History of the Slip Form Paver – Developed in Iowa

Todd Hanson, Concrete Materials Engineer
Iowa Department of Transportation
Credits

• L.M. Clauson (Chief Engineer 1960-66), Slip-Form Paving As Developed and Pioneered in Iowa, Presentation at Annual Highway Conference Maine Section ASCE, Bangor, ME, November 3, 1961
• Gordon Ray & Harold Halm, Fifteen Years of Slip-Form Paving, Journal of American Concrete Institute No. 62-8, February 1965
• Olubayo Olateju, Techniques in Slipform Paving and Continuously Reinforced Concrete Pavement Construction, JHRP Purdue University and Indiana State Highway Commission, March 1971
Introduction

- Early Roads in the US
- First Prototypes
- Johnson paver
- Improvements to Slip Form
- First Commercial Paver
- Advantages
- Slip Form Changes Pavement Construction
- Other Manufacturers
Early Roads

- After WWI, War Department noted importance of highways for national defense
- Army transcontinental convoy in 1919
- War Department teamed up with the Lincoln Highway Association
- 81 vehicles - 62 day trip from Washington DC to San Francisco
- Lt. Col. Eisenhower on the trip
- Registered vehicles – 6,679,133 cars and 897,755 trucks
Early Roads

- Found many poor roads
- Dusty when dry, muddy in the rain
- Stuck in mud in Nebraska and sand in Nevada
- Destroyed 14 bridges in one day in Pennsylvania
- Not adequate for large scale travel and needed to be paved
- Led push to pave Lincoln Highway
Interstate Highway System

- During WWII, Eisenhower drove the German Autobahns and saw the benefit of travelling with ease and speed.
- Post WWII, President Eisenhower knew an interconnected highway system would facilitate routine travel and provide an efficient escape route in the event of an attack.
Modernizing Iowa Primary Highways

- Post WWII, Iowa highways also in need of modernization.
- 4000 miles of 18 foot wide primary pavements needed widening to meet modern standards.
- Curb removal and widening projects in the early 1950’s.
Modernizing Iowa Primary Highways

• Slip form methods were used to widen approximately 1600 miles of 18-20 foot width pavements
Modernizing Iowa Secondary Roads

• Marketing agricultural products from high production fields in Iowa demands an extensive highway system.
• 90,000 miles secondary roads 34,000 on farm to market system largest in the nation.
Modernizing Secondary Roads

- Narrow widths are result of policy building higher grades within 80 to 100 ft ROW
- Allowed for efficiency in snow removal and permit wind to clear snow
- Objections were noted but lessened after heavy snow could travel and those on low roads had to wait
Secondary Paving with Forms

- Narrow widths were not adequate for efficient operation of forming operations.
- Elimination of forming would reduce labor costs and make paving operations on secondary roads more feasible.
- A good day forming was about 1000 ft, Best day 2000 ft.
Iowa Highway Commission

• Iowa Highway Commission engineers decided the best way to meet modern pavement construction was to develop an extrusion method
• 1946, Johnson, Rudy Schroeder, and Willis Elbert, watching a demonstration of cement treated base construction
• Johnson conceptualized a mix with increased cement could be vibrated into place by a machine and eliminate forms

James “Jimmy” Johnson Lab Chief
First Working Model 1947

- November 22, 1947
- Extruded slab 18 inches wide and 3 inches thick
- Vibrating unit actuated by an electric hammer
- Small motor on rear drove a flat belt to produce final finish of slab
- Forward motion accomplished with winches
- Slight batter of side forms
- Results were promising and a larger machine was constructed
Second Working Model 1948

- Placed in operation February 13, 1948
- Extruded a slab 36 inches wide and 6 inches deep
- Small vibrator was used for internal vibration
- Part of force required to propel it was provided by the unbalanced reaction of concrete against the machine
- Proved concrete could be laid by extrusion
Full Scale Experiment Model 1949

- Constructed a half mile in O’Brien County.
- Second experimental mile in Cerro Gordo county
- Adjacent 10 foot lanes and 3 to 4 inch gap filled with asphalt
- Two short pieces of chain attached the front end of the paver allowed to react independently from the power unit.
  - Settlement of wheels would not affect thickness
Full Scale Experiment Model 1949

- Demonstrated conclusively the feasibility of slip form paving method
- Acceptance by County & Iowa Highway Commission engineers was enthusiastic
- Generally accepted, little progress was made for next five years due to delay in commercial development
Johnson Paver (Jeep Skate)

- In 1954, Greene County Engineer grew impatient and secured permission to rent the pilot model
- Leased to Raymond Andrews, Sr. of Andrews Concrete from Mason City for 2 cents / square yard
- Two Mile Paving Project near Churdan, IA
Johnson Paver (Jeep Skate)

