Evaluation of Transverse Joint Forming Methods for PCC Pavement

National Concrete Pavement Technology Center

Tech Center

Final Report
January 2006

Sponsored by
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16. Abstract

The members of the Iowa Concrete Paving Association, the National Concrete Pavement Technology Center Research Committee, and the Iowa Highway Research Board commissioned a study to examine alternative ways of developing transverse joints in portland cement concrete pavements. The present study investigated six separate variations of vertical metal strips placed above and below the dowels in conventional baskets. In addition, the study investigated existing patented assemblies and a new assembly developed in Spain and used in Australia. The metal assemblies were placed in a new pavement and allowed to stay in place for 30 days before the Iowa Department of Transportation staff terminated the test by directing the contractor to saw and seal the joints. This report describes the design, construction, testing, and conclusions of the project.

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EVALUATION OF TRANSVERSE JOINT FORMING METHODS FOR PCC PAVEMENT

Final Report
January 2006

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EXECUTIVE SUMMARY

The members of the Iowa Concrete Paving Association, the National Concrete Pavement Technology Center Research Committee, and the Iowa Highway Research Board commissioned a study to examine alternative ways of developing transverse joints in portland cement concrete pavements. The present study investigated six separate variations of vertical metal strips placed above and below the dowels in conventional baskets. In addition, the study investigated existing patented assemblies and a new assembly developed in Spain and used in Australia. The metal assemblies were placed in a new pavement and allowed to stay in place for 30 days before the Iowa Department of Transportation staff terminated the test by directing the contractor to saw and seal the joints. This report describes the design, construction, testing, and conclusions of the project.

INTRODUCTION

Current practice in Iowa to control drying and thermal shrinkage in concrete pavements at placement is the development of transverse joints by sawing the surface to induce cracks. The joints are placed at regular intervals and cut to a depth of T/3 or T/4 to induce the cracks. The sawing must be accomplished during the set time of the concrete, but must not dislodge the aggregates in the concrete surface. Sawing time is greatly affected by the weather, concrete mix design, and set time. Joint sawing costs time and money, involves environmental issues, and is sometimes more of an art than a science in terms of determining the proper sawing time window.

Recent research has identified one or more potential methods of using the slipform paver to induce a plane of weakness in the longitudinal direction at the pavement surface. In this way, the need for longitudinal sawing is eliminated. As a result, the paving industry is asking for similar research to develop some type of joint-forming device or method for transverse joints.

BACKGROUND

The research team investigated the problem to date and field tested two devices aimed at forming the transverse joints. Two joints were installed in Buchanan County, Iowa, in 2003. Both used a galvanized L-shaped piece of metal placed in the area of the dowel basket to form the joint. One joint placed the device above the dowels (but below the vibrators), and the other placed the device on the base material below the dowels. Both devices performed adequately, but not in the manner expected. Further refinements and multiple installations were required to field test the devices fully.

In a separate research activity, cores were extracted from a former state highway, Number 111 south of Britt, Iowa. The two cores were extracted from existing transverse cracks and revealed vertical metal joint-inducing devices near the interface of the pavement and the subgrade. The crack was relatively straight and tight without the addition of dowels. This finding suggests that such means can be employed to get a transverse joint.

A similar joint development device made with plastic has successfully been developed by a Spanish engineer and has been marketed in Australia. It has been tested with some success. However, this is not the first time that such a device has been considered. Several ideas have been patented, but most are not in use due to costs or the perception of performance problems.

RESEARCH OBJECTIVES

The objective of this research was to evaluate known and conceptual joint-forming equipment that can be employed efficiently and cost effectively at the time of pavement construction to form transverse joints or induce the vertical crack that acts as a joint in a dowelled or plain concrete pavement. Efficiency was measured in terms of ease of installation, and the cost factor involved measuring the savings in the difference between the materials and labor costs of installing the device versus the cost of the joint sawing. Performance was measured in terms of crack formation, irregularity, and performance over time.

The work was carried out in six tasks, outlined as follows:

Task 1: Identification of materials and potential installation projects. In cooperation with the Office of Construction and the Office of Materials Research in the Iowa Department of Transportation (DOT), the research team identified a 2005 construction project (U.S. Highway 20 near Fort Dodge, Iowa) that could be used to test available joint ideas. The project design called for dowelled joints, which allowed for the installation of the joint materials in the area of the dowel basket.

Task 2: Identification of potential material ideas for materials and methods to be used in joint formation in the plastic concrete. The goal in this task was to form the joint from within instead of by inserting something in the fresh surface. The research team selected from ideas obtained through industry representatives and from the team's own ideas, such as the sheet metal ideas tested in 2003. Materials and methods were considered in conjunction with conventional dowel baskets as a first choice, and for non-dowelled situations as a second choice.

Task 3: Installation. The research team, with the assistance of the highway paving contractor, installed three test sites for each material tested. Test sites consisted of six joints of a given material and were separated from the next test section by 10 conventional doweled and sawed joints. All pavement surface area was longitudinally tined for consistency. Vibrator heights were checked to assure that vibrators do not come in contact with devices placed above the dowels. Materials secured from commercial vendors were placed in accordance with their specifications.

Task 4: Monitoring. All test sites were monitored continuously for the first two weeks after construction, every two weeks over the following month, and once per month thereafter, for a total monitoring length of six months. The measurements included, but were not limited to, the following items:

1. Cost of construction materials and manpower to install.
2. Continuous weather records from the time of paving until the end of monitoring to identify maximum and minimum temperatures, precipitation, relative humidity, and solar radiation.
3. Time of crack identification on the surface, location and path of the crack, width of crack at 10 locations across the pavement.
4. Time of cracking, location of cracks, and width of crack in the default sections.
5. Coring of selected joints to determine the source of irregularities in the crack in the test sections.

Task 5: Development of reports. Quarterly reports and a final report were developed to document the progress of the research, identify the performance of the various joint materials and methods, note the relative cost of each, and explain the limitations on the production and installation of such devices.

Task 6: Presentation of findings. The findings of this work will be presented to the Iowa Highway Research Board for approval.

LITERATURE REVIEW

Inspiration for the present research arose from two sources. The first source is two cores taken from a former state highway in north-central Iowa. The two cores of transverse cracks, taken at random locations in a 16-km (10-mile)-long project, yielded vertical steel materials at the bottom of the slab. These cores are shown in Figures A1–A3 in Appendix A. The cracks had migrated from the top of the steel strip to the pavement surface. The steel material was 76–89 mm (3 to 3.5 inches) in height and 3.2 mm (1/8 inch)in thickness. The crack formation and the randomness of the cores taken would indicate that the metal extends across the width of the slab. The surface cracks were very straight in alignment across the slab and had not spalled over time. The concrete in Figures A1 and A2 is approximately 24.1 cm (9.5 inches) in depth, and the core in Figure A3 is 27.9 cm (11 inches) in depth.

The second source of inspiration came from the International Pavement Management Conference in Sidney, Australia in October 2004. One of the exhibitors provided information about a joint called JRI+ developed by Farobel SL, a Spanish concrete company based in Barcelona. The JRI+ joint is essentially a plastic insert (placed before paving) that eliminates the need to saw joint faults. Details of that joint material's configuration and placement are shown in Figures 1–4.

Figure 1. JRI+ joint before concrete placement

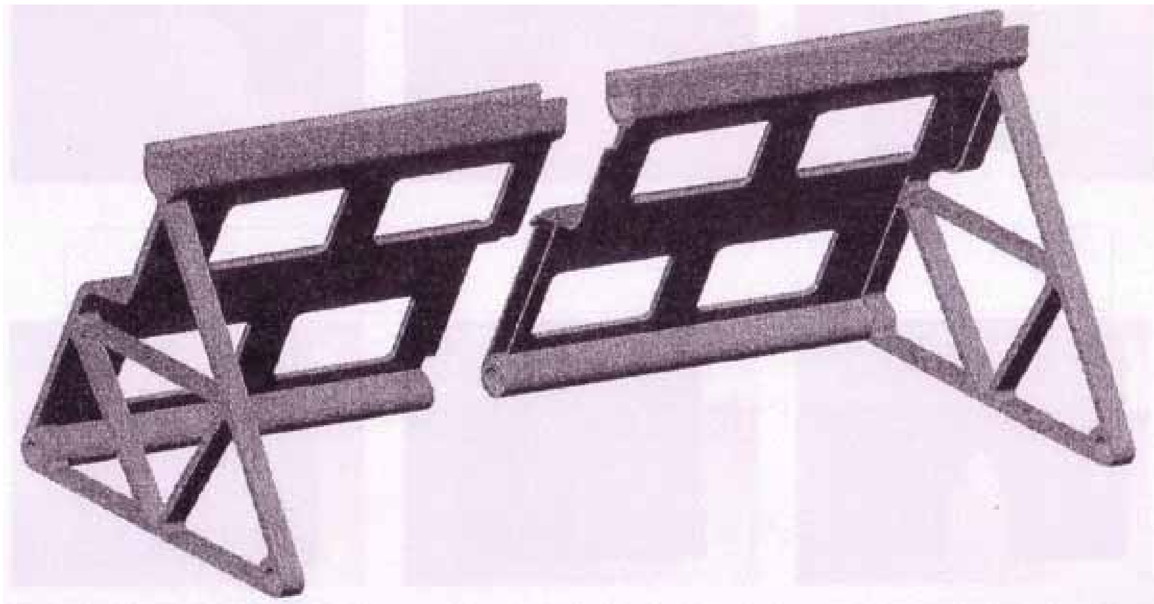


Figure 2. JRI+ joint drawing

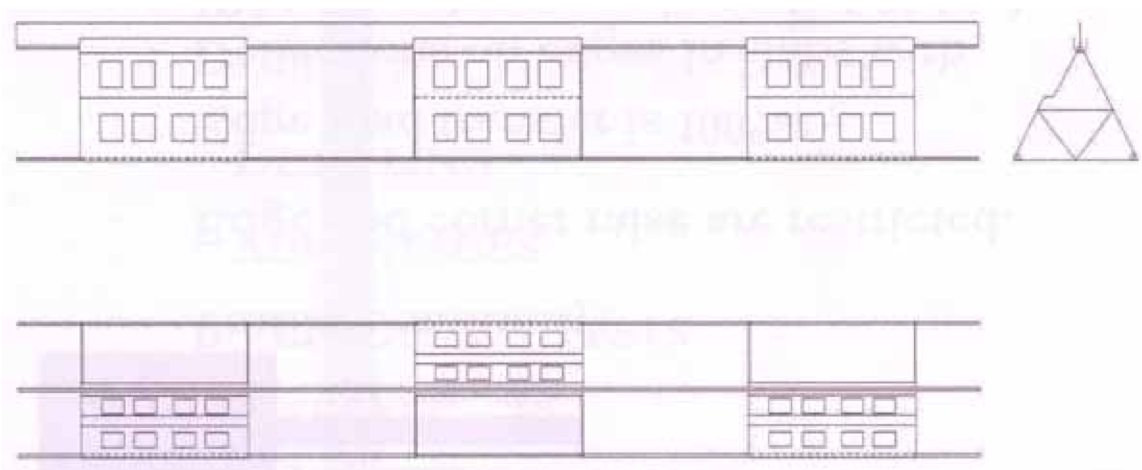


Figure 3. JRI+ joint schematic diagram

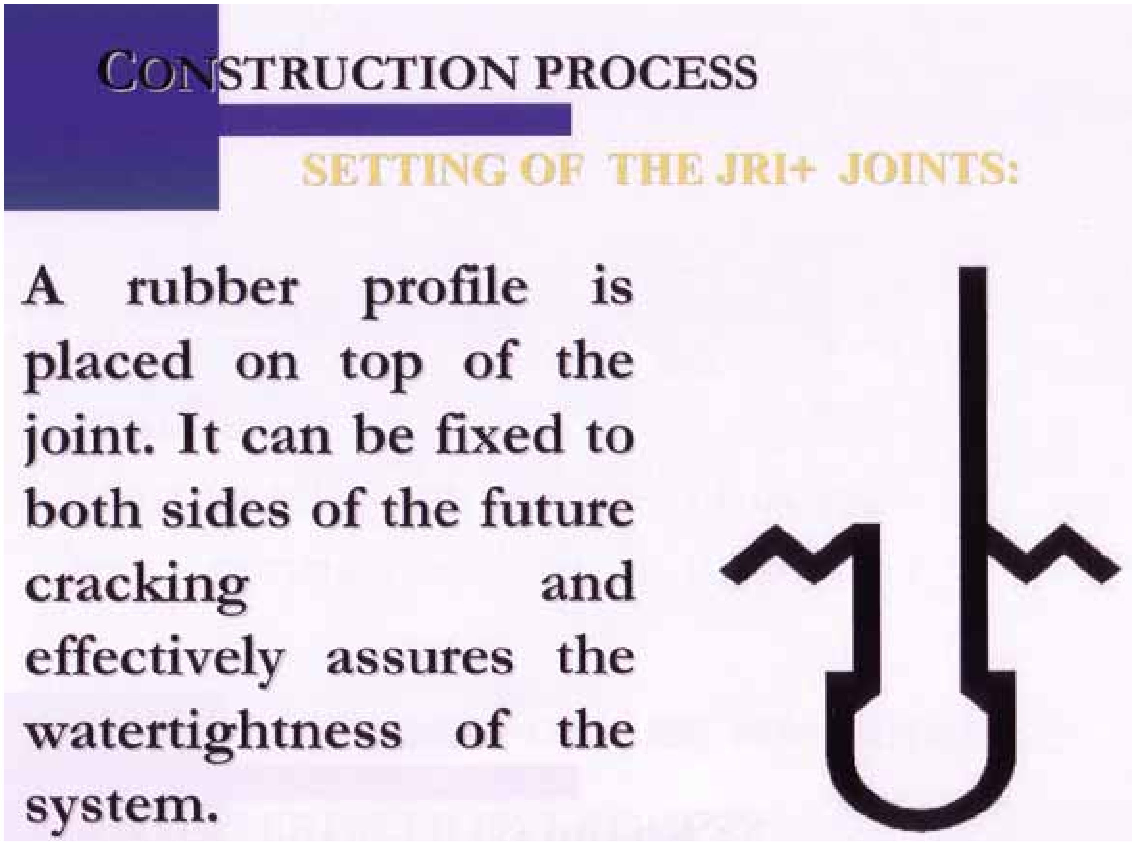


Figure 4. JRI+ joint construction process

However, the use of alternative materials for joint formation is not a new idea. A search of existing patents shows that many have tried to solve this problem and have patented their ideas. A summary of the results of this search is included in Appendix B.

