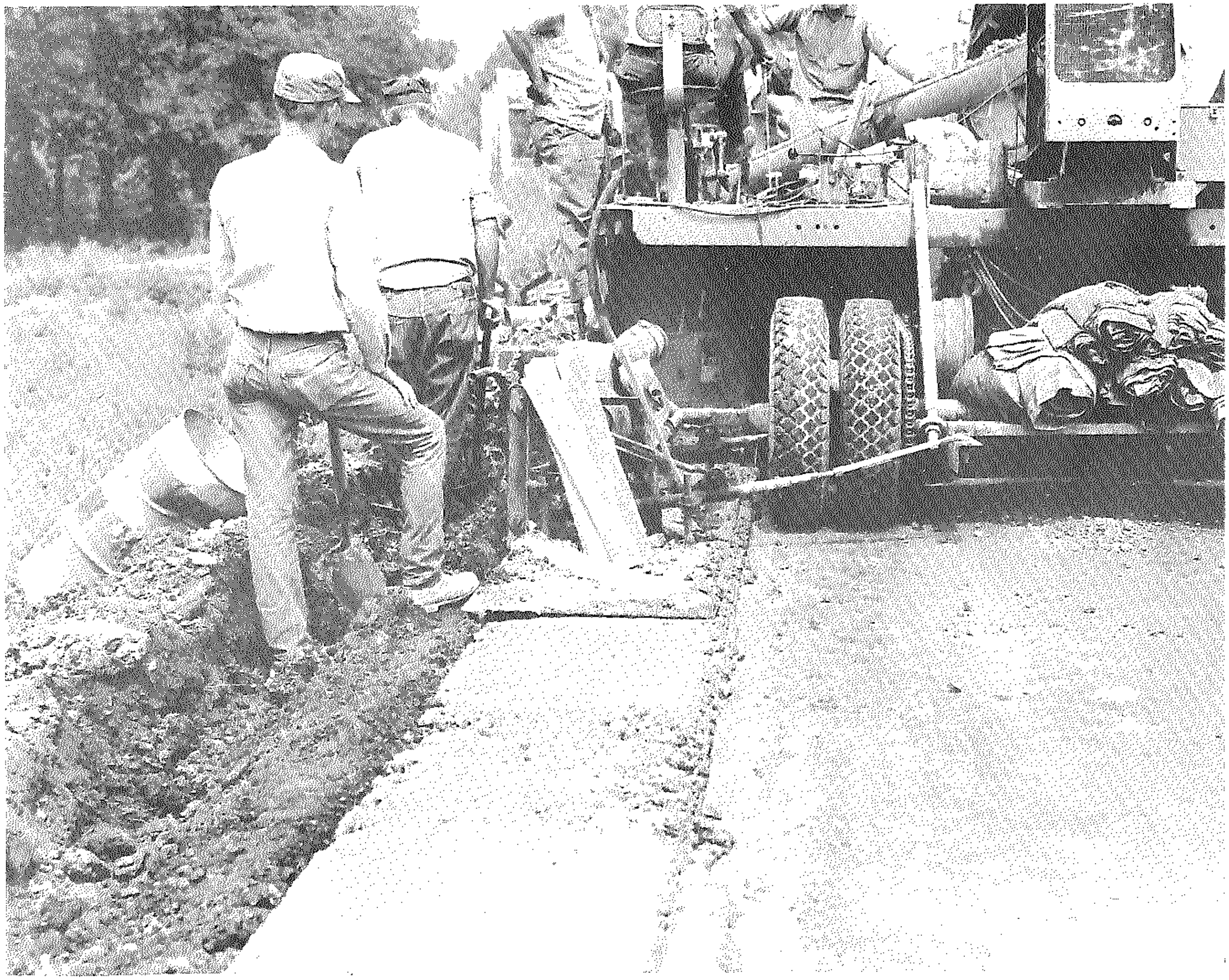


Figure 7. Vibratory Extrusion Plate on Slip-Form Paver. Note Rough Texture of Concrete.

was used to bring soil in against the vertical edge of the concrete. Large voids were left in the concrete surface after the machine had passed and these were hand-filled. The surface was then finished with a bull float and broomed (Figure 8).

The 5-bag mix consisted of No. 36 crushed limestone, river sand, and 5 to 6.2 percent air. Slump was maintained at 2 inches or less. All concrete was cured with wet burlap, and transverse joints were formed with steel dividers.

The first full-width pavement placed in the State with a slip-form paver was a 12.8-mile section of I 71 in Gallatin County. The reinforced pavement was 10 inches thick and 24 feet wide and was placed during the summer of 1967. The pavement was constructed using two Maxon spreaders and a Rex Paver.

Since the first project, 89 miles of parkway and interstate pavement have been constructed by slip-form methods. Special provisions for slip-form paving were first prepared in 1965; the latest revision is dated 1969 and both are included in the appendix of this report.

THE SLIP-FORM PROCESS

With the exception of Kentucky's pavement-widening experience, the State's slip-form paving operations have conformed basically to the procedures presented in this section of the report. Minor variations are necessary for various pavers. The paving process is discussed according to basic operations.

PREPARING THE SUBGRADE

The subgrade is trimmed to final grade (±1/8-inch in ten feet) by machines which are electronically controlled and maintain grade and lateral alignment by senors riding two, taut, offset wires erected adjacent to the working area.

PREPARING THE BASE

Dense graded aggregate is hauled to the project, spread, and compacted. The compacted base is then trimmed to grade with the same type of machine used to prepare the subgrade (Figure 9). Dowel assemblies, if used, are installed on the prepared base.

DEPOSITING THE CONCRETE

The prepared base is moistened prior to placement of the fresh concrete. Concrete is deposited uniformly on the base to a depth of about 2/3 of the design thickness by means of a spreader. The first lift placed is about 6 inches short of its full width to allow room for a second spreader to advance without interference or damage to the concrete. Tie bars are inserted into the slab of fresh concrete by laborers or a special attachment on the rear of the spreader. Wire mesh, carried on a wagon drawn behind the spreader, is then placed on the first lift of fresh concrete. The top lift of concrete is deposited over the first lift and wire mesh by a second spreader, identical to the first. The second spreader places concrete over the entire width of the pavement. Sufficient concrete is deposited by the spreader to compensate for shrinkage during consolidation.

An alternate to the use of two spreaders is the use of one full-depth spreader and a mechanical mesh depressor. The mesh depressor follows the spreader and vibrates and mechanically forces the mesh to its proper depth in the concrete. Other variations may be allowed if the concrete is continuously reinforced or if a non-reinforced concrete pavement is specified.

Concrete spreaders are usually guided by sensing a string line, as are other machines in the paving train. Spreaders may receive concrete from conventional transit trucks or standard dump trucks, depending upon the spreader model. The Maxon spreader (Figure 10) deposits concrete by means of a hopper which traverses the pavement width, leaving a layer of concrete on the base. This spreader is charged by side-dump

Figure 8. Finishing of Concrete on US 51.