- Concrete was used to fill the 3 to 4 inch gap immediately after construction of second lane
- Battered edge still used and there was some objection to abutting slabs w/o vertical joint
- Although performing well (1961)
- Last project used
Issues That Needed Addressing

- Some method was needed to strike off before paver
- Machine tends to climb on the concrete
- Specifications were changed to require some mechanical device to strike off the concrete before the pan
- Trailing forms were used because it was thought the concrete would slump
  - Some states required up to 120 ft
Quad City Paver

- In 1955, Quad City Paver became the first commercial manufacturer available
- Glen Perkins and Bill Dale, Jr. patented track driven paver
- Required to be constructed on subgrade shaped to road profile
- Soon after, newer machines with more automation began work in Colorado, California, and Oklahoma
- All modern pavers were modeled after the Quad City machine
Quad City Paver

- Approximately, 550 miles slip form paved 1955-1961 in Iowa
- Also, used to widen ~1600 miles
- By 1970, 2500 miles of slip form paving on the secondary system
Advantages of Slip Forming

- Reduced Construction Time
  - 1000 ft per day using forms
  - Over 1 mile per day slip forming
- Reduced Labor
  - 15-30 less on crew
- Reduced Equipment
  - Slip form paver replaced 3 to 4 machines
- Simplified Project Management
  - Less equipment/ Less maintenance
  - Shorter working space
- Less Concrete Waste
  - Better control of subgrade
Advantages of Slip Forming

• Lower Bid Prices
  – As much as $0.50 less per square yard
  – At the time, bid prices were in the $2.00 - $3.50 per square yard

• Improved Smoothness
  – Iowa 1960 BPR Data
    • 104 miles Slip form 64 in/mi
    • 193 miles Conventional 78 in/mi
Secondary Roads

- Iowa Special mid 1960s
- Conveyor attached to front of subgrade trimmer to allow contractor to deliver concrete down the grade
- Concrete carried over the trimmer, while subgrade was trimmed, deposited concrete on grade in front of the paver
Interstate Slip Form Paving

- First use of slipform paver on the Interstate in Iowa
- Fred Carlson Co. 1964 I-80 Iowa County
Changes to Pavement Construction
Slip Form Paving-Changes to Jointing

- At the time, parting strips, both longitudinal and transverse were used.
- Longitudinal float was required and combination with air entrainment mix was sticky and parting strips moved around.
Slip Form Paving-Changes to Jointing

Preplaced metal parting strip
1920s-30s

Parting strip inserted 1950s

Sawing Joints 1956
Slip Form Paving-Changes to Curing

1 day wet burlap cure

7 days wet earth cure 1920s
Slip Form Paving—Changes to Curing

• Began using white pigmented curing
  – Prevent water curing break down the edge

White Pigmented Curing
Slip Form Paving – Changes to Batching

- **Dry Batch Mixers**
  - 11E – 11 cu. ft.
  - 27E – 29.7 cu. ft.
  - 34E – 37.4 cu. ft

11E Mixer DeWitt, IA 1921

34E Mixers US 30 Nevada, IA 1964
Slip Form Paving – Changes to Batching

• Need for high rate of concrete production with slip form paving
• Steady supply of concrete and batch to batch consistency
• 1963 Green Construction Oaktown, IN first to pave 2 miles in one day
• 1971 Matich Corporation Colton, CA first to pave 3 miles in one day.


I35 Franklin 1975
Slip Form Paving – Mix Design

1948 Specifications

C, Standard Concrete Pavement. The concrete used for standard concrete pavement shall conform to one of the following proportions:

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement Minute</th>
<th>Water</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.159920</td>
<td>0.460047</td>
<td>0.355448</td>
<td>0.479534</td>
</tr>
<tr>
<td>2</td>
<td>0.130319</td>
<td>0.352202</td>
<td>0.294600</td>
<td>0.352202</td>
</tr>
<tr>
<td>3</td>
<td>0.113734</td>
<td>0.299002</td>
<td>0.265340</td>
<td>0.312140</td>
</tr>
<tr>
<td>4</td>
<td>0.117932</td>
<td>0.264598</td>
<td>0.240598</td>
<td>0.334898</td>
</tr>
</tbody>
</table>

The total quantity of free water in the concrete, including the water in the aggregate shall not exceed 5.054 gallons of water per bag of cement (0.500 pounds per pound; 0.75330 cubic feet per bag).