In 2003, the research team was contacted by members of the construction industry to investigate ways to form transverse joints without sawing. This came after the initial success of the longitudinal joint former (Bobsled) in eliminating the need for sawing and sealing of longitudinal joints. For this research, research staff from the Iowa DOT installed two metal joints in a sample pavement in 2003. Galvanized metal angles were placed above the dowels in one location and below the dowels, on the base, at another location. The performance was monitored during and after construction. However, due to the minimal number of joints, conclusions could not be made from this test.

SITE LAYOUT

Because the transverse joints project was identified in 2004 as a priority by staff from the National Concrete Pavement Technology Center and the Iowa Highway Research Board, a project was approved for construction in 2005. In consultation with the Iowa DOT's Office of Construction, a site in Webster County, Iowa, on U.S. Highway 20 near Fort Dodge was selected for installation of the test materials. Figure 5 shows the construction site selected. The installations were made in the east 3.2 km (2 miles) of an 8-km (5-mile) section of the westbound lanes of this highway. The test area is identified in the circles on the project maps and diagrams in Figures 5 and 6. Six separate test locations of six joints each between Stations 933 and 942 are shown in Figure 6 and in Table 1.

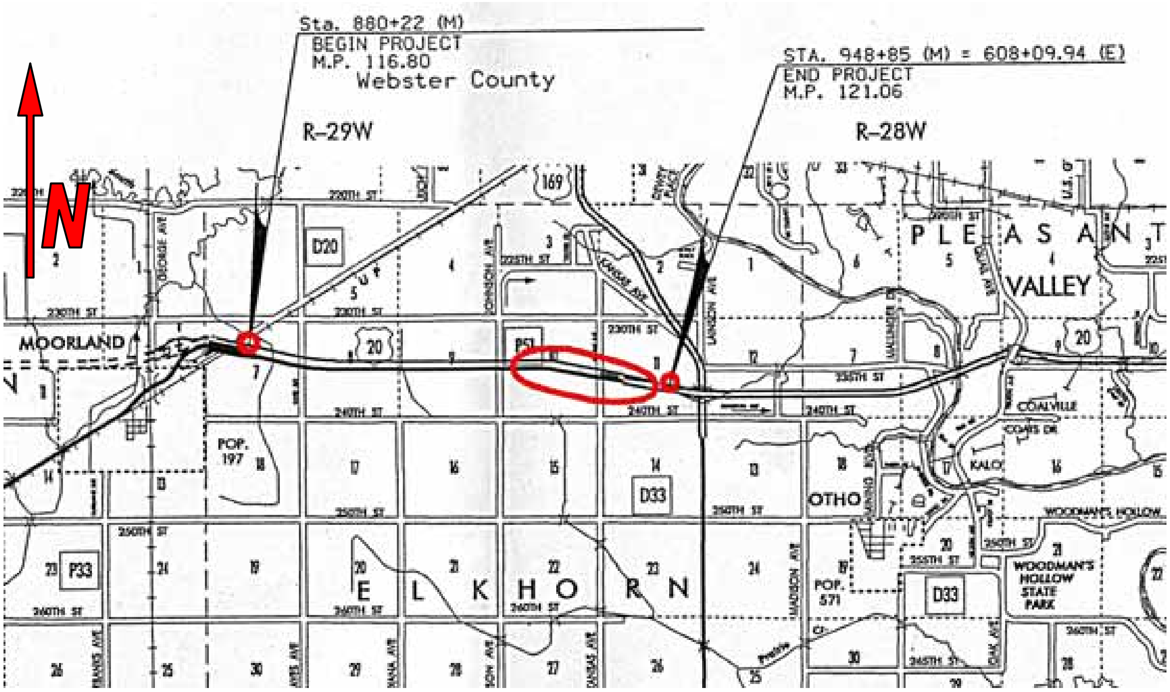


Figure 5. Site location

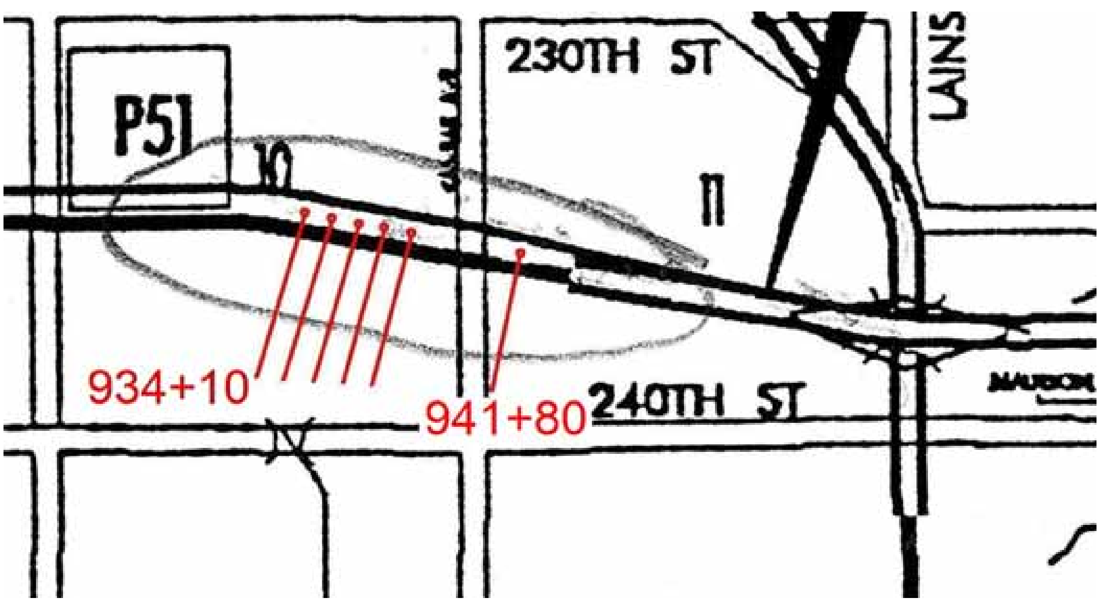


Figure 6. Approximate location of each test set with first and last stations

Table 1. East and west ends of the six test sites

Approximate station (m)	East/west end of test	Bottom/top	Size
933+74	West	Top	51-mm (2.0 in.) plate
934+10	East		
934+74	West	Top	44.5-mm (1.75-in.) plate
935+10	East		
935+74	West	Top	38.1-mm (1.5-in.) plate
936+10	East		
936+64	West	Bottom	76.2-mm (3.0-in.) plate
937+00	East		
937+64	West	Bottom	70-mm (2.75-in.) plate
938+00	East		
941+44	West	Bottom	64-mm (2.5-in.) plate
941+80	East		

Figures 7 and 8 illustrate the configuration of the galvanized metal angles placed over the dowels and on the base materials.

Figure 7. Typical cross-section of metal angles placed over dowels

Figure 8. Typical cross-section of metal angles placed on the base materials

CONSTRUCTION

The test devices were installed on the grade on May 9, 2005 by a crew of five members of the research team. Installing the 36 separate joint-forming devices took approximately 4 hours. Dowel basket pins were placed on approximately 610 mm (2-foot) centers along the joint formers placed on the base. The pins were driven behind the "L" of the metal (away from the paver) to prevent the metal from being overturned with concrete pressures at the paver. The devices above the dowel basket were secured with wire ties to the dowels themselves at 305 mm (1-foot) intervals. This work included placing the devices below the dowel baskets or on top of the dowels and securing them in order to prevent rollover when the concrete was placed in front of the slipform paver. Prior to paving, measurements were taken to reference the relative location of the metal strips in each joint. The distance between the joint-forming material in each joint was measured at each edge of the pavement and at the quarter points. This spacing is recorded in Appendix C.

Paving over the test sections began May 17 and covered all test sections by the following day, May 18. Paving was delayed approximately three hours on May 18 due to rain. During the following two weeks, rain showers were scattered and the temperature remained fairly mild, often peaking in the high 70s (°F). During paving, the alignments of the metal joint formers were observed as they were being covered with concrete. These visual notes are shown in the tables in Appendix D. No problems with the alignment of the metal strips were experienced during this operation.

MONITORING AND RESULTS

The first day of monitoring was May 17. Photographs were taken from various points around each test site before, during, and after concrete was poured. Data was recorded during the paving process and after the concrete had set enough to walk on (one day after pouring was deemed an appropriate set time). Notes on the alignment of the devices during the paving operation are shown in Appendix D. These data identify the visual notes made by the research team member as the devices were being covered with concrete. No specific problems were noted in this activity.

For the next two weeks, each test joint was checked for transverse cracks every weekday, excluding May 27 and May 30 (Friday and Monday of Memorial Day weekend). A final check was performed on May 31. No transverse cracks had yet developed, apart from a centerline crack at station 938+00. The weather for this period, as recorded at the Fort Dodge weather station approximately 8–16 km (5–10 miles) north of the project, is noted in Appendix E. The weather data indicate cool days and nights with some precipitation, as is expected in Spring paving.

On June 14, the Iowa DOT's Office of Construction decided to saw the joints and thus advised the resident engineer and the contractor. On June 16, the joints were sawed and sealed by the Fred Carlson Co. Also on that date, the research team took one core from each of the test groups to verify the position of the devices relative to the dowel baskets and vertical orientation.

In accordance with the contract documents, the principal researcher performed additional reviews of the site on the following dates:

1. June 7, visual survey
2. June 14, visual survey
3. June 16, visual survey and pavement coring
4. June 23, visual survey
5. July 6, visual survey
6. July 9, final shoulder rock applied and beginning of signing
7. July 12, ribbon cutting
8. July 19, route opened to traffic
9. August 21, visual survey
10. September 13, visual survey and joint opening survey
11. January 6, 2006, visual survey

The results of the surveys mentioned in the list above are shown in Appendix F. No surface cracking was identified above the joint materials in any of the surveys. Also, no secondary cracking has occurred to date, due to the location of the saw cut relative to the location of the joint former in any of the cases. The coring was done in one joint in the passing lane, outside wheel path, of each of the six test groups progressing from east to west (downward in stationing). Coring was done across the newly sawed joints, and in two locations a second hole was required to locate the device in the center of the hole. A second hole was required in test sections 5 and 6. Photos of the test section cores are shown in Appendix G.

The cores indicate two specific details that may be of interest in the future. First, in section four the joint former is above the dowels and, as indicated in the photos, contains a crack that extends between the top of the metal and bottom of the sawed joint. The crack is highlighted by the center black ink mark in Figures G5 and G6 in Appendix G. It is not possible to tell which way this crack initiated, but the crack is of interest to the research.

Second, in most of the core locations the metal joint former is offset from the sawed joint by up to 25 mm (1 inch) or more. The location is offset because the saw crew followed crude paint lines on both edges of the slab, which the research crew placed to help locate the joint-former crack. The saw crew connected these lines with the sawed joint. This process may have created a long-term spalling problem or an irregular crack in the surface. To date, no such activity has been noted.

CONCLUSIONS

Due to the sawing of the joints, no specific conclusions can be drawn as to the effectiveness of any of the six joint-former patterns placed for this project. However, it should be noted that most of the traditionally sawed joints in the area of the test sites did not crack completely through the slab in the first 30 days after paving. In many cases, a crack only occurred late in the month on every sixth to eighth joint. However, further monitoring was not possible after the asphalt shoulders were applied. The researcher feels that weather played a major part in this project, in that the cool temperatures of spring and small amounts of rain did not enhance the ability of the slab to cure and crack.

RECOMMENDATIONS

It is recommended that this research be continued in the future. The following are recommendations for future research projects:

1. A county road project should be selected for the next test.
2. The materials used on this project should be placed in the same manner on the next project.
3. The JRI+ joint device and others currently identified in conjunction with dowel assemblies should be placed in the same road for testing.
4. Joints in the test areas should be left in place and monitored for one year before any other actions are taken by the highway owner.