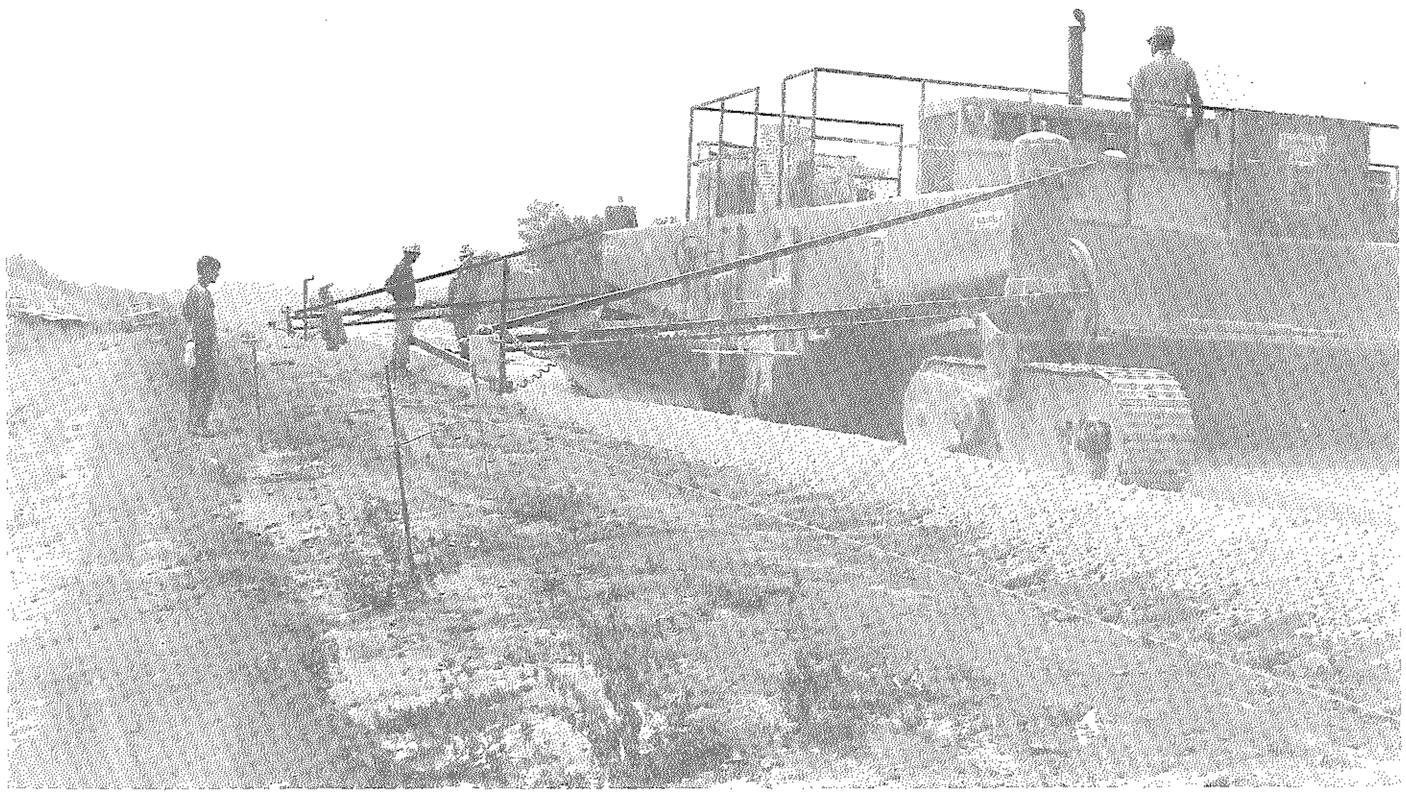


Figure 9. Subgrade Trimmer, Shown Here Trimming the Base Course. Note String Line and Sensors.

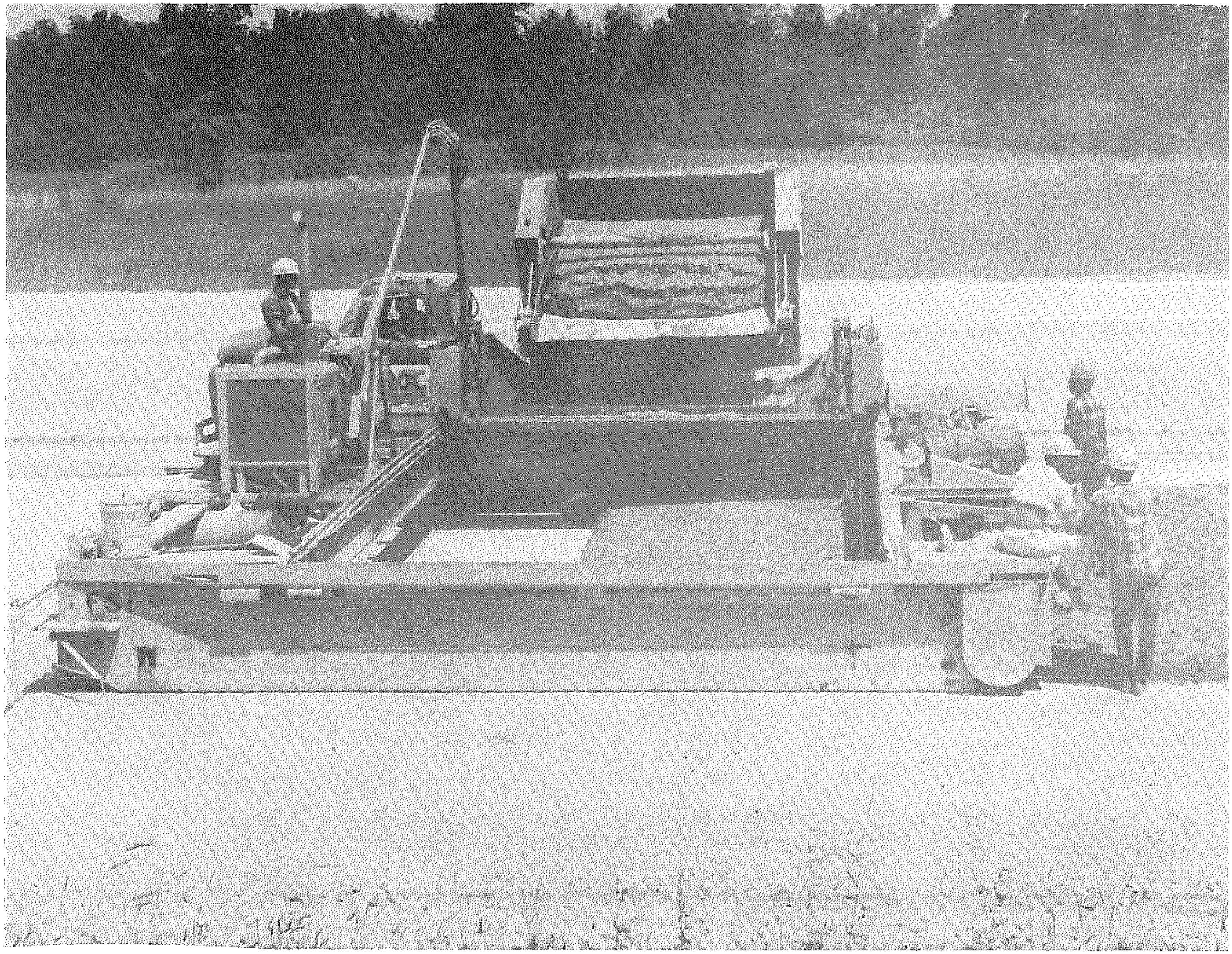


Figure 10. Maxon Spreader Receiving Concrete from Side-Dump Truck.

or conventional transit trucks. The CMI spreader (Figure 11) includes a conveyor which protrudes sufficiently to receive concrete from a dump truck and to carry it back to the center of the roadway. Concrete is deposited on the base in front of an auger, which distributes it uniformly.