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.50 bbl (558 lb.)</td>
<td>0.5200 tons</td>
<td>1.070 tons</td>
</tr>
<tr>
<td>2</td>
<td>1.54 bbl (579 lb.)</td>
<td>0.5370 tons</td>
<td>1.090 tons</td>
</tr>
<tr>
<td>3</td>
<td>1.60 bbl (623 lb.)</td>
<td>0.5730 tons</td>
<td>1.030 tons</td>
</tr>
<tr>
<td>4</td>
<td>1.66 bbl (662 lb.)</td>
<td>0.6220 tons</td>
<td>1.050 tons</td>
</tr>
</tbody>
</table>

1964 Specifications

C, Class C. Concrete. The proportions used for Class C concrete with other than Class V aggregate shall conform to one of the following:

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Cement Minute</th>
<th>Water Approximate</th>
<th>Hydromastic Air Approximate</th>
<th>Fine Aggregate Approximate</th>
<th>Coarse Approximate Approximate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.152552</td>
<td>0.487144</td>
<td>0.06</td>
<td>0.397826</td>
<td>0.459903</td>
</tr>
<tr>
<td>2</td>
<td>0.145123</td>
<td>0.442394</td>
<td>0.08</td>
<td>0.393035</td>
<td>0.464898</td>
</tr>
<tr>
<td>3</td>
<td>0.113936</td>
<td>0.360198</td>
<td>0.06</td>
<td>0.340818</td>
<td>0.353031</td>
</tr>
<tr>
<td>4</td>
<td>0.127979</td>
<td>0.384471</td>
<td>0.06</td>
<td>0.379338</td>
<td>0.387630</td>
</tr>
</tbody>
</table>

The total free water in the concrete, including the free water in the aggregate, shall not exceed 5.5 gallons per bag of cement (4.88 pounds per pound), 0.78517 cubic foot per cwt.

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Approximate Quantity of Dry Materials Per Cubic Yard of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.441 lbs. 895 lbs. 378 tons</td>
</tr>
<tr>
<td>2</td>
<td>1.460 lbs. 904 lbs. 385 tons</td>
</tr>
<tr>
<td>3</td>
<td>1.280 lbs. 890 lbs. 370 tons</td>
</tr>
<tr>
<td>4</td>
<td>1.788 lbs. 915 lbs. 402 tons</td>
</tr>
</tbody>
</table>

Added mixes with higher sand content
Other Manufacturers
Rex Paver

- Quad City Paver eventually became the Rex Paver with minor modifications
- Rex Chainbelt Inc. of Milwaukee, WI
- Most common paver of the 1970s

https://www.constructionequipmentguide.com/a-100-year-history-of-paving-compaction-milling-iron/27983
G&Z Paver

• Guntert & Zimmerman 1956
• First dual lane, crawler track mounted slipform paver with auto line and grade control
• Hwy 99 near Manteca, CA was let with forms so Teichert Construction was forced to slipform over forms
• 1959 Caltrans approved slip form paving

From G&Z Profiles Winter 2017, 75th Anniversary
Lewis Paver

- Hurst Lewis of California
- First four crawler track machine
- In 1963, Lewis slipform paver with central batch plant exceeded 1 mile of paving per day in New Mexico
Hanson Paver

- R. A. Hanson Paver 1967 Washington State
- R. A. Hanson developed a self leveling mechanism for wheat combines
- Construction firms doing canal work wanted to adapt their leveling device to canal trimmer and paver
CMI

• CMI Corp. Bill Swisher
• Invented the dual-lane, automated grader in the mid-1960s.
  – Most concrete paving at the time was limited to about 3,000 ft per day
  – CMI subgrader enabled up to two miles of grade preparation in a single day, significantly increasing productivity and efficiency and allowing unprecedented paving.
• 1969 CMI Paver without trailing forms
GOMACO

- Early 1960s bridge deck finishing machines
- 1962 double oscillating screed
- 1966 cone drum finisher for skew ability on wider freeway bridge decks (C-450)

http://www.gomaco.com/Resources/corporatehistory.html
GOMACO

- 1969 C-550 (C-450) on tracks for city paving
- 1975 HW-165 Paver for secondary roads

http://www.gomaco.com/Resources/corporatehistory.html
GOMACO

- 1980 GP-2500 Full width slip form paver
- 1984 GP-5000 Up to 50’ Width

http://www.gomaco.com/Resources/corporatehistory.html
Other Slip Form Manufacturers

- Hetzel Paver – Warren, OH
- Koehring Paver – Milwaukee, WI
- Blaw-Knox Paver
- Some contractors built their own
Manufacturers Today

• Several manufacturers making multiple models
Modern Slip Form Paver

Vibration Monitoring

Real time Smoothness

String-less Paving
Slip Form Summary

• Although developed for secondary roads, became the standard method for all concrete paving
• Instrumental in accelerating construction of interstate highways
• James Johnson “Father of the Slip Form Paver” awarded ACPA first Hartmann-Hirschman Award in 1968 & ICPA Outstanding Achievement Award in 1979
Thank You !! & Any Questions ??

Johnson Paver on Display Iowa
DOT 75th Anniversary 1989