APPENDIX A. CORE IMAGES OF STEEL INSERTS

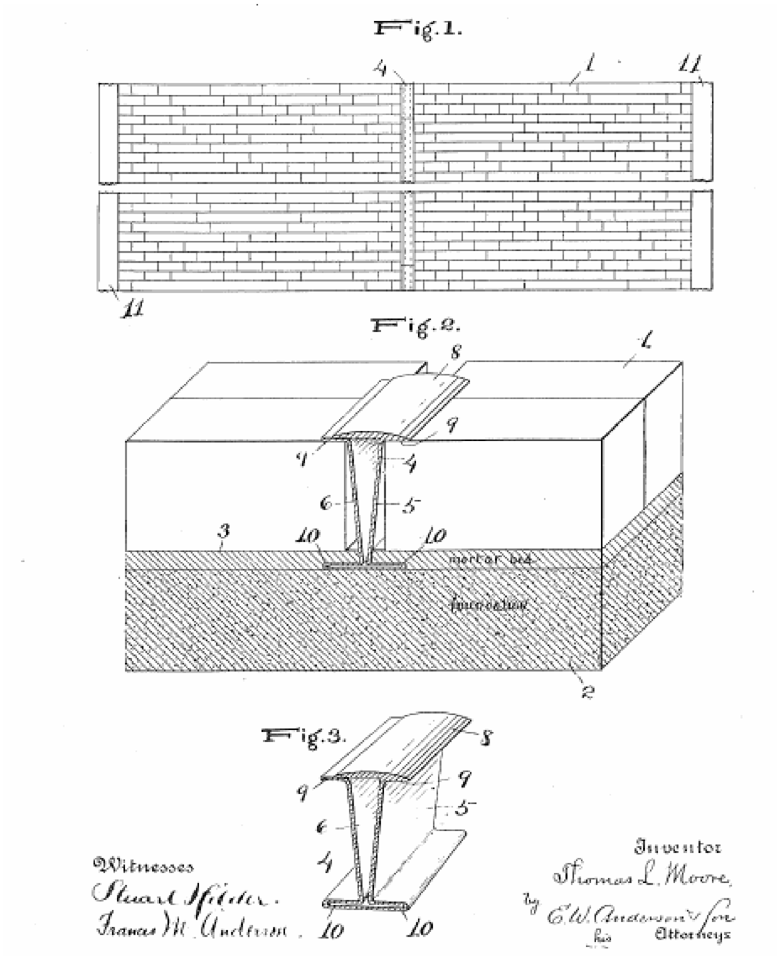
Figure A1. Core 1

Figure A2. Core 1 detail

Figure A3. Core 2

APPENDIX B. REVIEW OF PATENTS FOR CONCRETE JOINTS

#1040731



Inventor: Thomas Moore
Material: Metal

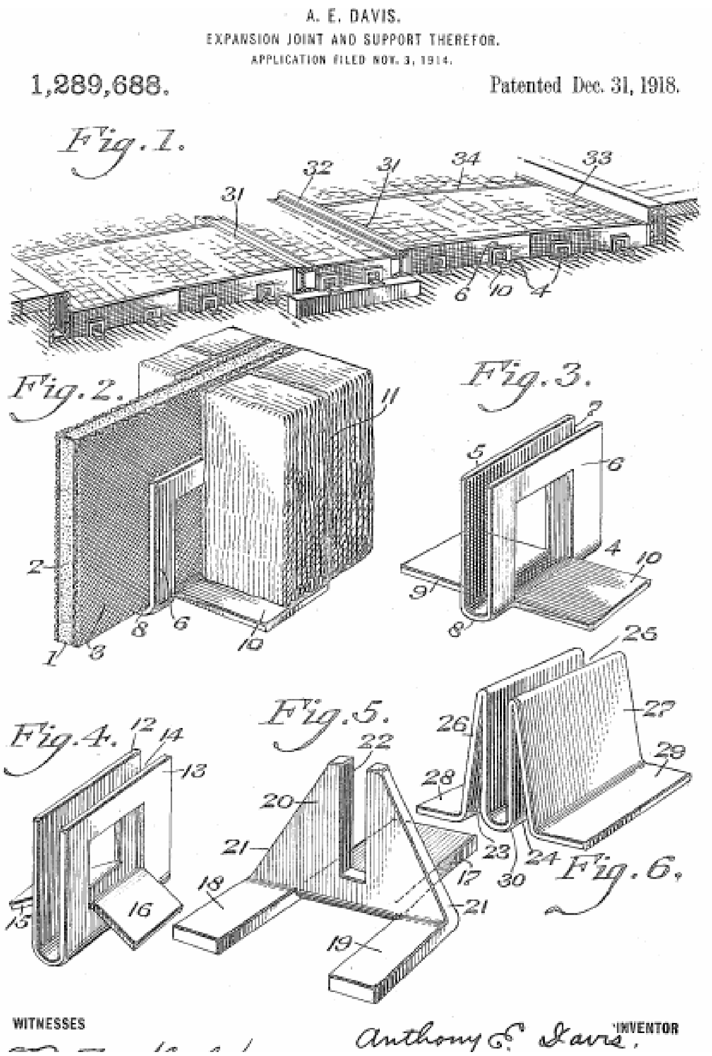
1) wooden block pavement
2) concrete foundation
3) mortar bed
4) joint, preferably placed in position longitudinally of the pavement along the centerline of the roadway

5&6) lateral flanges

7) substantially horizontal extensions
8) outward extensions or shoulders
9) lower lateral extensions
10) Curbing

The joint is a spring metal paving joint

#1289688

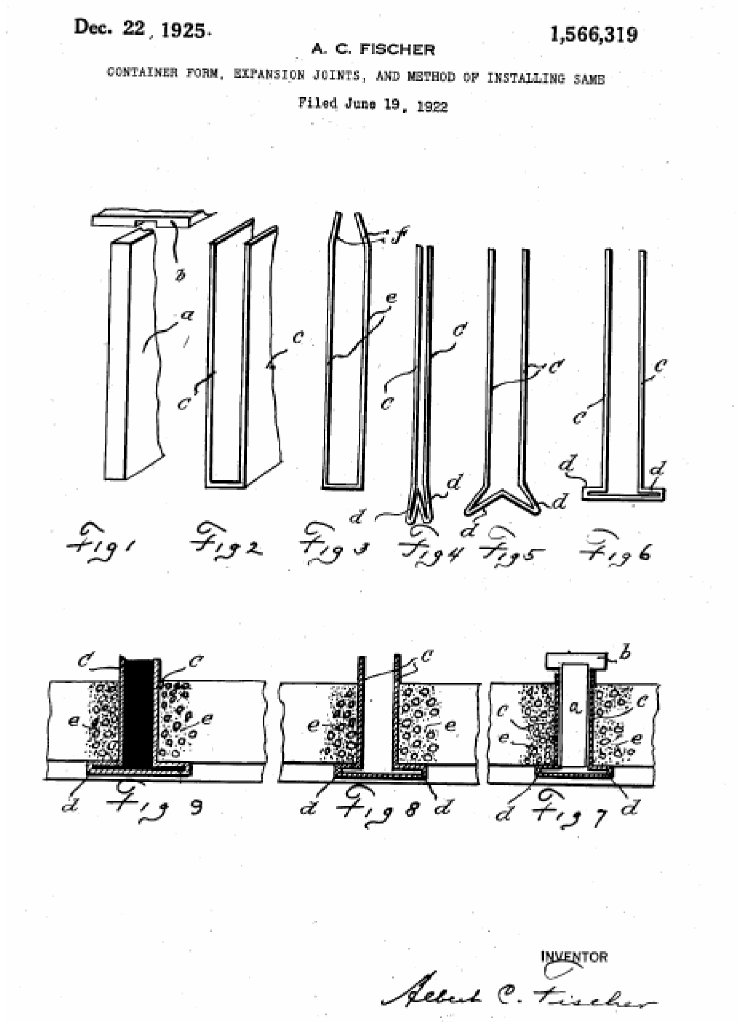


Inventor: Anthony E. Davis
Materials: Aerated asphalt, fabric, metal used for building support chairs
Figure 1: Pavement with joints and supporting chairs
Figure 2: Position of parts during construction
Figures 3–6: different supporting chairs

1) Malleable joint strip, preferably consisting of aerated asphalt
2 & 3) Strips of fabric used to reinforce joint strip
4) Supporting Chair
5 & 6) Outer sides of the supporting chair
7) Supporting chair slot
8) Base of supporting chair
9) Lateral extension plate form from punching out part of sidewall 5
10) Lateral extension plate from sidewall 6
11) Blocks of any desired material
12–16) Similar to 4–10, but with extension plates bent downward instead of perpendicular to

the side walls
17–19) Plates attached to main chair structure to form supporting base
20) Plate deflected upward with inclined sides (21)
22) Gap which will receive the joint strip
23–30) A sheet is bent upward to provide a space to receive the joint strip. Each side is then bent downward and then the ends the sheets are bent to be parallel to the ground in order to provide a base.
31) Expansion joint extending along the tracks (32)
33) Expansion joint extending along the curb
34) Transversely arranged expansion joints

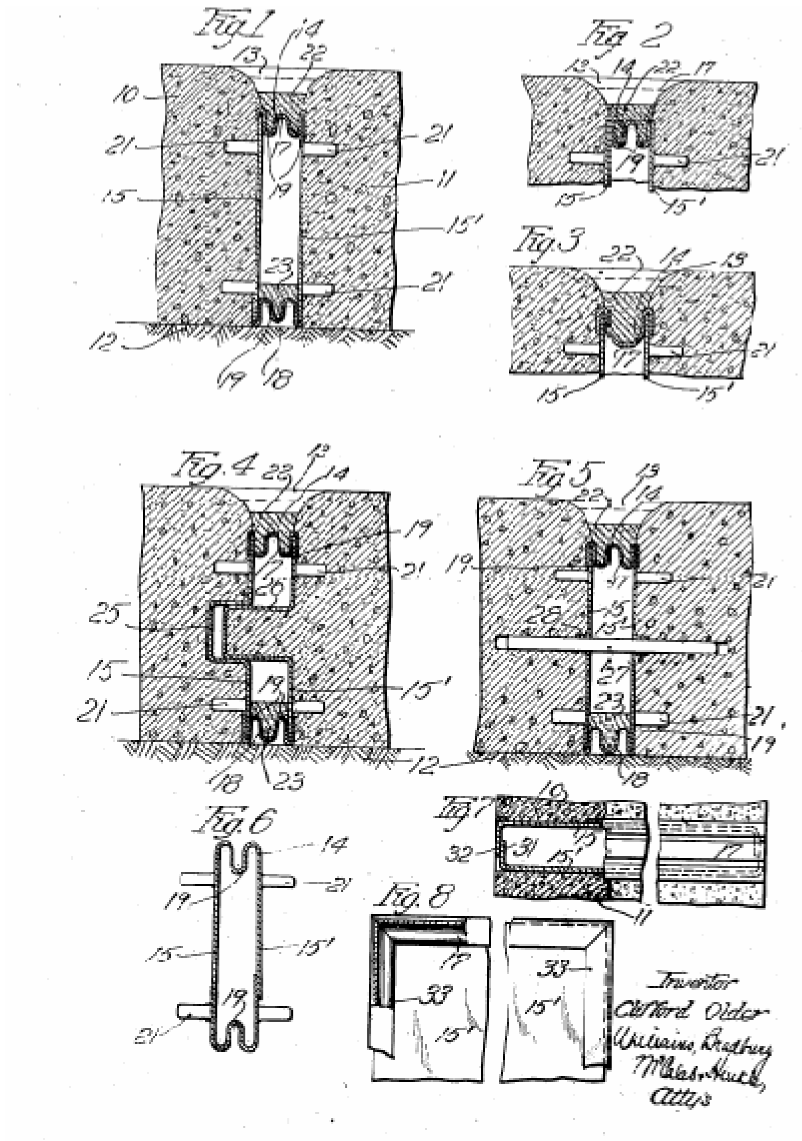
#1566319



Inventor: Albert C. Fischer
Material: The envelope in preferably made of felt, but can be made from paper, burlap, cloth, or canvas. The outside is coated with bituminous or other suitable adhesive. The envelope is placed about a spacing or backing board. When the board is removed the enveloped stays in place due to its flanged base. An appropriate filler is then placed in the envelope.

Figure 1: Folding container with spacing strip (a). The strip is made of wood. (b) is the crowning strip which is not necessary, but can be placed over the base or inserted in (a).
Figures 2–6: Cotainer being prepared to have concrete poured around it.
Figure 7: Folding container with board about it about concrete around it.
Figure 8: Folding container once board is removed.
Figure 9: Folding container once it has been filled.

#1586326



Inventor: Clifford Older
Material: Metal joint with bituminous filling
Figure 1: Vertical sectional view through the paving. This illustrates the improved expansion joint of two adjacent sections of concrete.

10 & 11) Typical concrete slabs
12) Earth subgrade or desired foundation
13) Customary expansion joint
14) Improved expansion joint
15 & 15') Side plates (depth is slightly less than concrete slabs)
17&18) Corrugated edge plate
19) Corrugations extending longitudinally of plates

21) Anchor pins to secure plates to concrete
22) Bituminous filling poured on top of joint
23) Optional bituminous filling

Figure 2: Illustration of different method of attaching corrugated edge plates
This figure is similar to Figure 1, but edge plates 17 & 18 extend up along the inner sides of the side plates.

Figure 3: Illustration of another design of an edge plate
This figure is similar to figures 1 & 2, but the edge plates are dished inwardly in a single corrugation to obtain the necessary expandable and contractional flexibility.

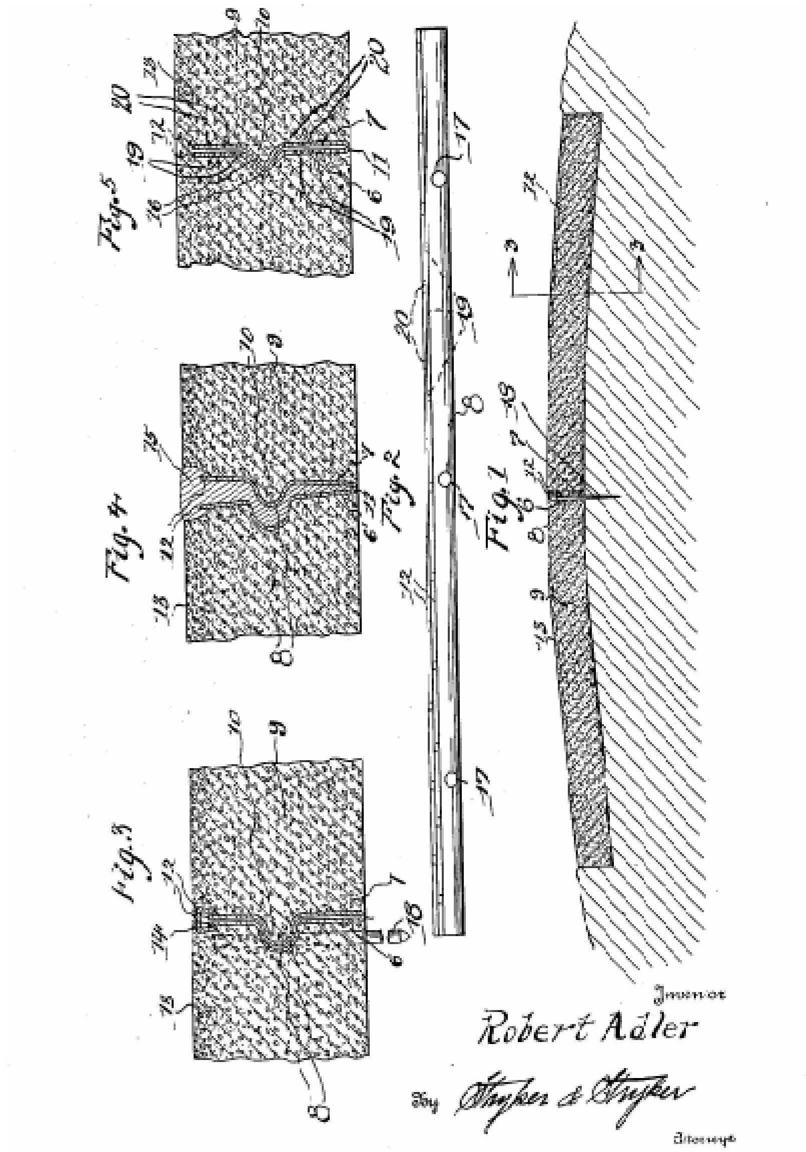
Figures 4 & 5: Similar to Figure 1 illustration different embodiments
25) Intermediate recess extending longitudinally from the side plate
26) Cooperating tongue snapped out to protrude from the side plate and have a sliding fit to #25
27) Dowel pins
28) Flanged hubs struck outwardly from the sides to guide the dowels