FORMING THE SLAB

After fresh concrete has been deposited, it is metered, consolidated, extruded, and floated by the slip-form paver to give the slab its shape and a preliminary finish. The Rex paver (Figure 12) is tread mounted and may be guided manually or automatically by sensing a string line. Across the front of the paver are two augers, end to end, which distribute concrete evenly across the pavement width. Immediately behind the augers is a strik-off bar which meters the quantity of concrete passing under the paver. Following strik-off is a consolidation mechanism consisting of internal vibrators, a surface vibrator (extending the width of the pavement), and tamping bars. Following the consolidation mechanism is a conforming plate, which extrudes concrete in the form of a pavement slab. A pan float follows the conforming plate and provides an initial finish. Incorporated into the rear of the machine is an oscillating belt finisher. The machine pulls approximately 30 feet of trailing side forms with edge formers at the rear end on each side to properly edge the slab. Because the strike-off and pan floats are hinged at the center, the Rex paver is capable of producing a crown or superelevated section. The edge and center elevations of the pavement may be controlled independently by the paver operator. The crown is smoothed to a parabolic shape by the belt finisher.

Construction joints are formed at the end of each day's pour by placing bulkheads across the roadway. To enable the positioning of the paver over the portion of pavement previously placed, 3/4 inch boards are inserted inside the sliding forms for the last 25 feet. This, in effect, reduces the width of the roadway 1 1/2 inches.

The CMI paver (Figure 14) is mounted on four tracks and is guided by sensing a string line. It automatically levels in the event one track hits an irregular portion of base. The screeds and floats are hinged in the middle so that crown and superelevation may be controlled. At the front of the paver are two augers, similar to the augers on the Rex model. Behind the augers is a metering screed or strike-off which controls the volume of concrete passing under the paver. Following the screed are internal bayonet-type vibrators and a vibrating feed meter. Two oscillating extrusion finishers follow the vibrating screed. Next in line are the edge formers (Figure 15) at each side of the pavement. At the rear of the paver is a float which gives the slab surface an initial finish. An oscillating belt finisher is not part of the paver and thus must be provided as a separate machine behind the paver. End-of-day procedure is the same as with the Rex paver.

The CMI paver differs from the Rex paver in several ways. CMI has no tampers and no trailing forms. The CMI paver lacks a belt finisher, but this is compensated for by having an oscillating belt finisher follow the paver. The CMI uses oscillating finishers to form the slab while the Rex paver has a stationary plate that forms the slab (Figure 17). The CMI pavers are fully automatic while some of the Rex pavers are manually guided and leveled.

FINISHING THE SLAB

The slip-form pavers provide a nearly finished slab of pavement, but additional working of the concrete is sometimes needed to fill tears and other imperfections in the slab surface. Workmen with long handle floats fill in small holes on the pavement surface with mortar. A self-propelled tube finisher (Figure 18), with two 8-inch steel pipes as floats, finishes the slab. During the final pass, the tube finisher drags a burlap mat to texture the surface.

CURING THE CONCRETE

After the water sheen disappears, white-pigmented, membrane-forming, curing compound is applied by a self-propelled unit that straddles the pavement and rides on the subgrade (Figure 19). Longitudinal and transverse joints are sawed and sealed.

Figure 11. CMI Spreader. Note Receiving Conveyor.

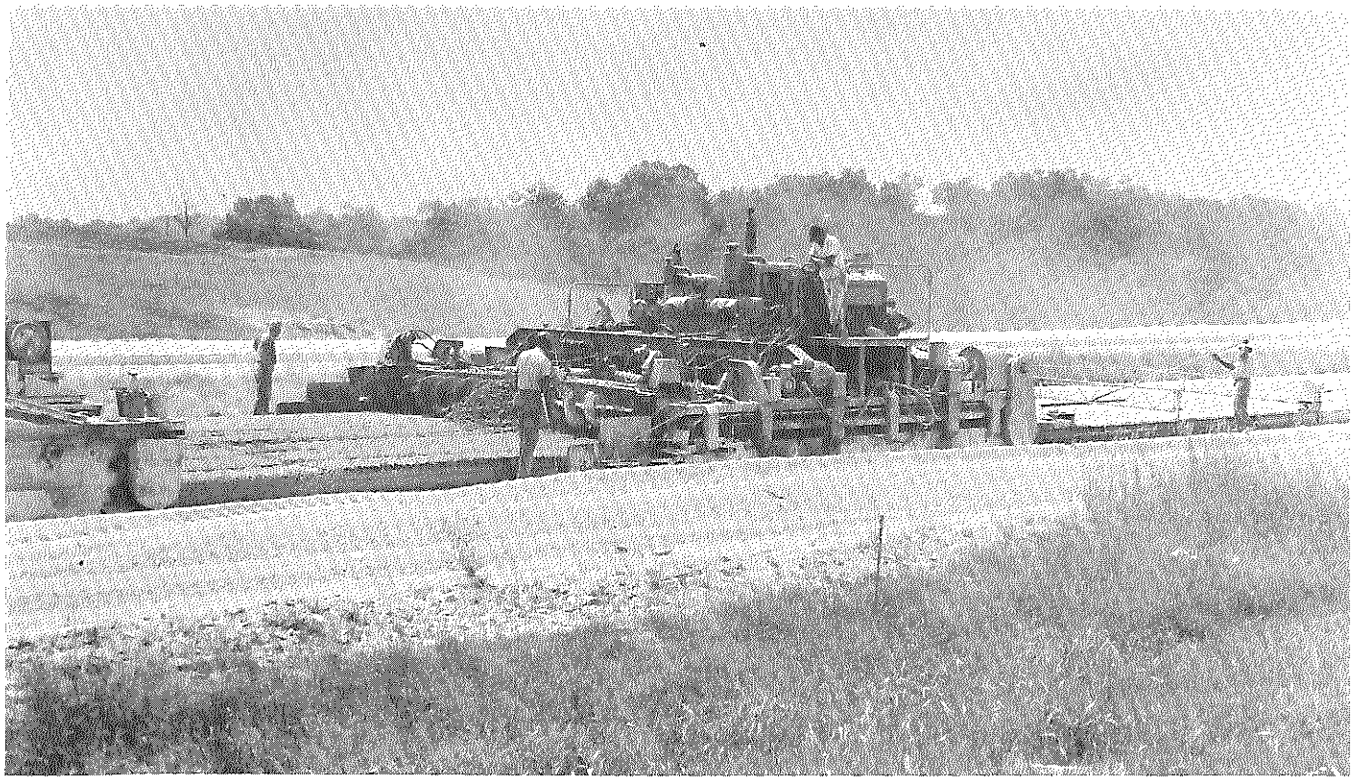


Figure 12. Rex Paver.

Figure 13. Rex Paving Train.

