History of the Slip Form Paver – Developed in Iowa

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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

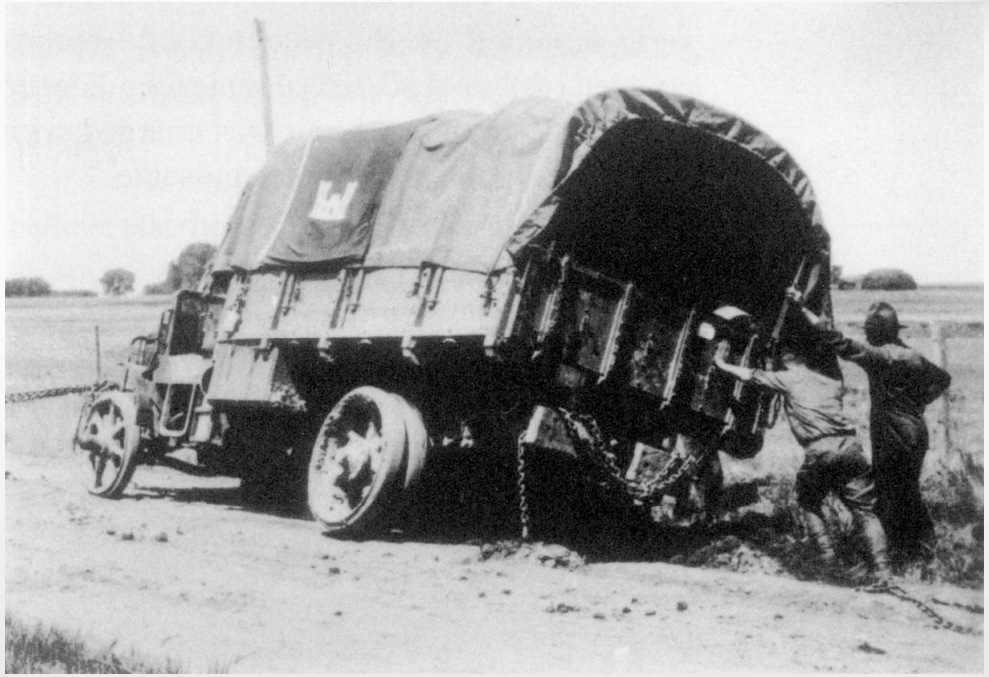
Early Roads

Army Convoy in Tama, Iowa 1919

- 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

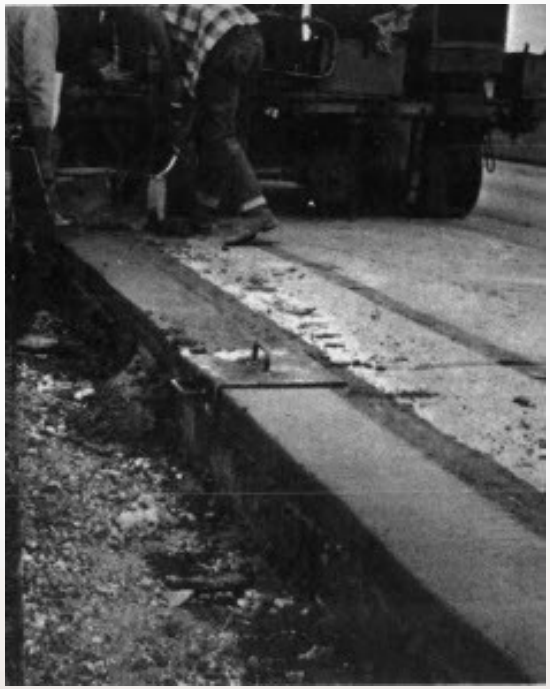
- During WWII, Eisenhower drove the German Autobahns and saw the benefit of travelling with ease and speed
- Post WWII, President Eisenhower knew an interconnected highway system would facilitate routine travel and provide an efficient escape route in the event of an attack.
- June 29, 1956, Congress 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 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