Figure 6: Sectional view of another embodiment made of a single sheet of metal folded to this specific shape

Figure 7: Fragmentary plan illustrating a different method of closing the ends of the joints.
31 & 32) End flaps turned from sidewalls of joint and having these flaps overlap with sufficient space to allow for expansion and contraction

Figure 8: Vertical section view illustration a different method of closing the ends of the joints.
33) Corrugated end walls

#1806275



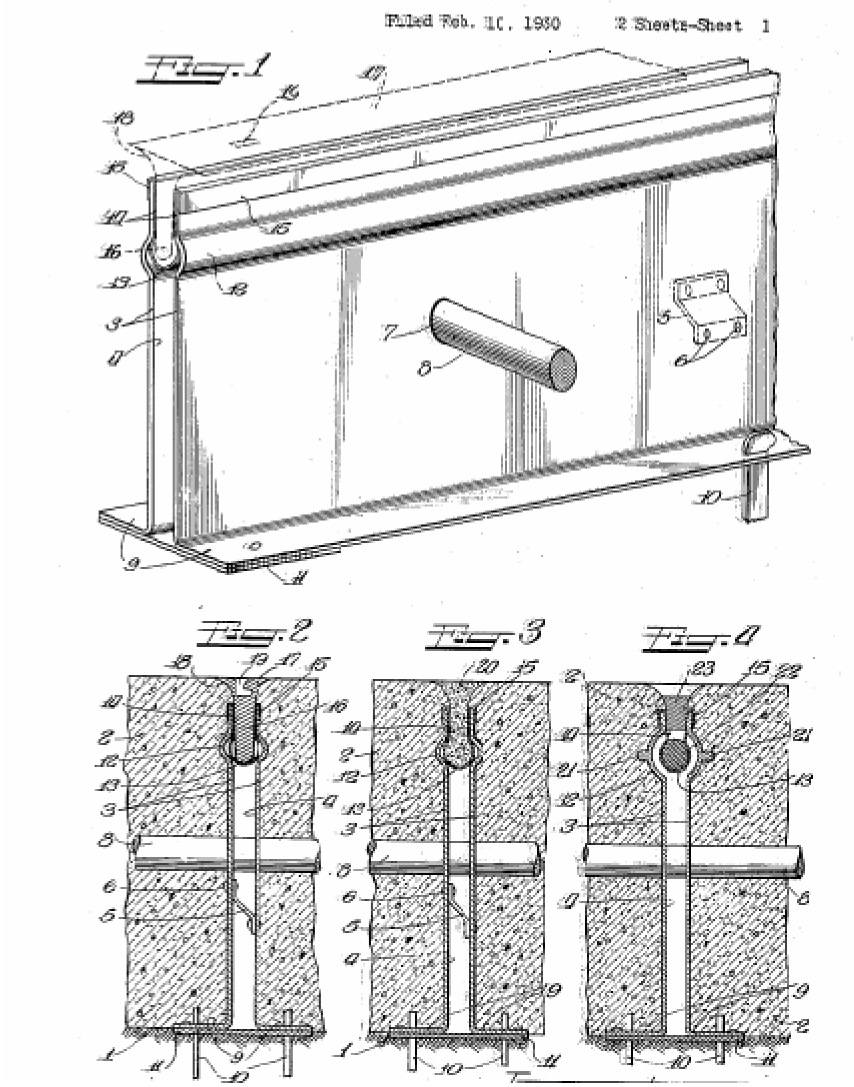
Inventor: Robert Adler
Material: The object of this design is to provide an insert made of 2 strips embedded in plastic that can be separated from each other under contractive stress. These strips will separate from each other more easily than each individual strip could separate from the concrete.

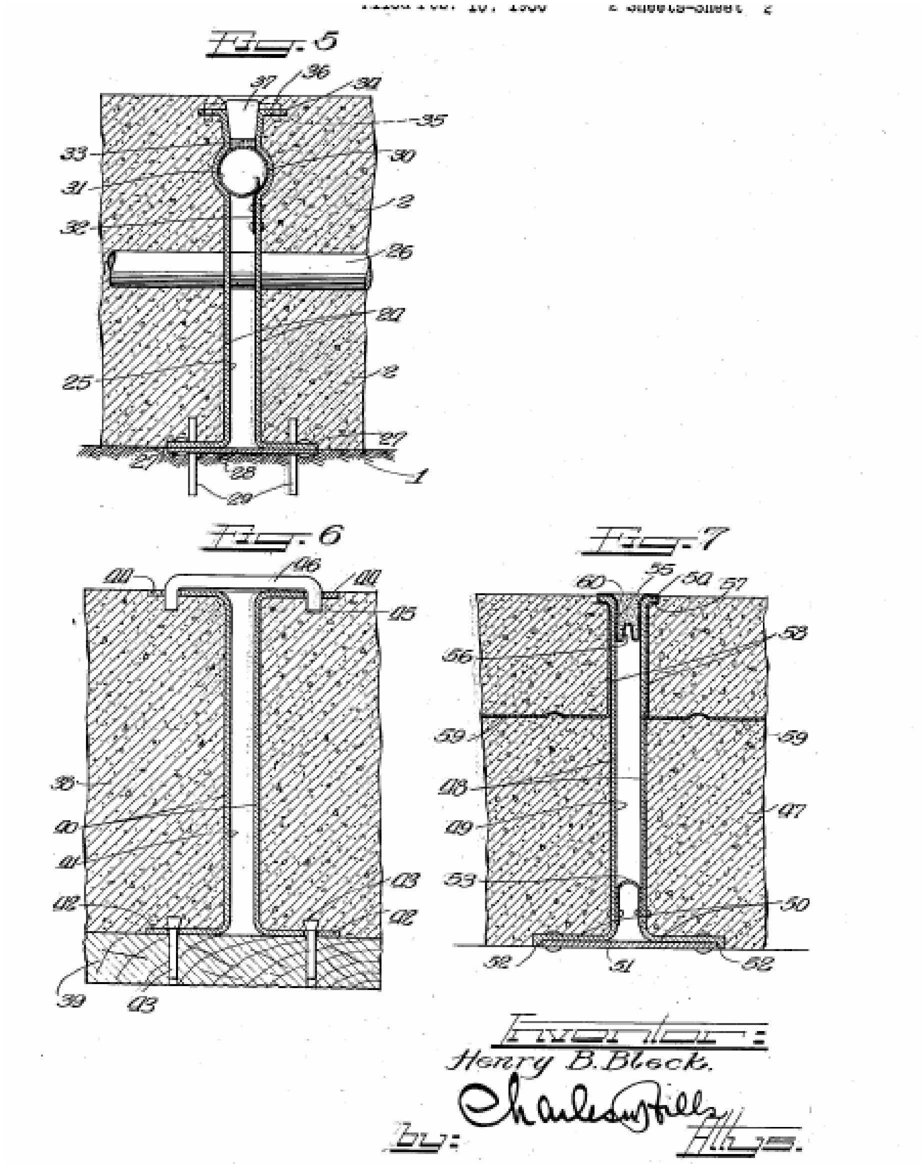
Figure 1: Diagram of cross section of road showing a suitable location for the insert
Figure 2: Enlarged plan view of the insert
Figure 3: Enlarged fragment view of section 3-3 of Figure 1. This shows the suitable clip for excluding plastic composition from between upper edges of component members
Figure 4: Diagram showing separation of 2 strips by contraction and the tar filling of the crack
Figure 5: Vertical view of slightly modified insert imbedding in plastic composition

> 6 & 7) Two strips made of non corroding sheet metal, normally lying one above the other with metal to metal contact

8) Longitudinal extensions of 6 & 7 that interlock with each other
9) Concrete of plastic body the embeds 8
10) Projecting flange which engages another grove from an adjoining portion of road to maintain proper alignment
11) Lower edges where strips (6&7) are joined together in hinge like form
17) Holes to assist in insertion
18) Stakes to drive in to sub-soil after insert are in place
12) Upper edges of strips
13) Upper surface
14) Optional channel clip over #12
15) Tar or other bituminous filler
16) Corrugations
19 & 20) Perforations used to interlock with concrete. These perforations insure that strips will stay bonded to concrete during contraction

#1880725





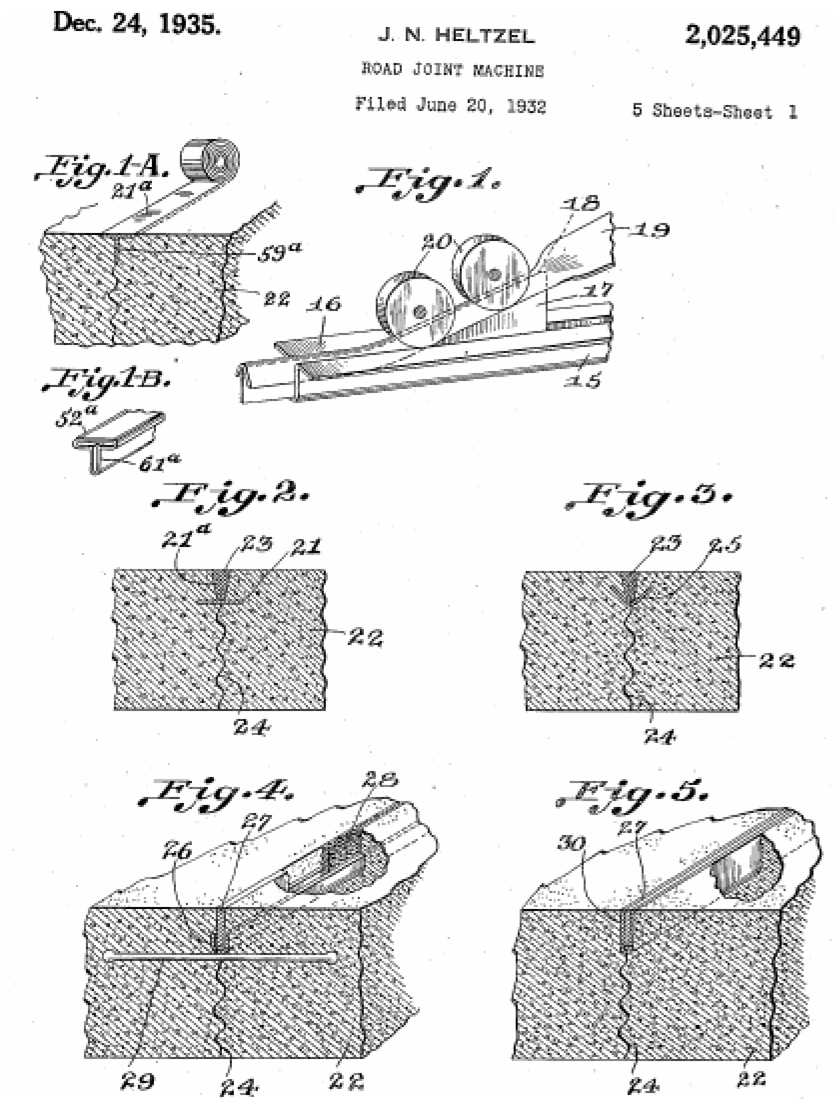
Inventor: Henry B. Black
Material: Walls constructed of asbestos cement composition board or fiberboard, air cell filled with an expansion material filler after wedge plug is removed

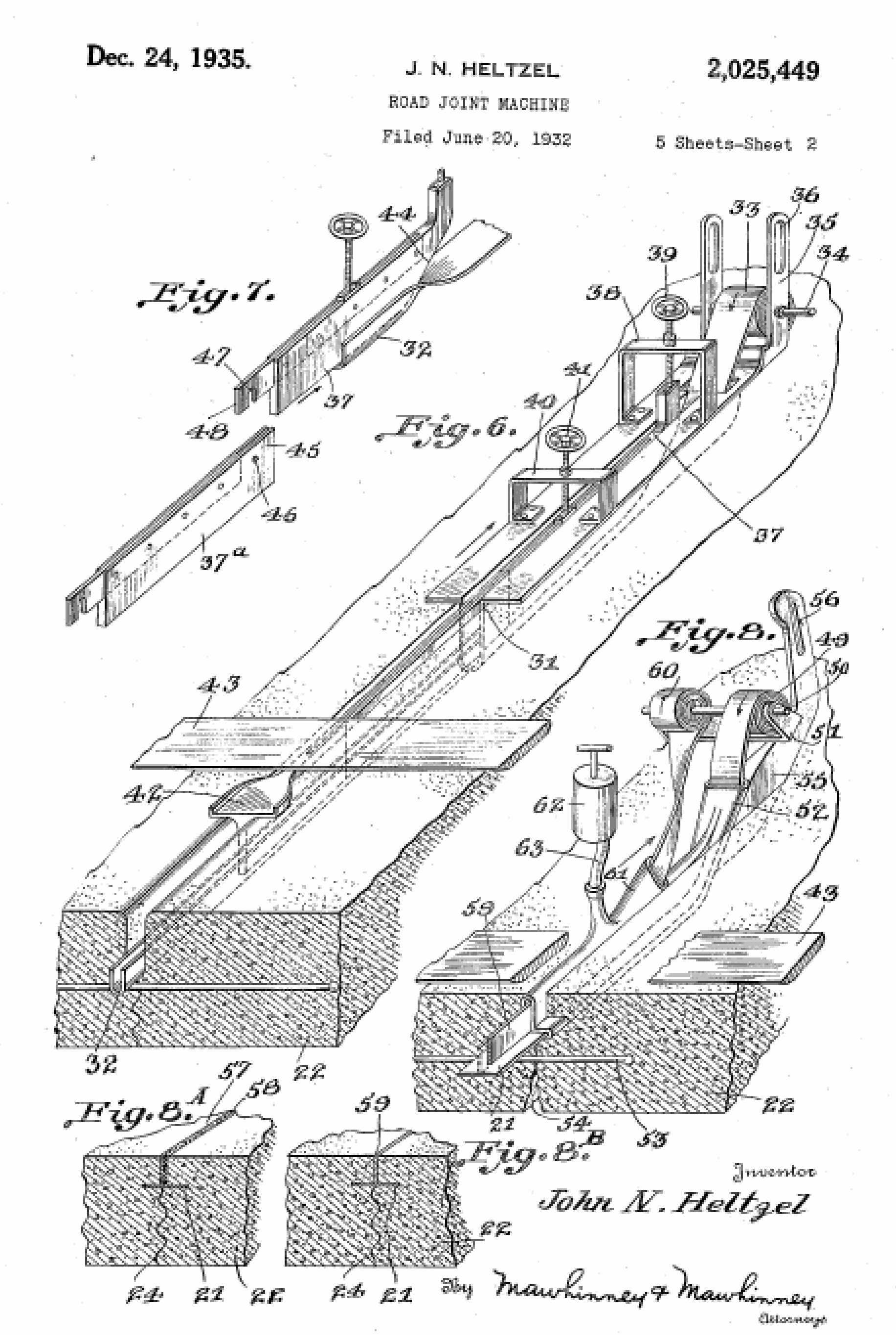
Figure 1: Fragmentary view of improve air cell joint showing the removable wedge plug in dotted lines
Figure 2: Transverse section of expansion joint and wedge plug
Figure 3: Transverse section of expansion joint with not wedge plug, showing filling of mastic material in groove
Figure 4: Modified design with filler and wedge
Figure 5: Transverse section of air cell joint with cylinder or spring ring mounted beneath a wedge and filler
Figure 6: Modified design for use between bridge slabs
Figure 7: Sectional view of modified design for use with tanks or reservoir walls