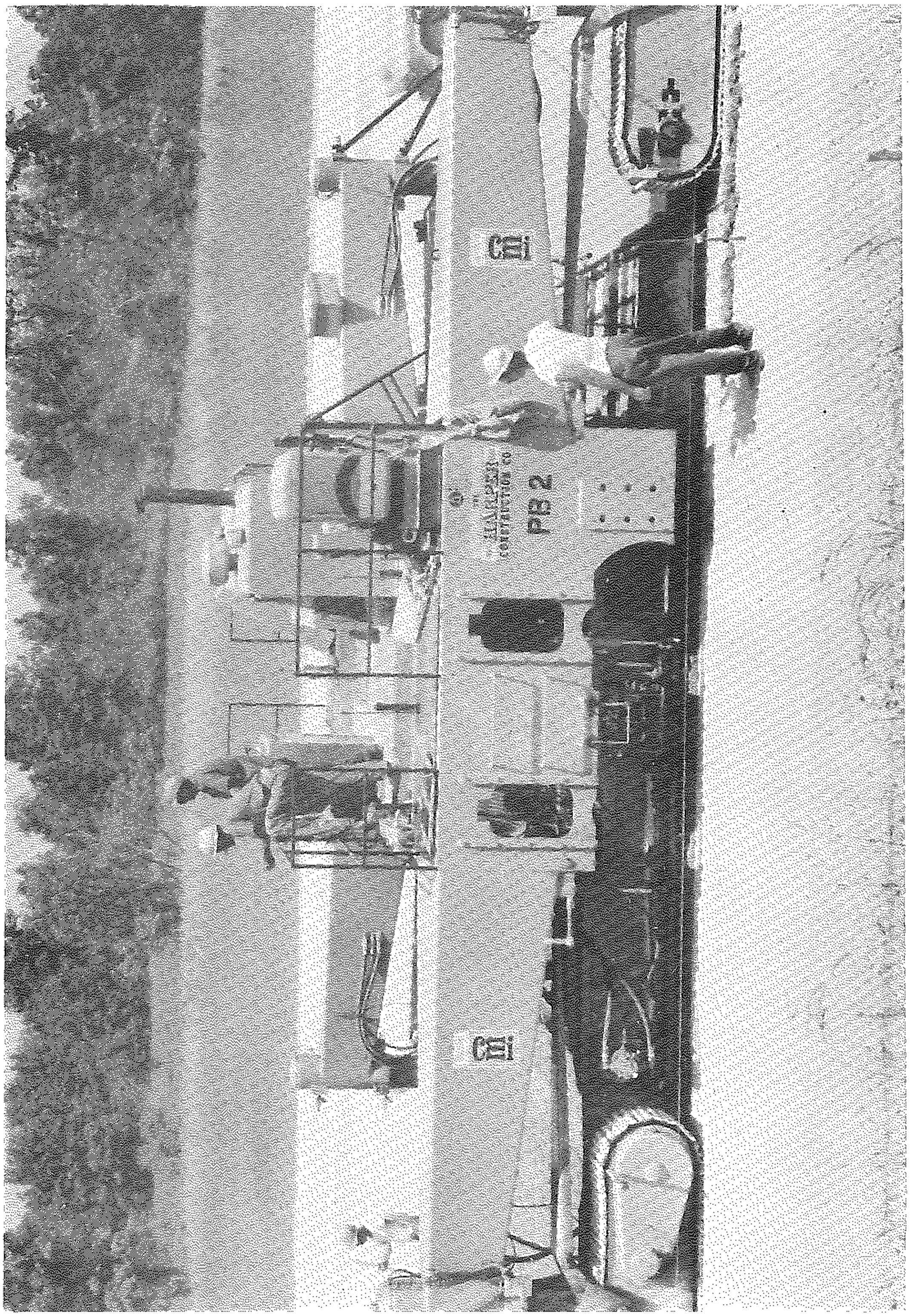


Figure 14. CMI Paver.

Figure 15. Close-Up of CMI Paver Showing Edge Former and Float.

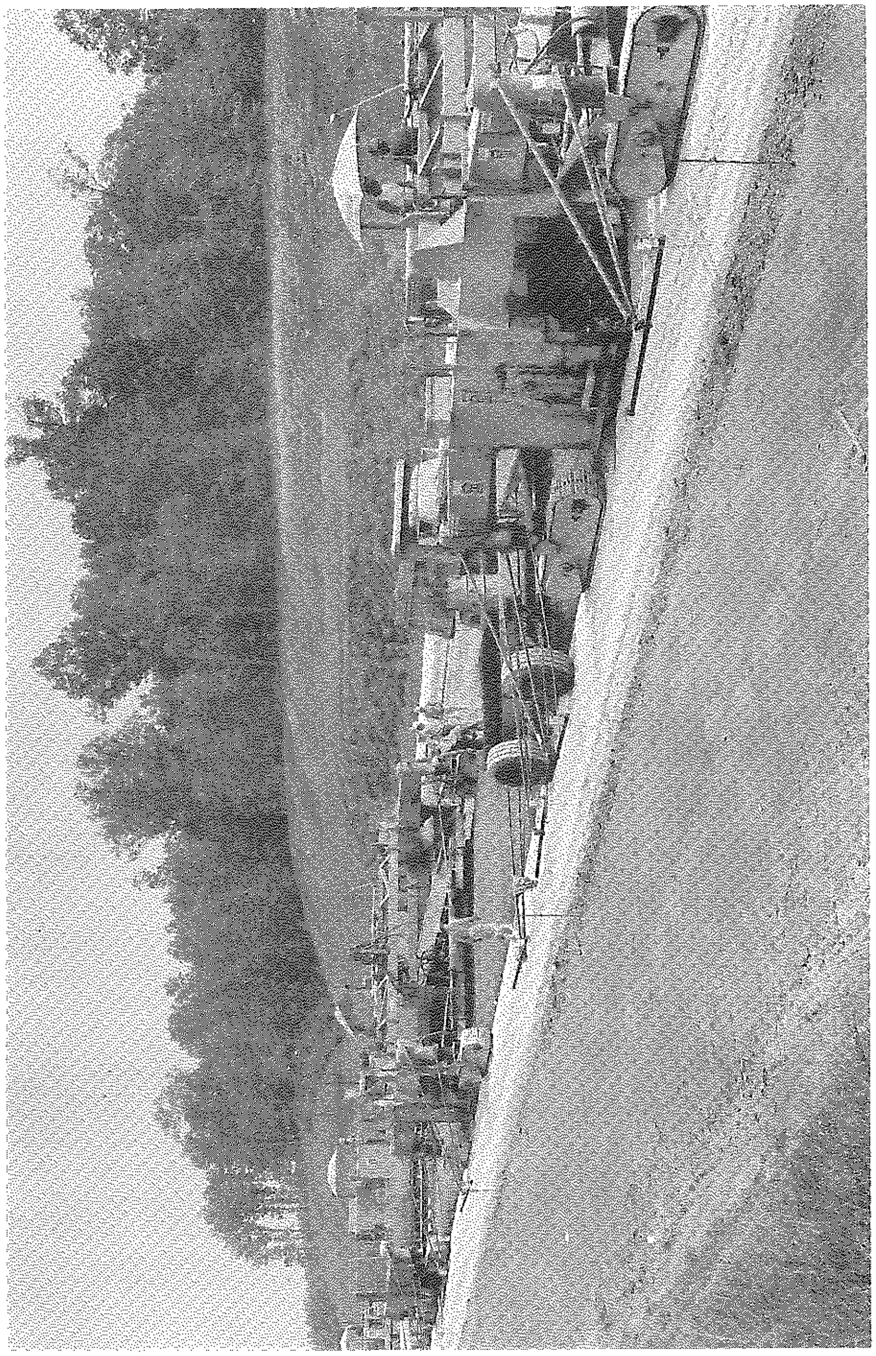
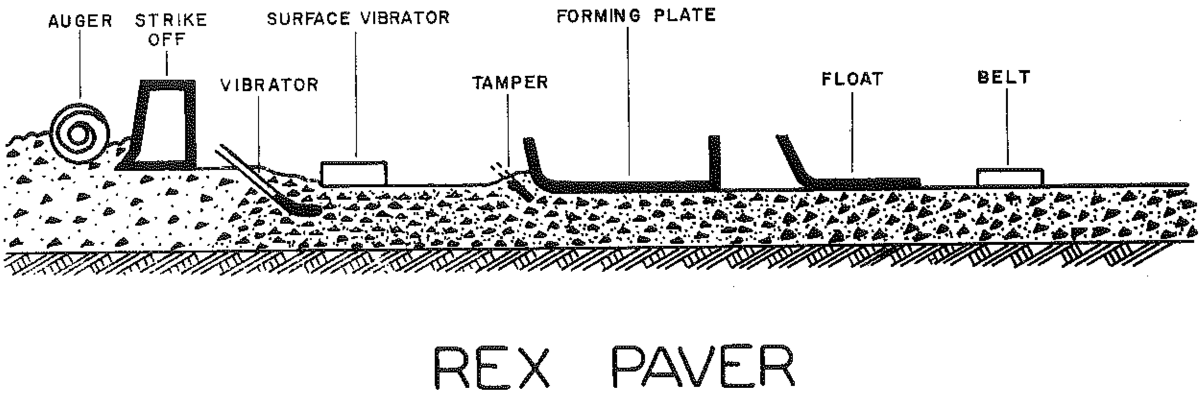