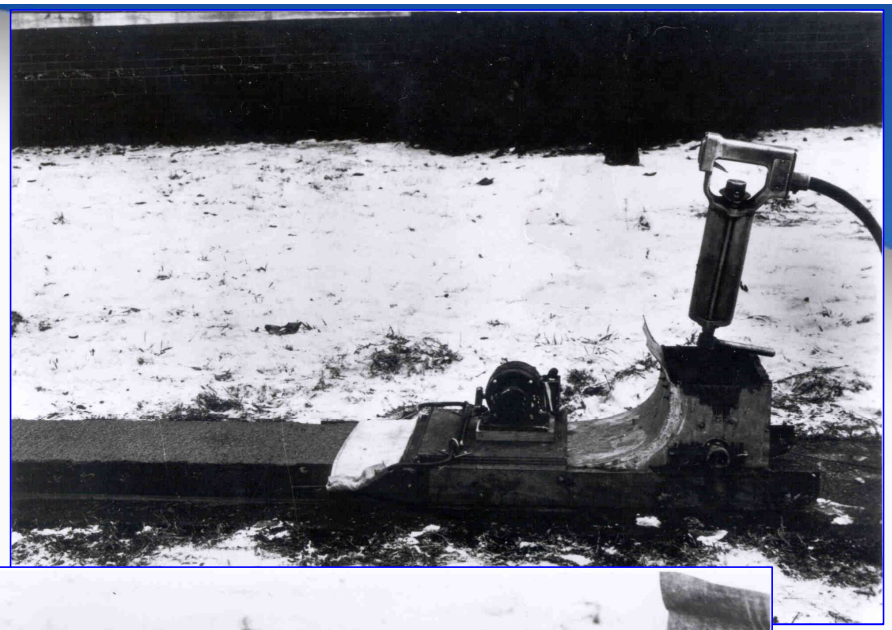
Iowa Highway Commission

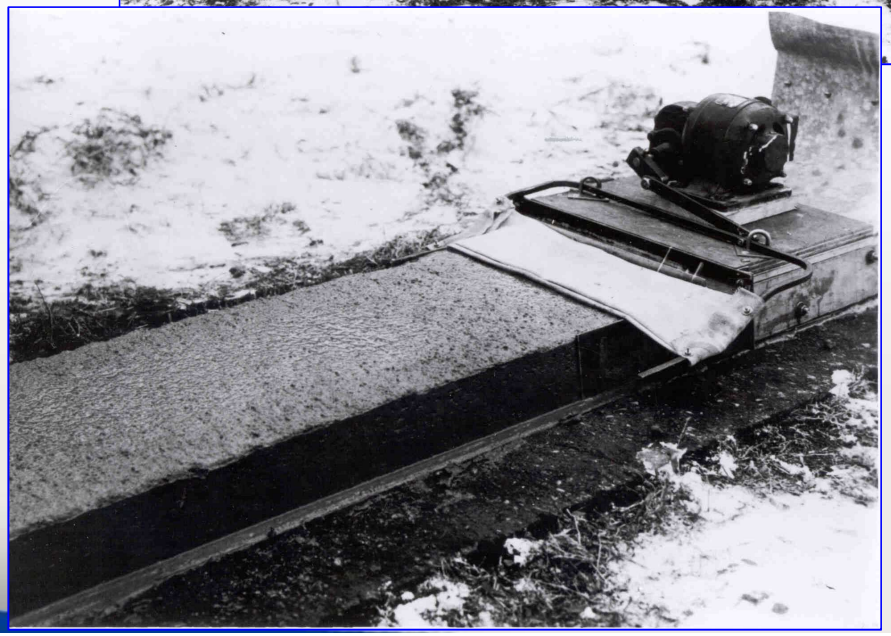
- Iowa Highway Commission engineers decided the best way to meet modern pavement construction was to develop an extrusion method
- 1946, Johnson, Rudy Schroeder, and Willis Elbert, watching a demonstration of cement treated base construction
- Johnson conceptualized a mix with increased cement could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