1) Sub-grade
2) Concrete slab
3) Walls or plates constructed of asbestos cement composition board or fiber board
4) Air cell chamber
5) Flanged spacers used to hold the walls (#3) together
6) Rivets to secure spacers to walls
7 & 8) Opening and dowel bar
9) Foot flange, forms 90 degree angle with walls
10) Retaining spikes
11) Spacers plates attached to flanges by rivets
12) Curved channel
13) Rounded expansion bulb channel
14) Pair of side walls
15) Channel hooks
16) Body portion of wedge plug
17) Enlarged wedge head
18) Walls to permit edges of concrete slab to be round to form mouth of the groove between the concrete sections
19) Spaced hook pockets to be used when wedge is removed
20) Filler, used after wedge is removed
21) Bond rib
22) Sponge rubber or composition elastic filler engaged in bulb channel 13
23) Wedge plug
24) Pair of spectured walls
25) Air chamber
26) Dowel bar
27) Foot flanges
28) Base plates or connecting strips
29) Spikes or stakes to hold air chamber in place
30) Curved channels
31) Spring cylinder of flexible spring roll
32) Mounting flange
33) Filler
34) Outwardly directed flange with appendages for reception of lugs
35) Lugs
36) Outwardly directed arms
37) Wedge plug
38) Bridge slabs
39) Wooden flooring or foundation
40) Pair of walls or plates
41) Air chamber
42) Apertured foot flanges
43) Nails for secured chamber to foundation
44) Upper flanges
45) Lugs or pins
46) Connectors or spacer plates
47) Spaced edges or tank or reservoir wall

48) Pair of walls or plates
49) Air cell chamber
50) Apertured flanges
51) Connecting plates or strips
52) Outwardly directed beads or ribs
53) U-shaped spacing brackets
54) Flange made from the bending of #48
55) Socket
56) Ribbed bottom
57) Channel shaped covers
58) Outer plates
59) Winged plates (constructed of sheet metal or copper)
60) Filler

#2025449


Dec. 24, 1935.
J. N. HELTZEL
2,025,449
ROAD JOINT MACHINE
Filed June 20, 1932
5 Sheets-Sheet 1
Fig. 1A.
Fig. 1.
Fig. 1B.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.


Dec. 24, 1935.
J. N. HELTZEL
2,025,449
ROAD JOINT MACHINE
Filed June 20, 1932
5 Sheets-Sheet 2
Fig. 7.
Fig. 6.
Fig. 8.
Fig. 8.A
Fig. 8.B
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Inventor
John N. Heltzel
By Mawhinney & Mawhinney
Attorneys

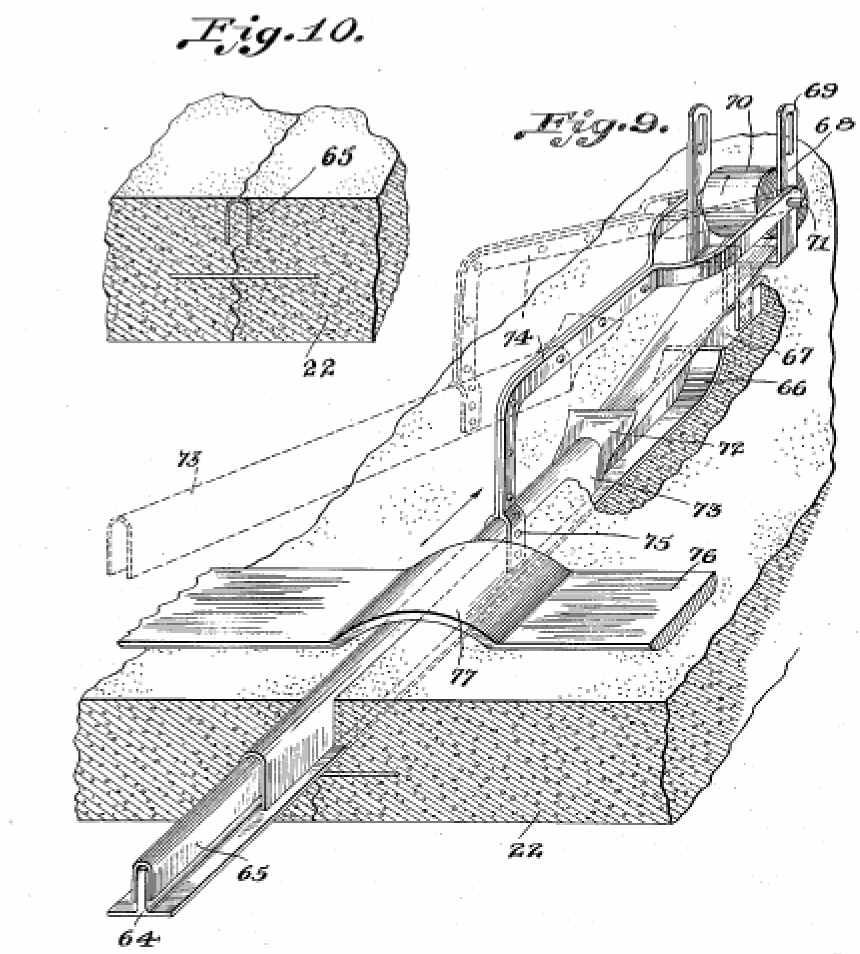
Fig. 10.
Fig. 9.
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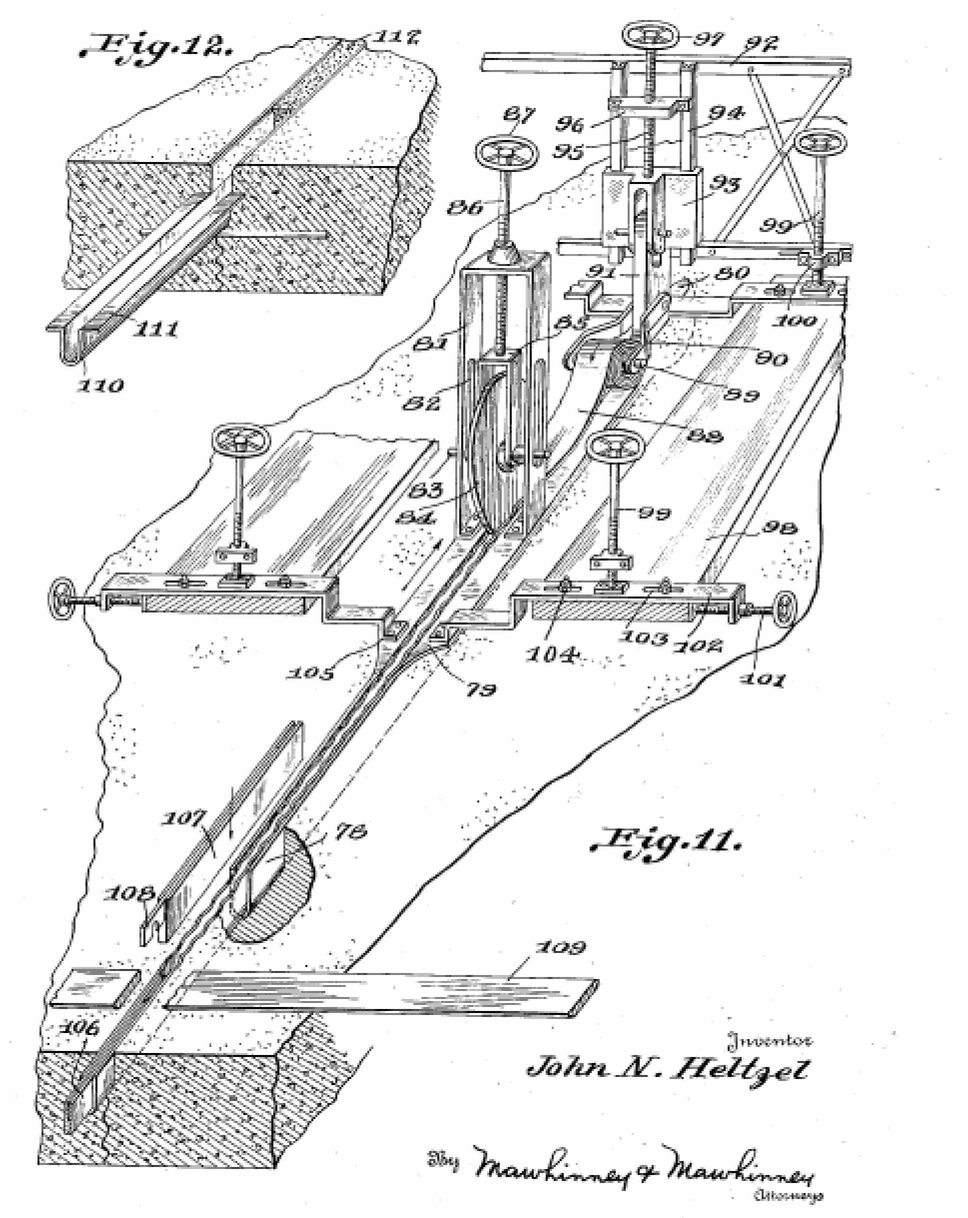

Fig.12.
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Fig.11.
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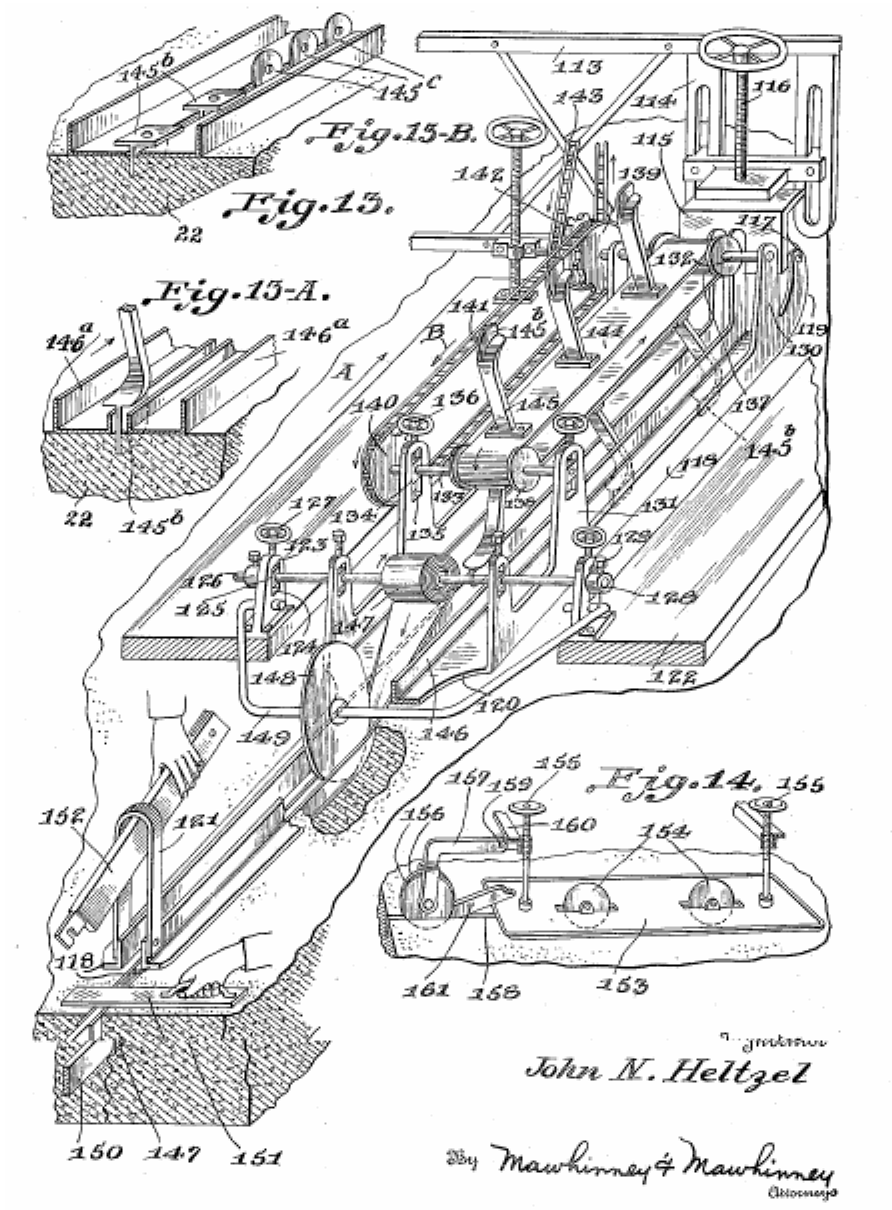
106
Inventor
John N. Heltzel
By Mawhinney & Mawhinney
Attorneys



Inventor: John M. Heltzel
Material: Joints are made of metal "envelopes" that have paper (or another foldable material) and then tar paper filled into the middle of these envelopes.

