History of the Slip Form Paver – Developed in Iowa

Todd Hanson, PE
Iowa Concrete Paving Association
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 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

Army Convoy in Tama, Iowa 1919
Early Roads

- 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
Early Roads

• Thomas McDonald
  – Chief Engineer in Iowa
  – Bureau of Public Roads Chief 1919-1953
  – Credited with vision of interstate system

• Federal Highway Act of 1921
  – Modern partnership between federal government and states
  – Enabled country to build a network of highways
Interstate Highway System

• During WWII, Eisenhower drove German Autobahns and saw the benefit of travelling with ease & speed
• An interconnected highway system
  – Facilitate routine travel
  – Efficient escape route in case of an attack
• June 29, 1956, Congress authorized the National Interstate and Defense Highways Act of 1956

I29 Monona County 1961
Modernizing Iowa Primary Highways

• Post WWII, Iowa highways also in need of modernization
• 4000 miles of 18-20 ft. wide primary pavements needed widening to meet modern standards
• Curb removal and widening projects in the early 1950’s
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 - 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 ~1000 ft
Jimmy Johnson’s Slip Form Concept

Sorry, No!
Jimmy Johnson’s Slip Form

- Iowa Highway Commission engineers decided the best way to meet modern pavement construction was to develop an extrusion method.
- 1946, while 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 18 in. wide by 3 in. thick slab with batter side forms
- 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
- Results were promising and a larger machine was constructed
Second Working Model 1948

- February 13, 1948
- Extruded 36 in. wide by 6 in. thick slab
- 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
- Enthusiastic Acceptance by County & Iowa Highway Commission engineers
- While generally accepted, little progress was made due to delay in commercial development
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
Removed the hopper – deposited concrete deposited on grade
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

- Machine tended 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
- Require tracks to operate on surface prepared by subgrade trimmer

Aberdeen Group, PUBLICATION #C640385, 1964
Quad City Paver

- In 1955, Glen Perkins and Bill Dale, Jr. patented first commercial track driven paver - Quad City 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
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 contractor was forced to slipform over forms
- 1959 Caltrans approved slip form paving

https://www.guntert.com/about/profile.html
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.
  – At the time, concrete paving grading was limited to about 3,000 ft/day & took 100 people
  – Enabled two miles of grade preparation in a single day
  – Increasing productivity & efficiency, allowed unprecedented paving
• 1969 CMI Paver without trailing forms

Olateju, Olubayo, Techniques in Slip Form Paving and Continuously Reinforced Concrete Pavement Construction, Joint Highway Research Project, C-36-67E, Purdue University, March 24, 1971
GOMACO

- 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
- 1974 Commander III
- 1975 HW-165 Paver for secondary roads

https://www.gomaco.com/Resources/timeline.html
GOMACO

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

https://www.gomaco.com/Resources/timeline.html
Early Slip Form Manufacturers

- Hetzel Paver – Warren, OH
- Koehring Paver – Milwaukee, WI
- Blaw-Knox Paver
- Pav-Saver Paver
- Some contractors built their own
Manufacturers in Iowa
Manufacturers in Iowa
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 - up to $0.50 less per sq. yd.
  – At the time, bid prices were ~$2.00 - $3.50 per sq. yd.

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

Bureau of Public Roads (BPR) Roughometer
Secondary Roads

- Iowa Special mid 1960s
- Quad City working with CMI
- Conveyor attached to front of subgrade trimmer
- Concrete carried over the trimmer, while subgrade was trimmed
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

• Concern with water curing breaking down the pavement edge
• Began using 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
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


I35 Franklin 1975
Slip Form Paving – Mix Design

1948 Specifications

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>C. Standard Concrete Paving. The concrete used for standard concrete pavement shall conform to one of the following proportions:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>BASIC ABSOLUTE VOLUME OF MATERIAL PER UNIT VOLUME OF CONCRETE</strong></td>
</tr>
<tr>
<td></td>
<td>Cement</td>
</tr>
<tr>
<td>1C</td>
<td>0.106600</td>
</tr>
<tr>
<td>2C</td>
<td>0.100416</td>
</tr>
<tr>
<td>3C</td>
<td>0.115794</td>
</tr>
<tr>
<td>4C</td>
<td>0.117952</td>
</tr>
</tbody>
</table>

The total quantity of free water in the concrete, including the water in the aggregate shall not exceed 5.634 gallons of water per bag of cement (0.500 pounds per pound; 0.75320 cubic feet per bag).

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>C. Approximate Quantities of Dry Material per Cubic Yard of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Cement</strong></td>
</tr>
<tr>
<td>1C</td>
<td>1.50 lb. (54 lb.)</td>
</tr>
<tr>
<td>2C</td>
<td>1.54 lb. (57 lb.)</td>
</tr>
<tr>
<td>3C</td>
<td>1.61 lb. (60 lb.)</td>
</tr>
<tr>
<td>4C</td>
<td>1.66 lb. (64 lb.)</td>
</tr>
</tbody>
</table>

1964 Specifications

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>C. Class C. Concrete. The proportions used for Class C concrete with other than Class V aggregate shall conform to one of the following:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Basis Absolute Volumes of Material per Unit Volume of Concrete</strong></td>
</tr>
<tr>
<td></td>
<td>Cement</td>
</tr>
<tr>
<td>C-2</td>
<td>115.025</td>
</tr>
<tr>
<td>C-3</td>
<td>113.725</td>
</tr>
<tr>
<td>C-4</td>
<td>112.025</td>
</tr>
<tr>
<td>C-5</td>
<td>112.025</td>
</tr>
</tbody>
</table>

The total free water in the concrete, including the free water in the aggregate, shall not exceed 6.5 gallons per bag of cement (488 pound per pound; 0.78217 cubic feet per cwt).

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>C. Approximate Quantity of Dry Materials per Cubic Yard of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Cement</strong></td>
</tr>
<tr>
<td>C-2</td>
<td>1.54</td>
</tr>
<tr>
<td>C-3</td>
<td>1.60</td>
</tr>
<tr>
<td>C-4</td>
<td>1.66</td>
</tr>
<tr>
<td>C-5</td>
<td>1.72</td>
</tr>
</tbody>
</table>

Added mixes with higher sand content
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!!

Johnson Paver on Display Iowa
DOT 75th Anniversary 1989