James “Jimmy” Johnson Lab Chief

First Working Model 1947

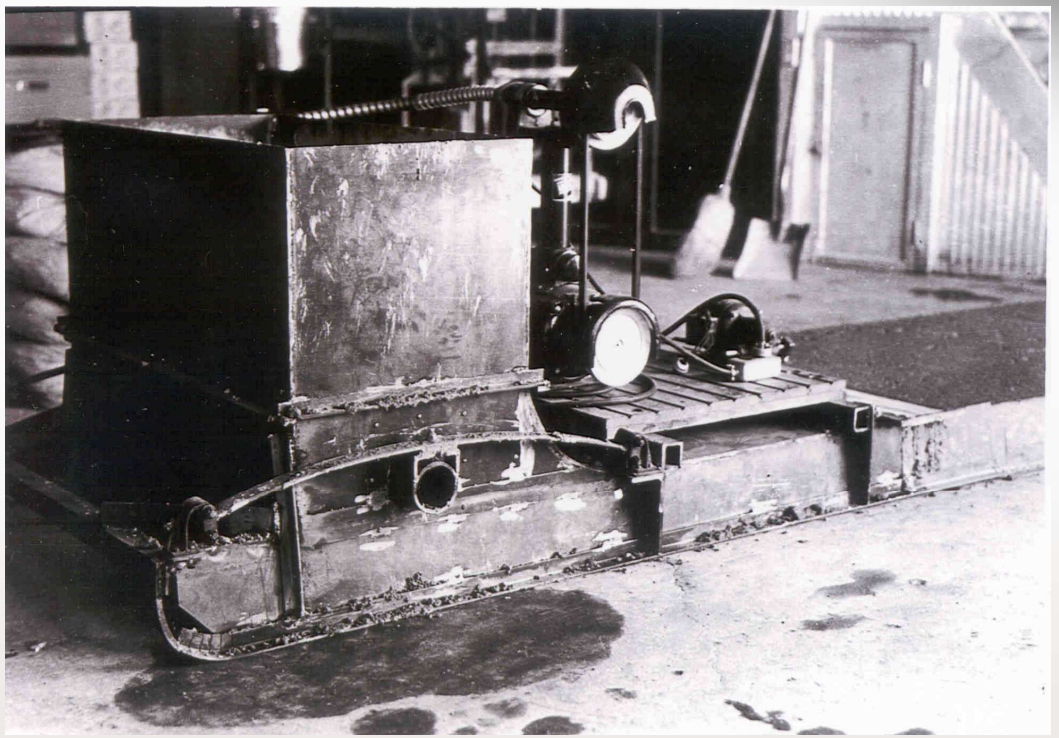
- November 22, 1947
- Extruded slab 18 inches wide and 3 inches thick
- Vibrating unit actuated by an electric hammer
- Small motor on rear drove a flat belt to produce final finish of slab
- Forward motion accomplished with winches
- Slight batter of side forms
- Results were promising and a larger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