#2040367

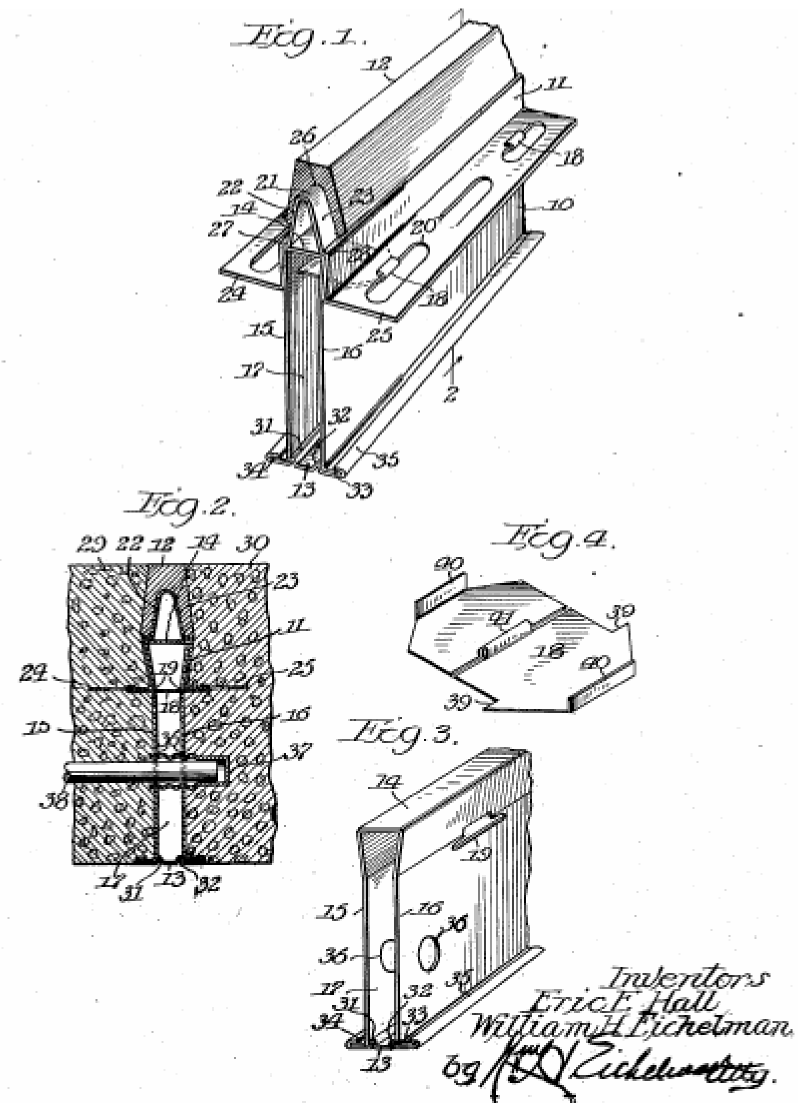
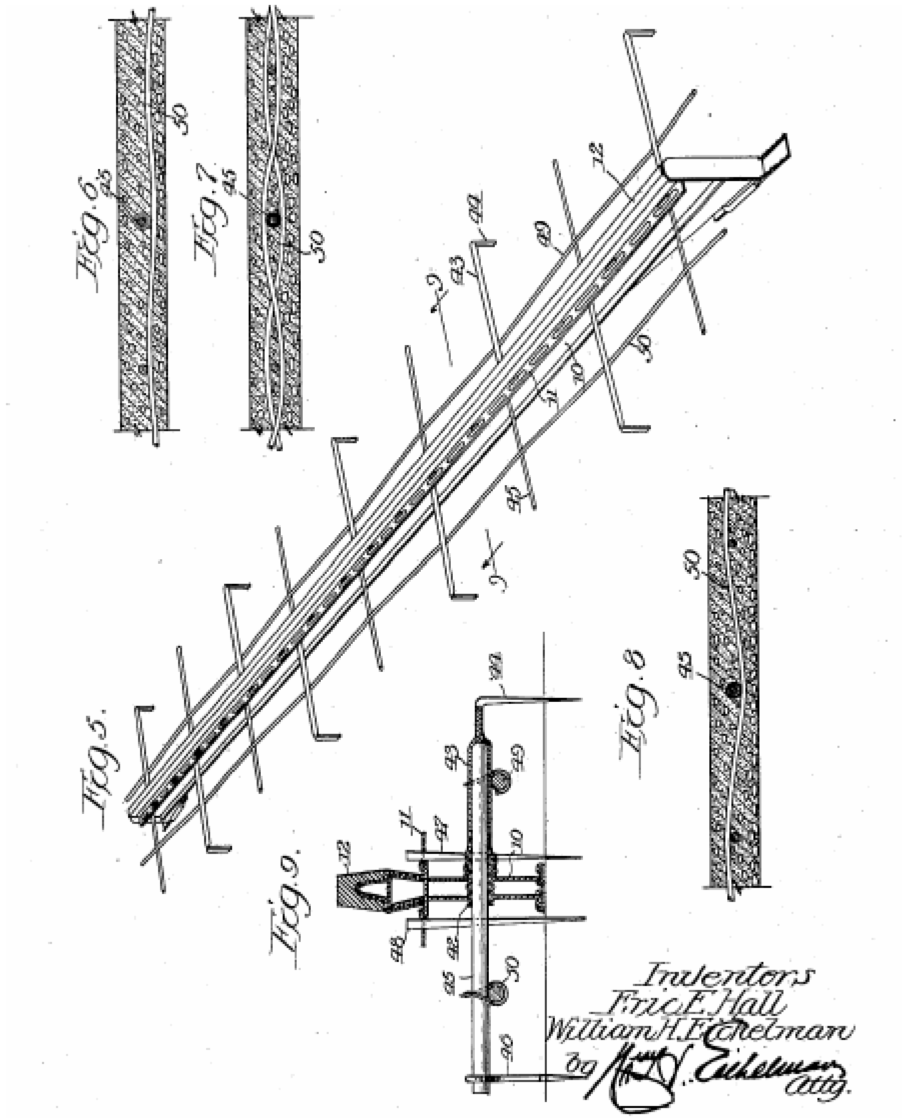


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Inventors
Eric E. Hall
William H. Eichelman



Inventor: Eric E. Hall and William H. Eichelman
Materials: Most of joint is made of sheet metal, with a seal (#11) on to made from copper or another flexible material.

#2042524

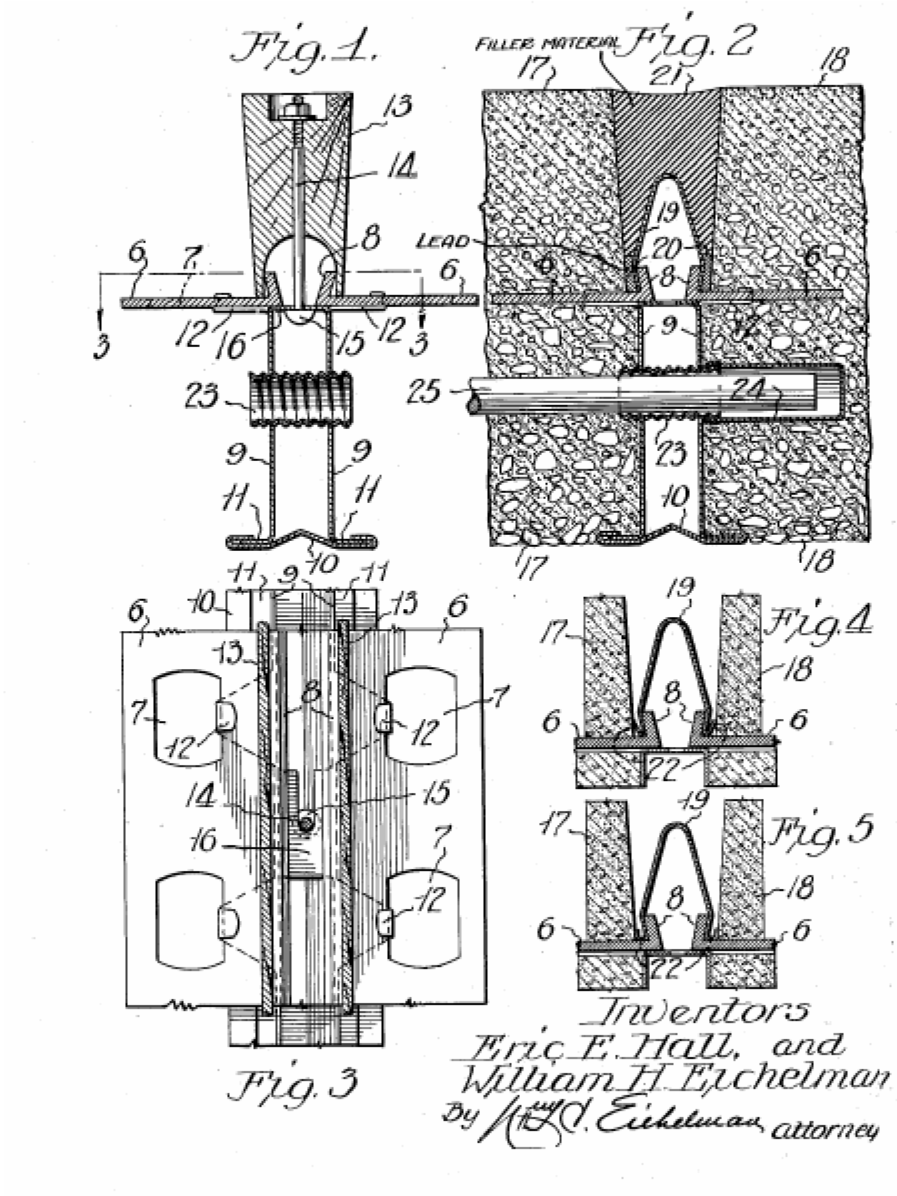
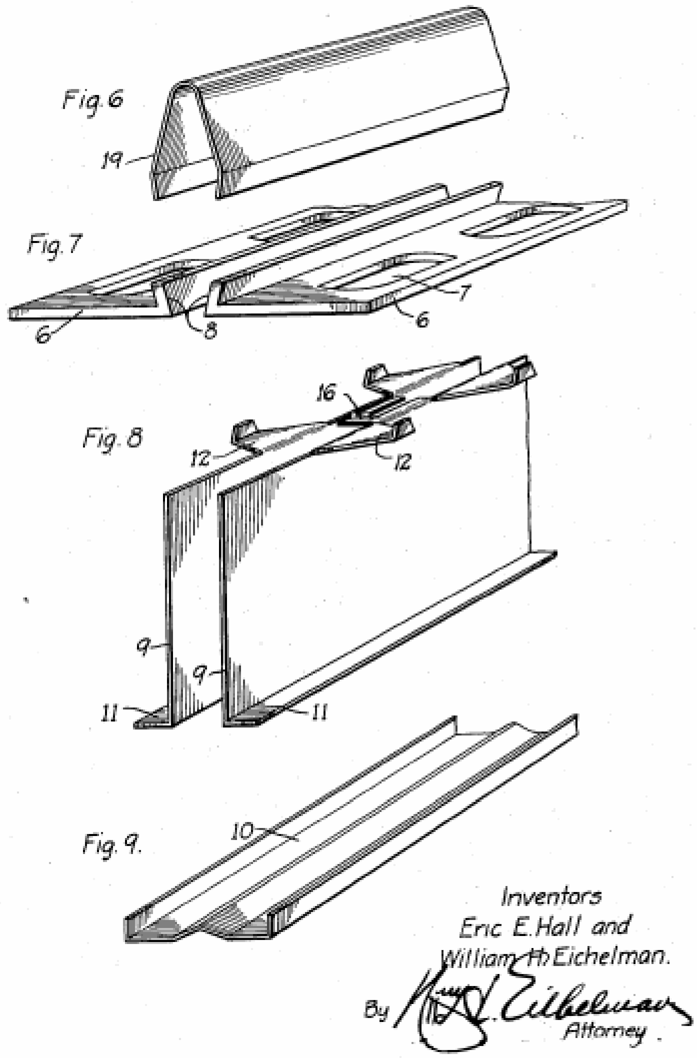


Fig. 1.
Fig. 2
FILLER MATERIAL
LEAD
Fig. 3
Fig. 4
Fig. 5
Inventors
Eric E. Hall, and
William H. Eichelman
By attorney



Inventor: Eric E. Hall and William H. Eichelman
Materials: Joint made from metal with an air chamber in the middle capped with a seal (#20). The seal sometimes has lead on top of it. On top of the seal or lead, tar (#21) is placed and fills the rest of the gap up to the surface.