Figure 16. CMI Paving Train.



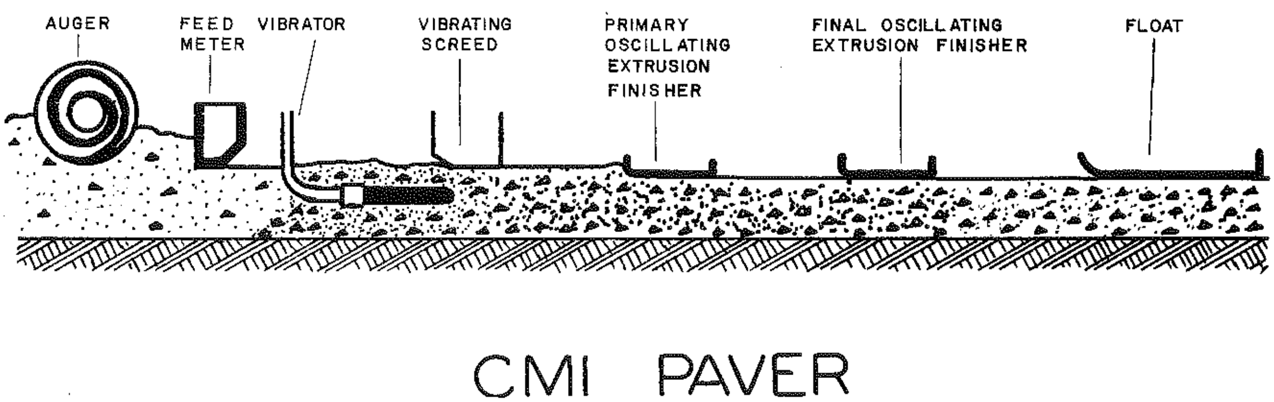


Figure 17. Schematic Diagram of Paver Functions Showing Rex Paver and CMI Paver.

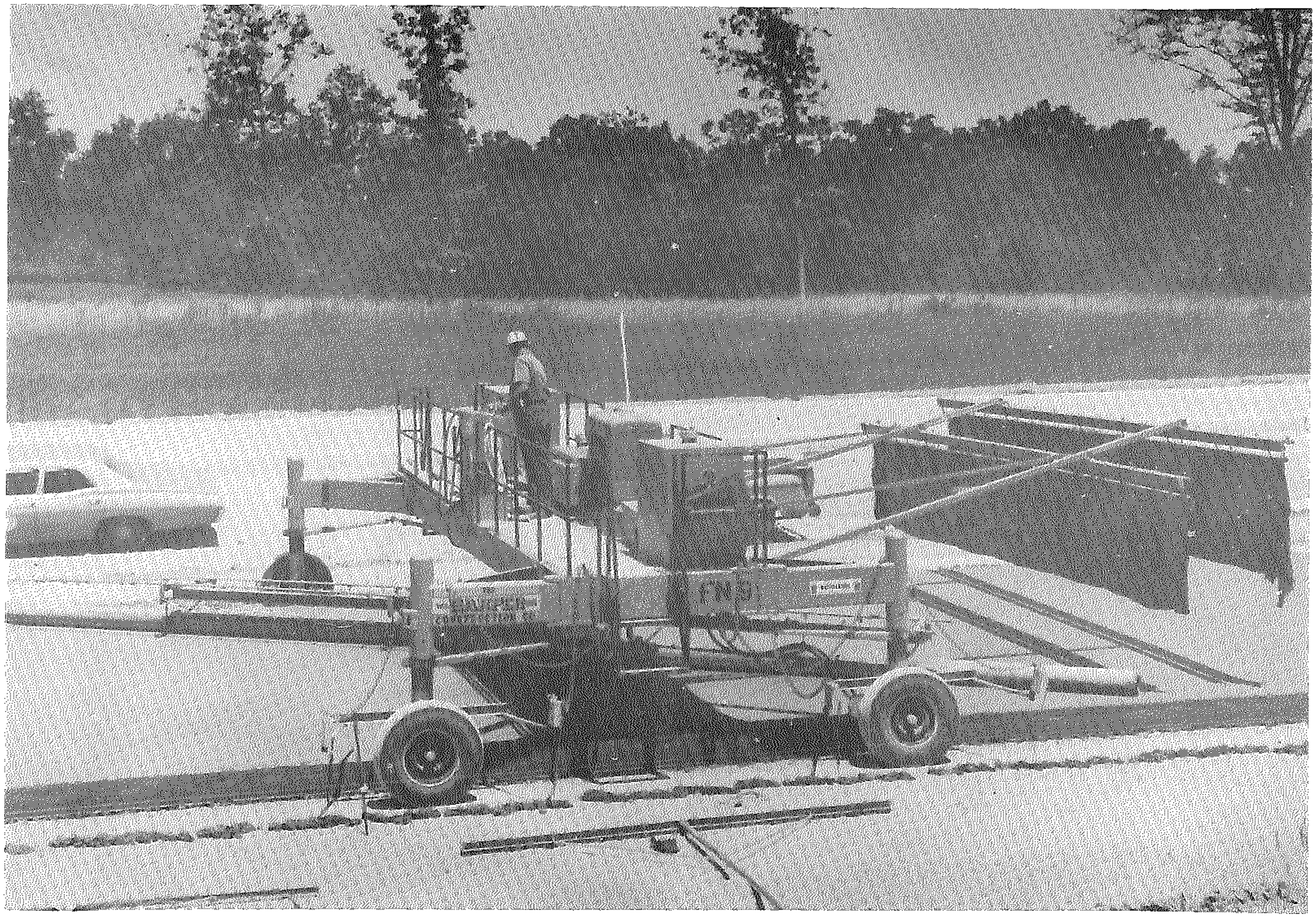


Figure 18. Tube-Float Finisher with Burlap Mat in Raised Position.