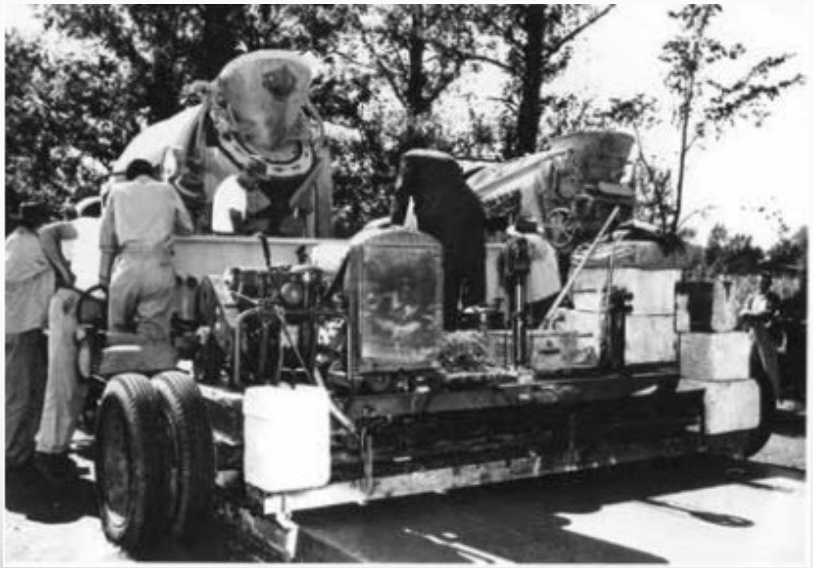


Second Working Model 1948

- 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

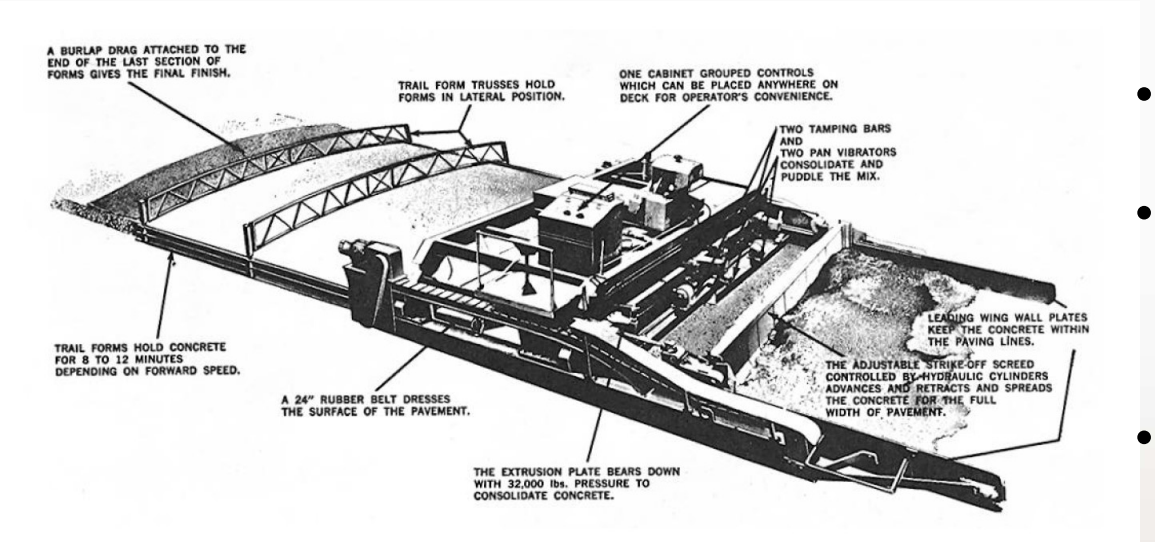
Johnson Paver (Jeep Skate)

- 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



Aberdeen Group, PUBLICATION #C640385, 1964

- 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 Polk County 1955

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

Quad City Paver near Graettinger 1957

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

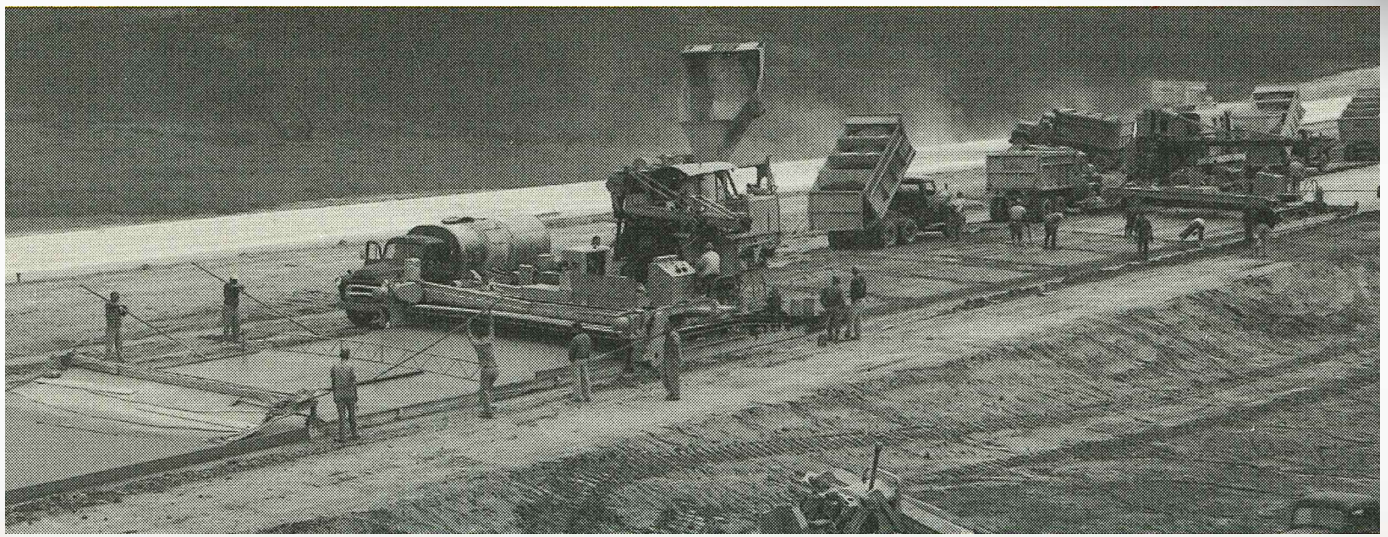
Bureau of Public Roads (BPR) Roughometer