#2082805

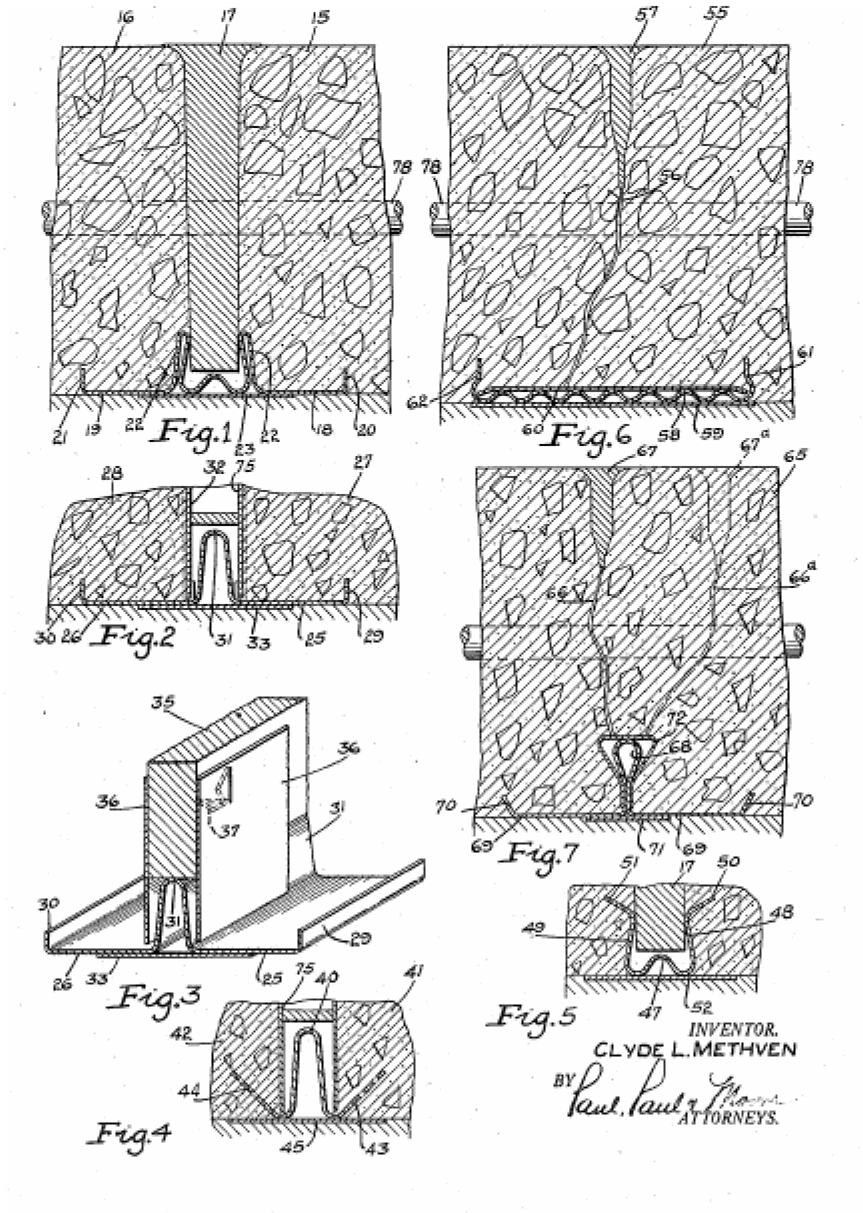
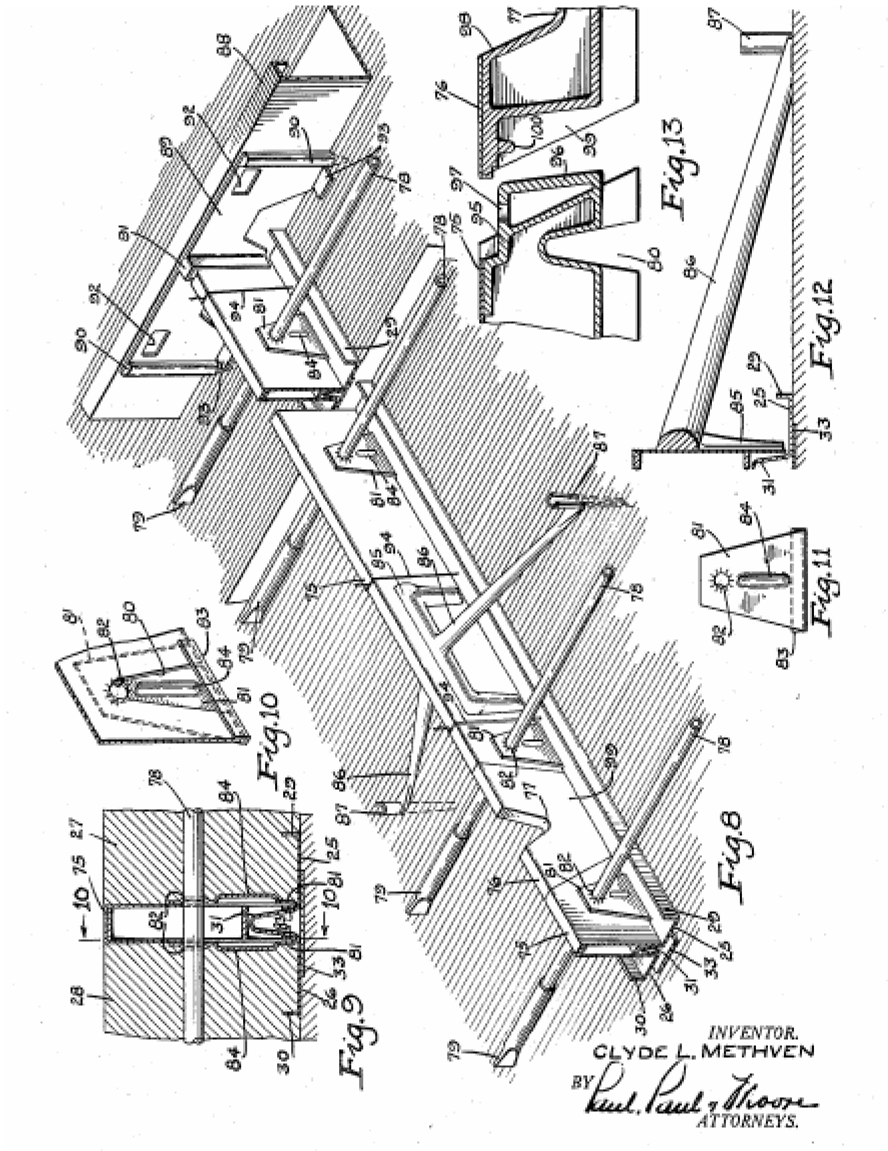
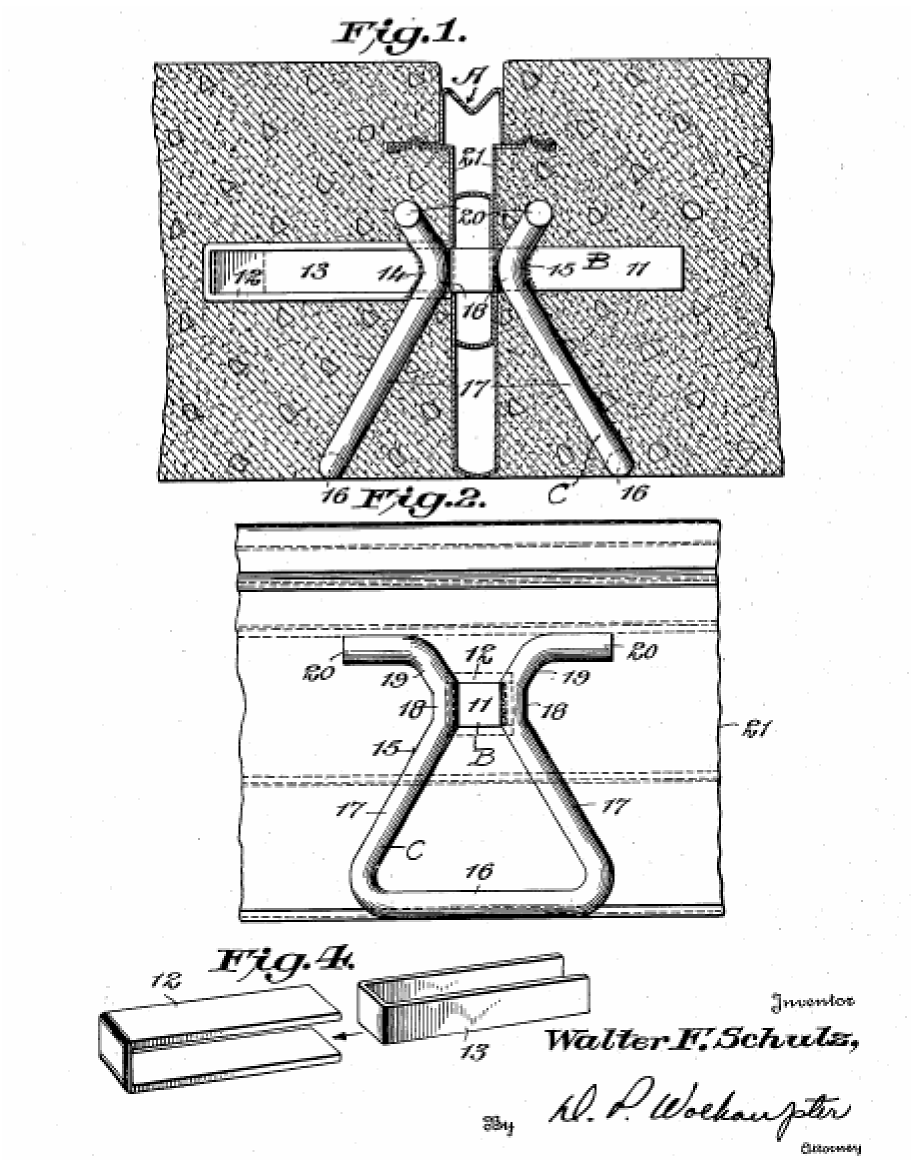


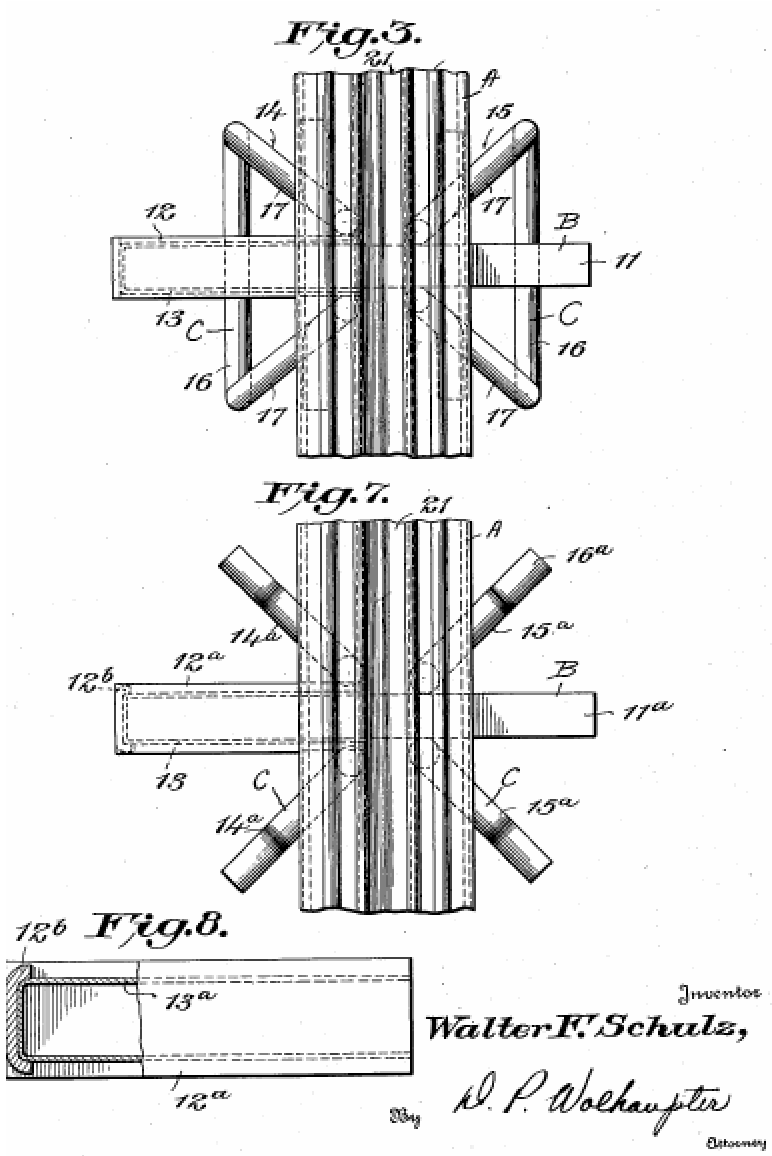
Fig.1
Fig.2
Fig.3
Fig.4
Fig.5
Fig.6
Fig.7
INVENTOR.
CLYDE L. METHVEN
BY
ATTORNEYS.



Inventor: Clyde L. Methven
Materials: Frame made from metal with bituminous material as filler. A water seal is present made of an enduring and non-corrosive metal.