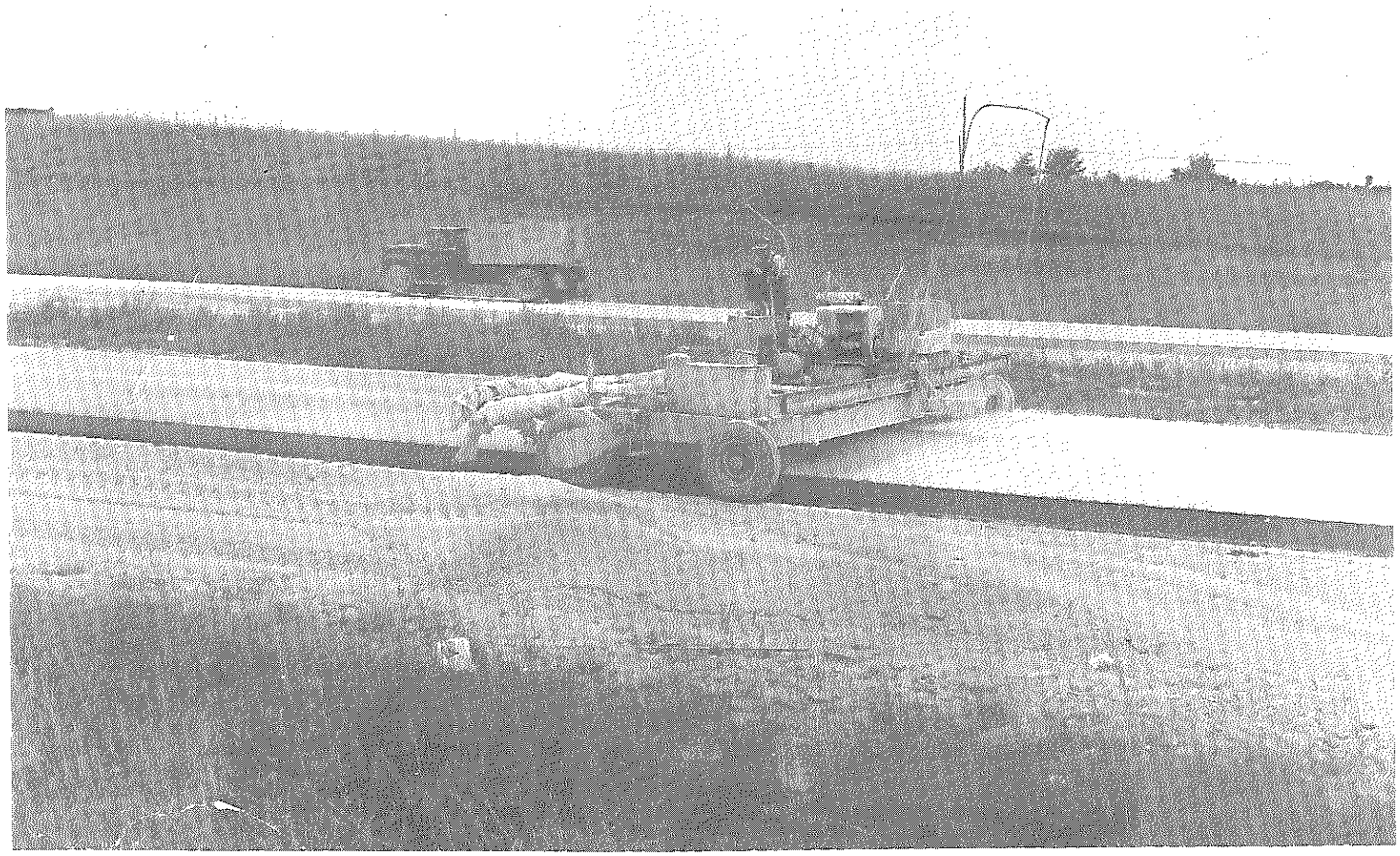


Figure 19. Curing-Compound Sprayer.

DISCUSSION

MIX CONSISTENCY

Kentucky's special provision for slip-form paving limits the maximum slump to 1 1/2 inches with a tolerance of plus 1/2 inch. Due to non-homogeneous moisture distribution in materials and variations in atmospheric moisture, batches with slumps ranging from zero to 6 inches have been placed. Extremely high-slump concrete will cause the pavement edges to slump excessively after the paver has passed. Surface subsidence can also be expected on interior portions of the slab. Extremely low-slump concrete is hard to consolidate and finish. When intermittent batches of high and low-slump concrete are spread, the paver operator must constantly adjust the metering screeds to assure proper feed. Machine adjustments of this type are subject to human error and frequently increase roughness of the finished surface.

MIX DESIGN

Concrete mixes used thus far on slip-form projects have been consistent with conventional paving mixes, except for the use of less water to obtain a lower slump.

REINFORCEMENT

Installation of reinforcement when using a slip-form paver is much the same as with conventional paving. When wire mesh is placed with a mesh depressor, the mesh sometimes hangs in the equipment. The depressor also has a tendency to vibrate too much water and mortar to the surface. Placing the pavement in two lifts so that the mesh may be placed on top of the first lift is expensive because of the cost of operating an extra spreader. In both methods, the mesh is sometimes carried forward by the paver. Tie bars and dowels seldom present any problem.

COST

The cost of a slip-form paving train is quite high, but through reduction in labor costs and elimination of form costs, the contractor is able to economize on total paving costs.

Unit bids have been generally lower for the jobs on which slip-form pavers were used than on conventional paving jobs. Tables 1 and 2 show the average bid on 9-inch reinforced pavement was reduced from $4.89 to $4.74 per square yard, a savings of 15 cents (3 percent), by use of slip-form methods. A reduction from $5.81 to $5.46 per square yard, or 35 cents (6 percent), was shown for 10-inch paving jobs of comparable length. These average values were calculated from paving projects longer than three miles which have been let since the first slip-form paving project in Kentucky.

STRENGTH

Cores taken from slip-formed paving projects have demonstrated very good compressive strengths. Table 1 reveals that the 28-day compressive strengths ranged from 4335 psi to 6073 psi for the pavements placed by slip-form methods. For a six-bag mix, pavement strengths in this range are above average.

ROUGHNESS

Slip-formed pavements have shown riding qualities at least as good as the quality of formed pavements. The riding quality of several recently constructed portland cement concrete pavements is shown in Tables 1 and 2.

The roughness data presented below (summarized from Tables 1 and 2) is limited because of the small number of pavements completed since the first slip-form project was constructed. The data do, however, show a tendency of slip-formed pavements to have very good ratings. It is interesting to note from Table 1 that the two slip-formed pavements which rated poor were the first two projects constructed in the State. It is anticipated that better riding pavements will result as contractors become more experienced.