Secondary Roads

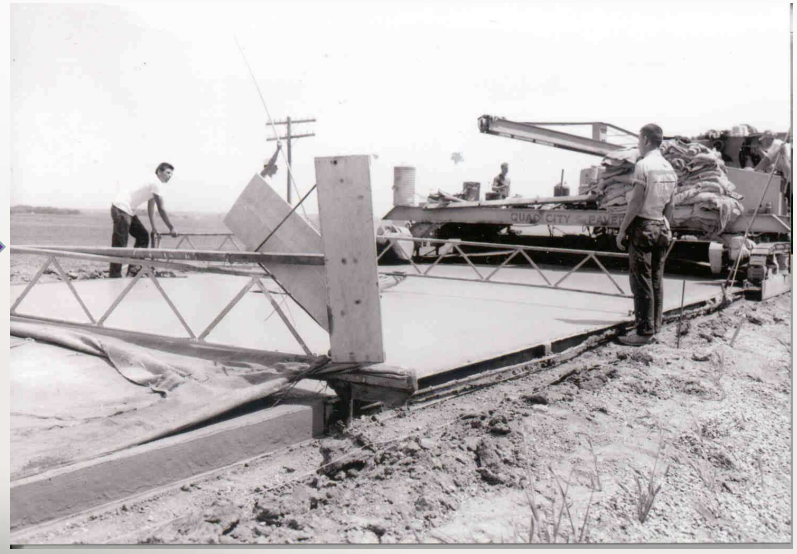
- Iowa Special mid 1960s
- Conveyor attached to front of subgrade trimmer to allow contractor to deliver concrete down the grade
- Concrete carried over the trimmer, while subgrade was trimmed, deposited concrete on grade in front of the paver

Interstate Slip Form Paving

- First use of slipform paver on the Interstate in Iowa
- Fred Carlson Co. 1964 I-80 Iowa County



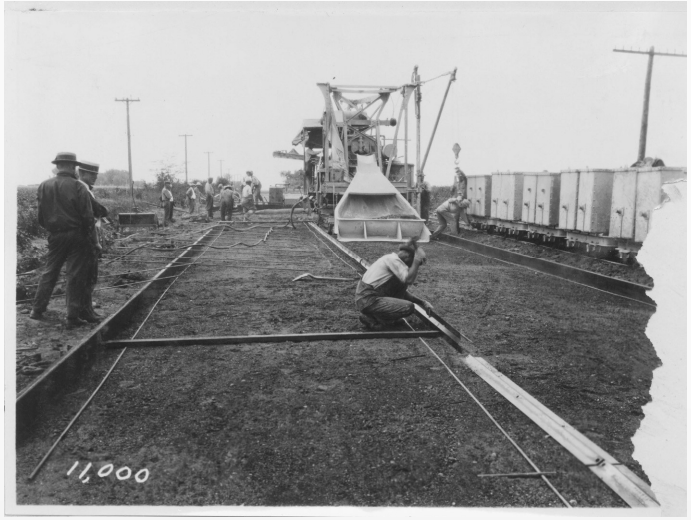
Changes to Pavement Construction



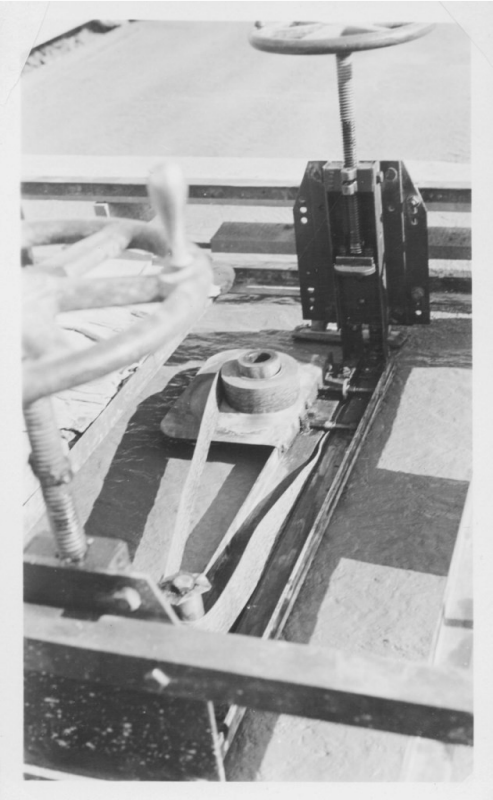
Slip Form Paving-Changes to Jointing

- 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



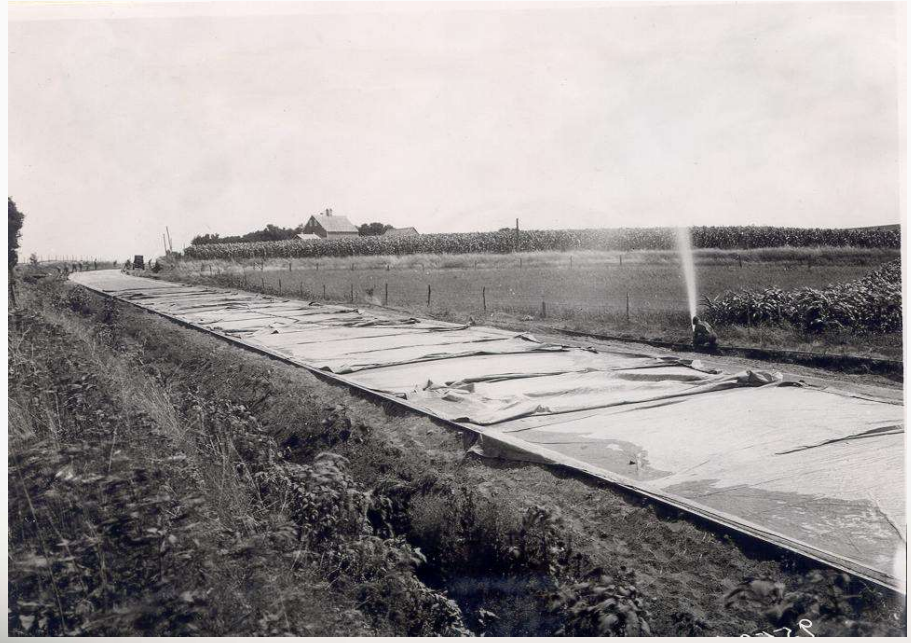
Preplaced metal parting strip
1920s-30s



Parting strip inserted 1950s

Sawing Joints 1956

Slip Form Paving-Changes to Curing



1 day wet burlap cure

7 days wet earth cure 1920s

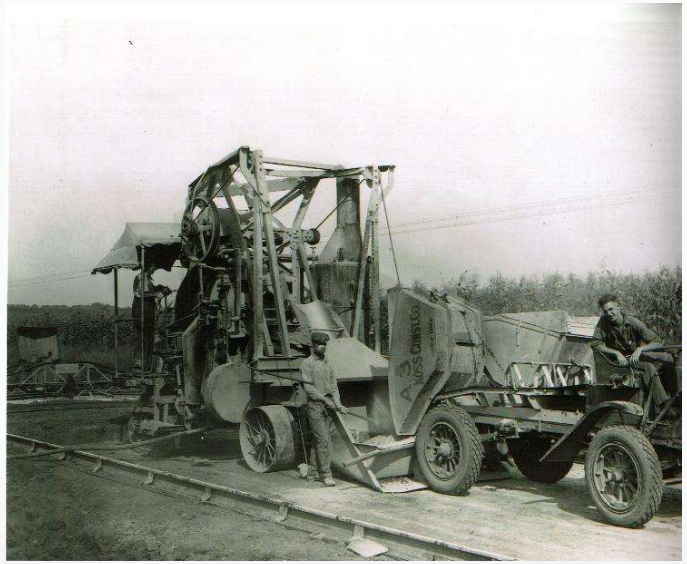
Slip Form Paving-Changes to Curing

- 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.

http://www.acpa.org/wp-content/uploads/2016/03/ACPA-Concrete-Legacy-LORES.pdf

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:

Mix No.	BASIC ABSOLUTE VOLUME OF MATERIAL PER UNIT VOLUME OF CONCRETE			
	Cement Minimum	Water Approximate	Fine Aggregate Approximate	Coarse Aggregate Approximate
1C	0.106620	0.155975	0.258047	0.479358
2C	0.109446	0.160109	0.292178	0.438267
3C	0.113794	0.166468	0.323882	0.395858
4C	0.117952	0.172552	0.354748	0.354748

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).