TABLE 1. SLIP-FORM PAVING PROJECTS

Project Number and County	Letting Date	Project Length (miles)	Pavement Thickness (inches)	Square Yard Unit Bid	Average Initial Roughness Index	Roughness Rating	Density (lbs/cu ft)	Strength (psi)
Pen 14 Christian	9/ 8/67	6.575	9	$4.56	300	Good	151.4	5196
Pen 15 Christian-Hopkins	9/ 8/67	6.820	9	$4.67	290	Excellent	150.9	6073
Pen 16 Hopkins	9/ 8/67	8.800	9	$4.98	255	Excellent	-----	4717
I71-3(11)61 Gallatin	12/16/66	4.626	10	$4.80	388	Poor	-----	4768
I71-1(27)22 Oldham-Henry	2/16/68	5.775	10	$5.19	250	Excellent	-----	5452
I65-2(12)48 Barren-Hart	12/ 1/67	10.079	10	$5.30	285	Excellent	-----	5045
I71-3(12)66 Gallatin	12/ 2/66	8.145	10	$5.34	395	Poor	145.9	5247
I65-2(14)35 Warren-Barren-Edmonson	12/ 1/67	12.195	10	$5.40	305	Good	-----	5227
I75-2(26)28 Laurel	1/24/69	5.403	10	$5.50	275	Excellent	-----	4335
I64-6(14)123 Bath-Rowan	1/12/68	7.081	10	$5.68	335	Good to Fair	148.0	4335
I75-3(27)65 Rockcastle	2/16/68	3.289	10	$5.69	260	Excellent	152.3	5285
I71-1(26)28, I71-2(13)34 Henry	2/16/68	9.352	10	$5.79	290	Excellent	-----	5571
I75-2(24)35 Laurel	3/ 7/69	6.268	10	$5.96	290	Excellent	146.3	----
I71-2(15)37 Henry-Trimble-Carroll	2/16/68	7.198	8	$6.56	215	Excellent	154.3	5600

TABLE 2. CONVENTIONAL PAVING PROJECTS

Project Number and County	Letting Date	Project Length (miles)	Pavement Thickness (inches)	Square Yard Unit Bid	Average Initial Roughness Index	Roughness Rating
Pen 13 Christian	8/25/67	5.401	9	$4.83	275	Excellent
Pen 12 Christian	10/ 6/67	4.185	9	$4.85	255	Excellent
Pen 17 Hopkins-Webster	9/22/67	8.397	9	$4.89	335	Good to Fair
Pen 18 Webster-Henderson	9/22/67	8.203	9	$4.89	380	Poor
Pen 19 Henderson	9/22/67	9.693	9	$4.90	325	Good
RVP 1, RVP 2 Henderson	12/13/68	8.557	9	$5.00	---	----
I71-1(28)9, I71-1(29)15 Jefferson-Oldham	2/16/68	12.570	10	$5.29	275	Excellent
I71-1(19)2, I264-1(30)22 Jefferson	6/ 2/67	5.109	10	$5.55	---	----
I75-3(23)69 Rockcastle-Madison	2/24/67	7.007	10	$5.56	335	Good to Fair
I64-6(15)130 Rowan	1/12/68	6.946	10	$5.63	375	Fair to Poor
I64-6(7)109 Montgomery-Bath	9/ 9/66	10.203	10	$5.65	360	Fair
I71-1(33)8, I71-1(20)6 Jefferson	6/ 2/67	4.814	10	$5.70	---	----
I71-3(10)74 Boone	12/16/66	7.555	10	$5.75	315	Good
I75-2(25)41 Laurel	1/24/69	6.977	10	$5.76	290	Excellent
I64-7(16)138 Rowan	3/ 7/69	8.789	10	$5.78	285	Excellent
I65-2(16)57 Hart	12/16/66	3.354	10	$6.00	415	Poor
I75-1(23)16, I75-1(24)23 Whitley	3/10/67	9.410	10	$6.05	320	Good
I75-2(28)47 Laurel	4/ 4/69	3.797	10	$6.98	310	Good

Roughness Rating	Slip-Formed PCC Pavements	Conventional PCC Pavements
Excellent	9	5
Good	2	4
Good-Fair	1	2
Fair	---------	1
Fair-Poor	---------	1
Poor	2	2
Total Number in Sample	14	15

DENSITY

Apparent densities of cores taken from slip-formed pavements are shown in Table 1. These densities, ranging from 146 to 154 pounds per cubic foot, are typical for pavements containing Kentucky aggregates. Inadequate density of the pavement slab was a problem during the first years of slip-form paving in other states, but the problem was corrected before slip-form pavers were used in Kentucky. Pavers presently used in the State have "Dart" vibrators spaced laterally at 24-inch intervals, or closer, to consolidate the concrete. At these spacings, the effect produced by the vibrators is visible continuously across the pavement surface. The "Syntron" vibrators mounted on the screeds aid in metering the concrete and are for producing a tear-free slab surface, although they do aid in compacting the slab.

AIR CONTENT

Tests with the Chase Air Indicator have shown that the concrete loses up to one percent air during placement by slip-form pavers. It is suspected that more air is lost in the high-slump batches than in low-slump batches of concrete.

EDGE SLUMP

Excessive edge slump is still one of the problems of slip-form paving that must be closely watched. When bituminous material is being compacted during the shoulder paving operation, rollers travel over the shoulder with one side riding upon the edge of the pavement. If the pavement edge dips, that side of the roller will follow its contour and produce a low place in the shoulder, which tends to pond water. High-slump concrete, humid days, or sudden rains can cause edge slump; better quality control and accessible rain protection for the concrete might minimize the problem. Minor edge slump is almost always present in slip-formed pavements, but it is usually tolerated unless another lane is to be added at some later date.

PAVING SPEED

The speed at which a slip-form paving train moves is more or less dependent upon the supply of concrete. Paving speeds of 4500 to 4800 feet per day are common for reinforced pavements. The spreaders can distribute an 8-cubic yard batch of concrete on the base in as little as 20 seconds. Intermittent concrete delivery is responsible for most paving slow downs. Efforts are always made to keep the paver moving, even at creep speed, because stopping the paver is one cause of pavement roughness.

CONCLUSIONS

Experiences with slip-formed pavements, to date, have been most encouraging. On the average, slip-formed pavements have been obtained at unit costs of 3 to 6 percent less than equivalent conventionally-formed pavements. Roughness data indicate the riding qualities of slip-formed sections to be comparable to that of conventional sections and even more favorable performance is anticipated for future projects as contracting personnel gain experience in use of the equipment. Slip-formed core strengths have exceeded average conventional strengths, and densities of the two are similar. On the basis of data and results to date, it is recommended that slip-form paving be permitted on all projects as an alternate to conventional paving.

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APPENDIX

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION
FOR
SLIP-FORM PAVING

This Special Provision covers the requirements for placing cement concrete pavements and bases with the use of a slip-form paver and shall be applicable to individual projects only when indicated on the plans or in the proposals; and when so indicated, shall supersede any conflicting requirements of the Department's Standard Specifications for Road and Bridge Construction.

I. GENERAL

Cement concrete pavements or bases may be constructed with the use of a slip-form paver in lieu of the construction methods employing forms and the spreading, consolidating, and finishing equipment specified in the Standard Specifications.

Except as otherwise provided herein, the pavement or base shall be constructed in full compliance with the Standard Specifications, and in accordance with the details shown on the plans and Standard Drawings.

The Contractor, if he elects to use the slip-form paver, shall state in the proposal his intentions to do so.