Mix No.	APPROXIMATE QUANTITIES OF DRY MATERIAL PER CUBIC YARD OF CONCRETE		
	Cement	Fine Aggregate	Coarse Aggregate
1C	1.50 bbl. (564 lb.)	0.5760 tons	1.070 tons
2C	1.54 bbl. (579 lb.)	0.6520 tons	0.9785 tons
3C	1.60 bbl. (602 lb.)	0.7230 tons	0.8835 tons
4C	1.66 bbl. (624 lb.)	0.7920 tons	0.7920 tons

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:

Mix No.	Basic Absolute Volumes of Material Per Unit Volume of Concrete				
	Cement Minimum	Water Approximate	Entrained Air Approximate	Fine Agg. Approximate	Coarse Agg. Approximate
C-2	.110203	.158144	.06	.267662	.403992
C-3	.114172	.163840	.06	.297395	.364593
C-4	.118330	.169808	.06	.325931	.325931
C-5	.122867	.176318	.06	.352948	.287867
C-6	.127782	.183371	.06	.378308	.250539

The total free water in the concrete, including the free water in the aggregate, shall not exceed 5.5 gallons per bag of cement (.488 pound per pound), 0.78217 cubic foot per cwt.

Mix No.	Approximate Quantity of Dry Materials Per Cubic Yard of Concrete			
	Cement		Fine Aggregate Approx. Tons	Coarse Aggregate Approx. Tons
	Bbls.	Pounds		
C-2	1.551	583	.5975	.9020
C-3	1.606	604	.6640	.8140
C-4	1.665	626	.7275	.7275
C-5	1.729	650	.7880	.6425
C-6	1.798	676	.8445	.5595