II. SLIP-FORM PAVING

A. Subgrade and Aggregate Base Course. The subgrade and aggregate base course shall be constructed in accordance with Article 307.3.5 of the Standard Specifications.

The aggregate base course shall be tested in advance of the paving operations for crown and elevation by the use of a template, or by other means as approved by the Engineer. All irregularities shall be corrected. Approved material shall be added for filling any depressions, shall be wetted if necessary and compacted as directed. Any excess material indicated by the templates shall be removed.

The finished aggregate base course shall be maintained in a smooth, compacted, and moistened condition.

A fine grading machine will be required to operate in front of the slip-form paver to provide pathway at the proper grade for the paving equipment. This pathway shall be finished to the accuracy necessary to ensure that the finished pavement, or base, will be in conformity with the tolerances set in the Standard Specifications.

B. Paver. The slip-form paver shall be an approved self-propelled type designed to spread, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine in such a manner that a minimum of hand finishing will be necessary to provide a dense and homogeneous pavement in conformance with the plans and specifications. The machine shall vibrate the concrete for the full width and depth of the strip of pavement being placed. Such vibration shall be accomplished with vibrating tubes or arms working in the concrete or with a vibrating screed or pan operating on the surface of the concrete. The sliding forms shall be rigidly held together laterally to prevent spreading of the forms. The forms shall trail behind the paver for such a distance that no appreciable slumping of the concrete will occur, and that necessary final finishing can be accomplished while the concrete is still within the forms. No tractive force shall be applied to the machine, except that which is controlled from the machine.

C. Paving. The concrete shall be held to a uniform consistency so that there will be no appreciable slumping at the edge of the pavement after the slip forms have passed. Slump of the concrete tested in accordance with A.S.T.M. Designation C-143 shall be not greater than 2 inches. The paver shall be operated with as nearly a continuous forward movement as possible and all operations of mixing, placing and indicate that the edge of the pavement being constructed is to be abutted by subsequently constructed pavement, either on the current or future contracts, the edge slump shall not exceed 1/8 inch. Immediately following passage of the paver, forms shall be used, if necessary, to prevent excessive slump from occurring where the edge is to be abutted by subsequent pavement. The fixed forms shall be of adequate length, depth, and thickness to protect and maintain the pavement edge in correct alignment and depth, and shall be staked firmly in place with metal stakes. Where the edge is not to be abutted by subsequent pavement, edge slump not in excess of 1/4 inch will be permitted. Straight-edge tolerances as required in Section 307 shall apply to that portion of the pavement bounded by lines 6 inches from the edges of the pavement. Edge slump will be measured with a 10-foot straightedge laid on the pavement perpendicular to the edge.

The Contractor shall utilize proper and adequate methods to prevent unacceptable slumping and to correct unavoidable slumping of the pavement edges due to all causes, in a manner approved by the Engineer, and shall have available at all times, the necessary materials, equipment, and labor to provide immediate protection of the edges and surface of the unhardened concrete against adverse weather conditions.

When concrete is being placed adjacent to an existing pavement, that part of the equipment which is supported on the existing pavement shall be equipped, or supplemented with approved protective materials, so as to not damage the surface of the pavement and shall be positioned at a sufficient distance from the edge of the existing pavement to avoid damaging the edge.

Special care and attention shall be excercised at all transverse construction joints to assure continuity of the pavement at the proper crown, thickness, grade, and alignment.

APPROVED January 7. 1969

A. O. NEISER
STATE HIGHWAY ENGINEER

KENTUCKY DEPARTMENT OF HIGHWAYS

SPECIAL PROVISION NO. 39-D
SLIP-FORM PAVING

This Special Provision shall be applicable when indicated on the plans or in the proposal; and supersedes any conflicting requirements of the Department's Standard Specifications for Road and Bridge Construction. Section and Article references herein are to the Standard Specifications.

I. GENERAL

Except as otherwise provided herein, cement concrete pavements or bases shall be constructed in accordance with the Standard Specifications, plans, and Standard Drawings. The pavements or bases may be constructed with the use of approved slip-form pavers and approved complementary spreading and finishing equipment including a belt in lieu of the spreading, consolidating and finishing equipment specified in Section 307, except that "Final Finish with Burlap Drag" as specified in Section 307 shall be required.

II. MATERIALS

The maximum slump of the concrete shall be 1 1/2 inches, with a plus 1/2 inch tolerance being allowed.

The load-transfer assemblies shall be modified at the ends to allow for approximately 4 inches of clearance between the assemblies and the slip-forms by welding the outer leg of the chair at an angle of approximately 90 degrees with the upper and lower spacer bars.

III. CONSTRUCTION METHODS

A. Subgrade and Aggregate Base Course. The subgrade and aggregate base course shall be constructed in accordance with all applicable requirements of Article 307.3.5, and a fine grading machine shall be required to prepare the proper grade for the paving equipment to the accuracy necessary to ensure that the finished concrete pavement or base will be in conformity with the tolerances set forth in the Standard Specifications.

If any traffic is allowed to use the prepared aggregate base course, the course shall be rechecked and corrected prior to placing the concrete.

B. Paver. The slip-form paver shall be an approved self-propelled type designed to spread, consolidate, and finish the concrete, in one complete pass of the paver, in such a manner that a minimum of hand finishing will be necessary. The paver shall consolidate the concrete in a manner so as to not damage or displace the load-transfer devices and the steel reinforcement, and shall finish the concrete so as to produce a smooth, uniformly textured surface with the specified crown and slope ready for the final finishing.

C. Paving. The Contractor shall not operate a mixing plant inside the area to be traversed by the slip-form paver. The concrete shall be held to a uniform consistency so that unacceptable slumping will not occur at the edge of the pavement. The paver shall be operated with as nearly a continuous forward movement as possible, and, when forward movement is stopped, the consolidating devices of the paver shall be stopped immediately.

If the concrete is placed in two operations, the width of the first placement may be reduced a maximum of 3 inches on each side.

Methods approved by the Engineer shall be used to construct longitudinal construction joints in accordance with the Standard Specifications, plans, Standard Drawings, and as specified herein. If the plans spreading shall be so coordinated as to provide a uniform forward progress with stopping and starting of the paver held to a minimum. If for any reason the forward progress is stopped, the vibrating and tamping element shall be stopped immediately.

The Contractor shall not operate a mixing plant inside the area to be transversed by the slip-forms.

Edge slump, exclusive of edge rounding, in excess of 1/4 inch as indicated by a 10-foot straightedge laid parallel to the edge, shall be corrected by the Contractor in a manner approved by the Engineer. The Contractor shall also maintain proper and adequate means to prevent edge slumping after the paver has passed due to all causes, including sudden rains.

Areas inaccessible to slip-form paving equipment shall be paved in accordance with applicable provisions of the Standard Specifications.

The methods and procedures of installing jointing materials and mesh reinforcement shall produce the results as will comply with the requirements set out in the Standard Specifications and Standard Drawings.

Straight-edge tolerances as required in Article 307.3.12 shall apply to that portion of the pavement bounded by lines 6 inches from the edges of the pavement.

In order that the concrete may be properly protected against the effects of rain before the concrete is sufficiently hardened, the Contractor shall have available at all times materials, equipment, and labor necessary to provide, without delay, protection of the edges and surface of the unhardened concrete.

APPROVED June 25, 1965

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