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

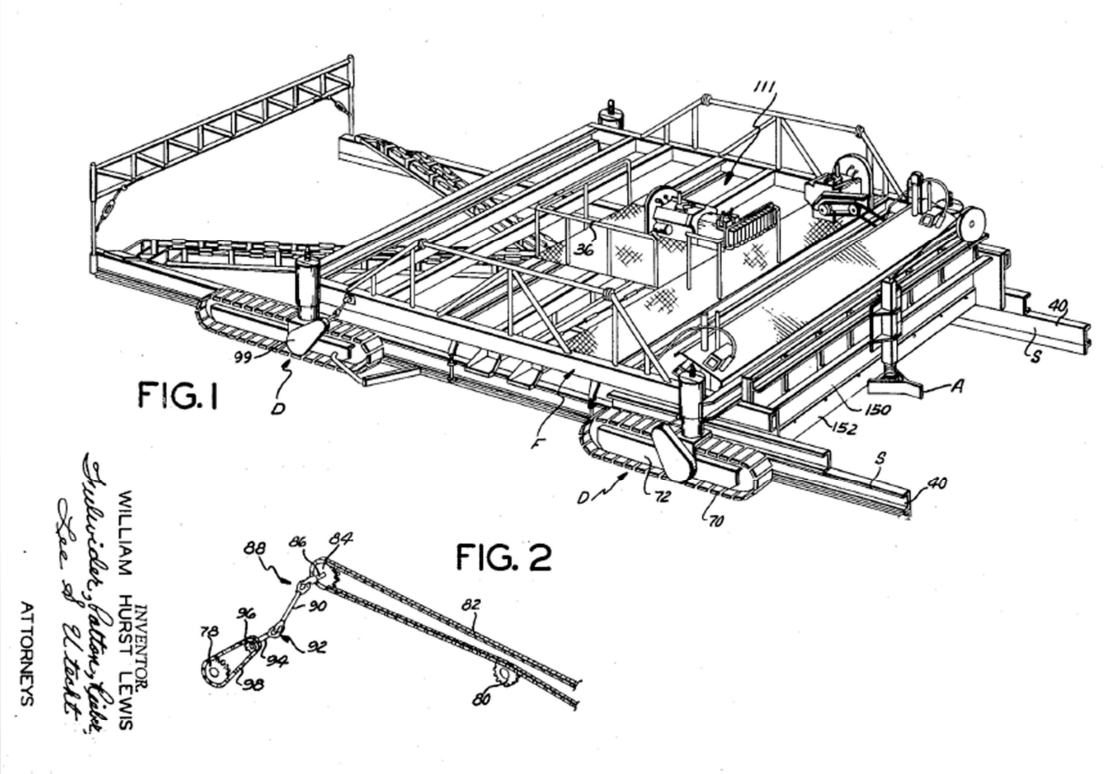
G&Z Paver

- 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

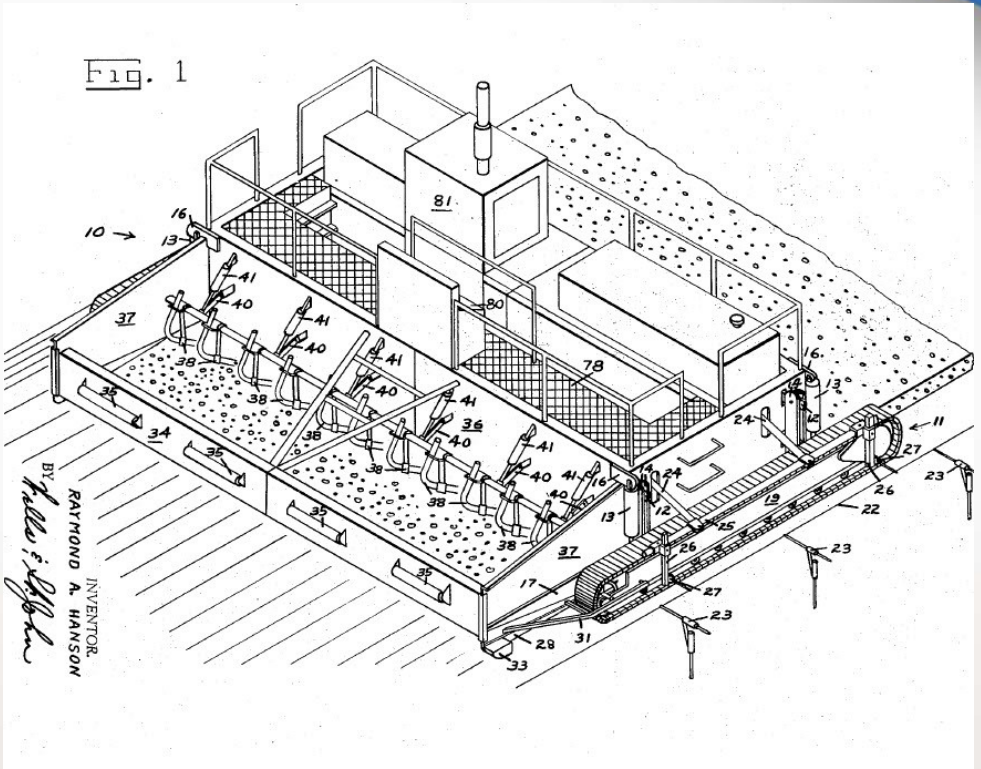
Lewis Paver

- 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

CMI Subgrade Trimmer

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

- 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

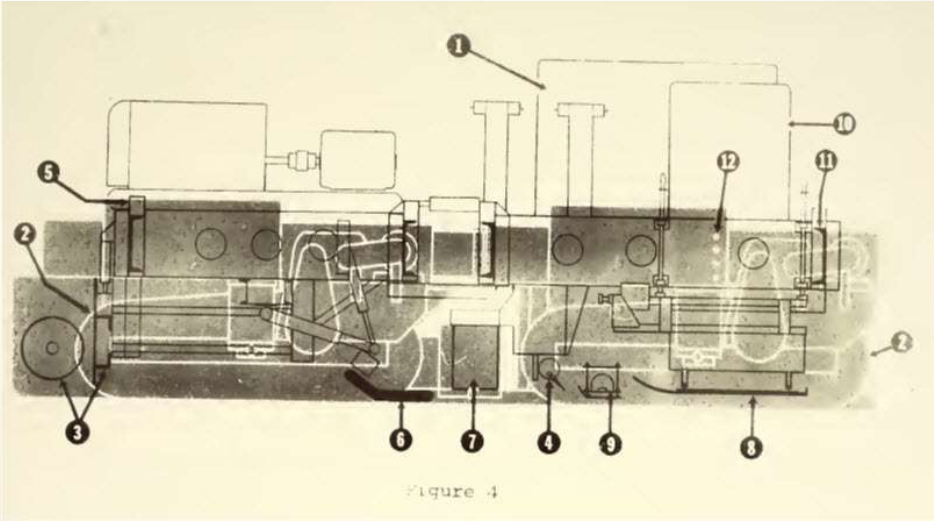
GOMACO

- 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