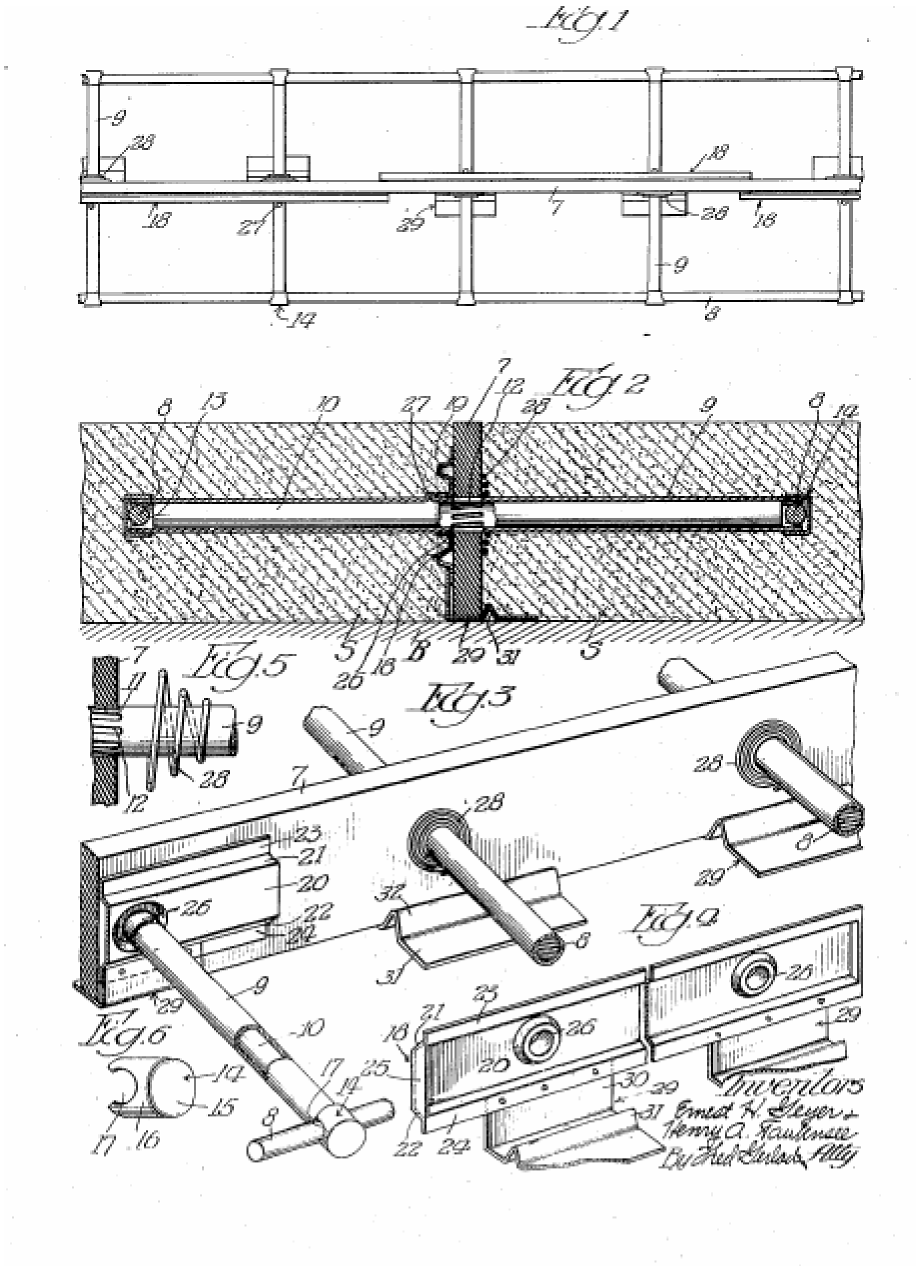
#2152751





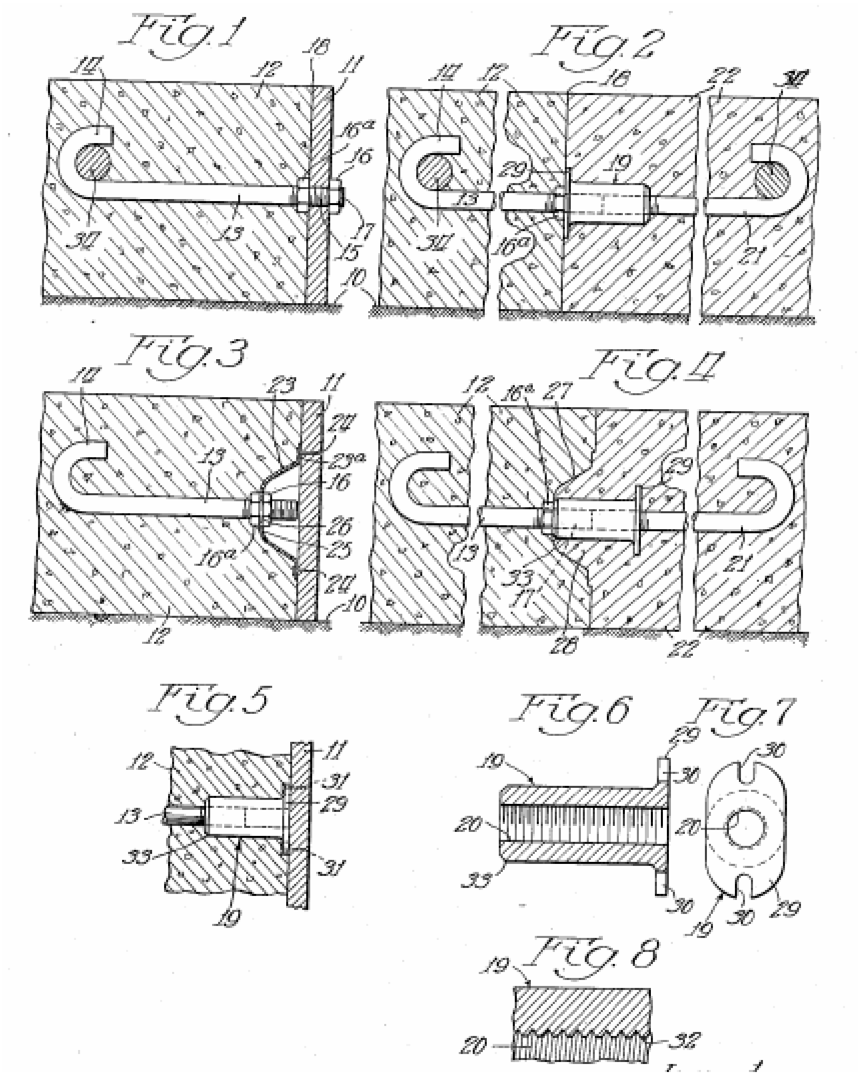
Inventor: Walter F. Schuls
Materials: Metal, only specifics given were that #13 was a light strip of metal and #12 is relatively heavy gauge metal.

#2186104



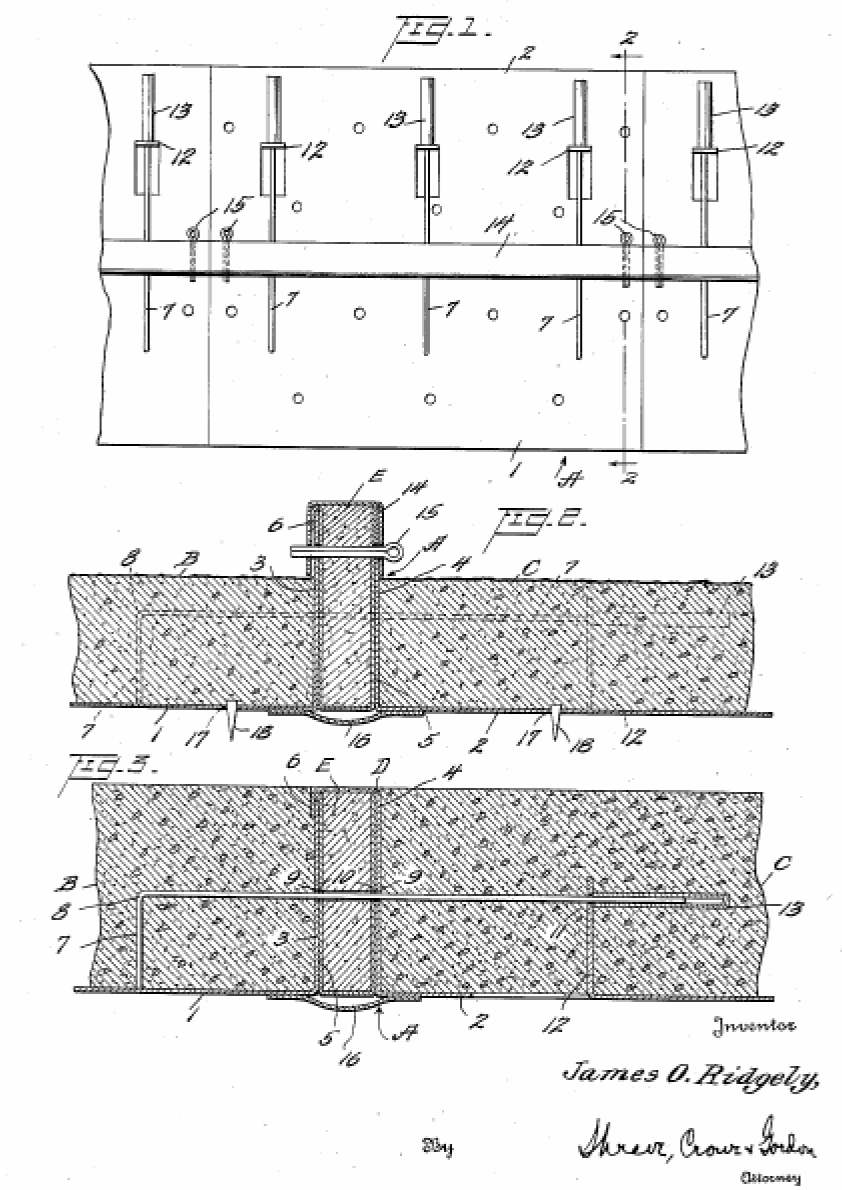
Inventors: Ernest H. Geyer and Henry A. Taubensee
Materials: Metal and elastic filler strip (usually made from felt or treat sponge rubber)

#2187912



Inventor: Ralph S. Pierce
Materials: The hook shape is made of metal. #11 is a wooden support.

#2197438



Inventor: James O. Ridgely
Materials: Metal walls and bars. #5 is made from bronze. E represents expandable material poured between the joint walls. #14 and #5 are caps to keep water sealed out of the expandable material.

#2203078

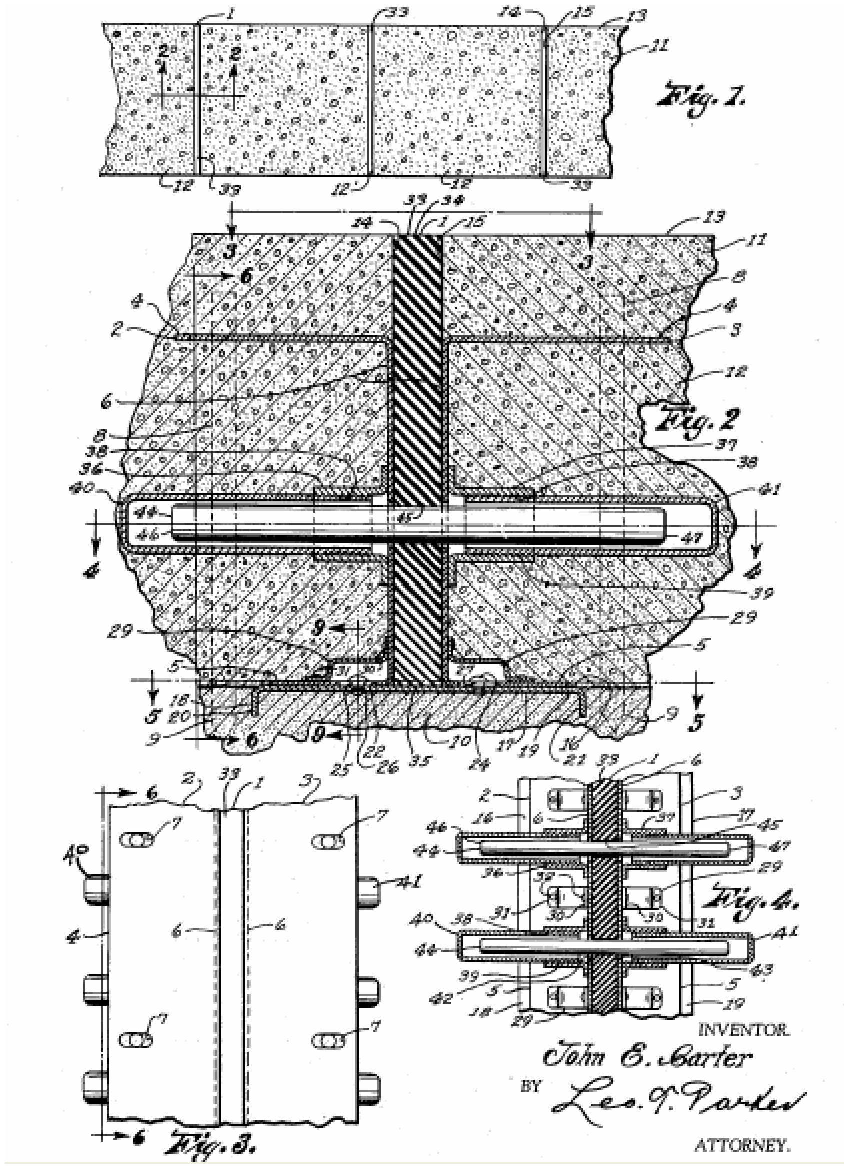
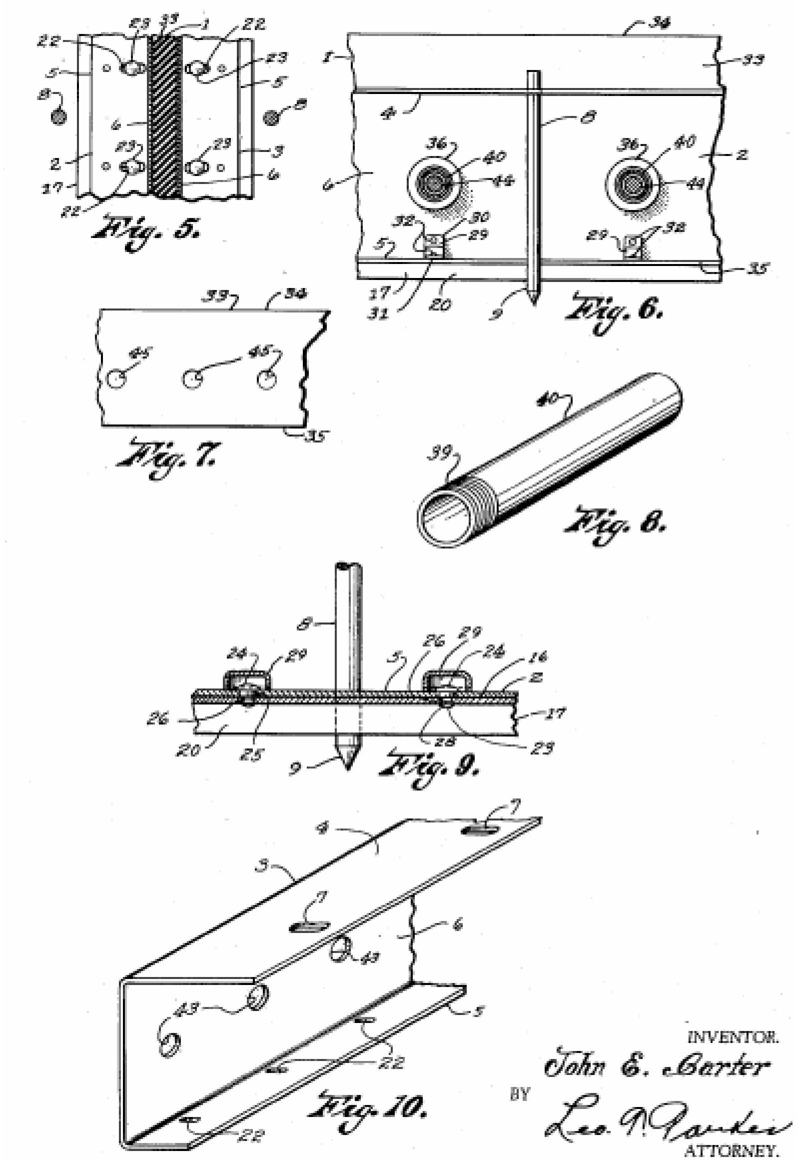


Fig. 1.
Fig. 2
Fig. 3.
Fig. 4.
INVENTOR.
John E. Carter
BY Leo. T. Parker
ATTORNEY.



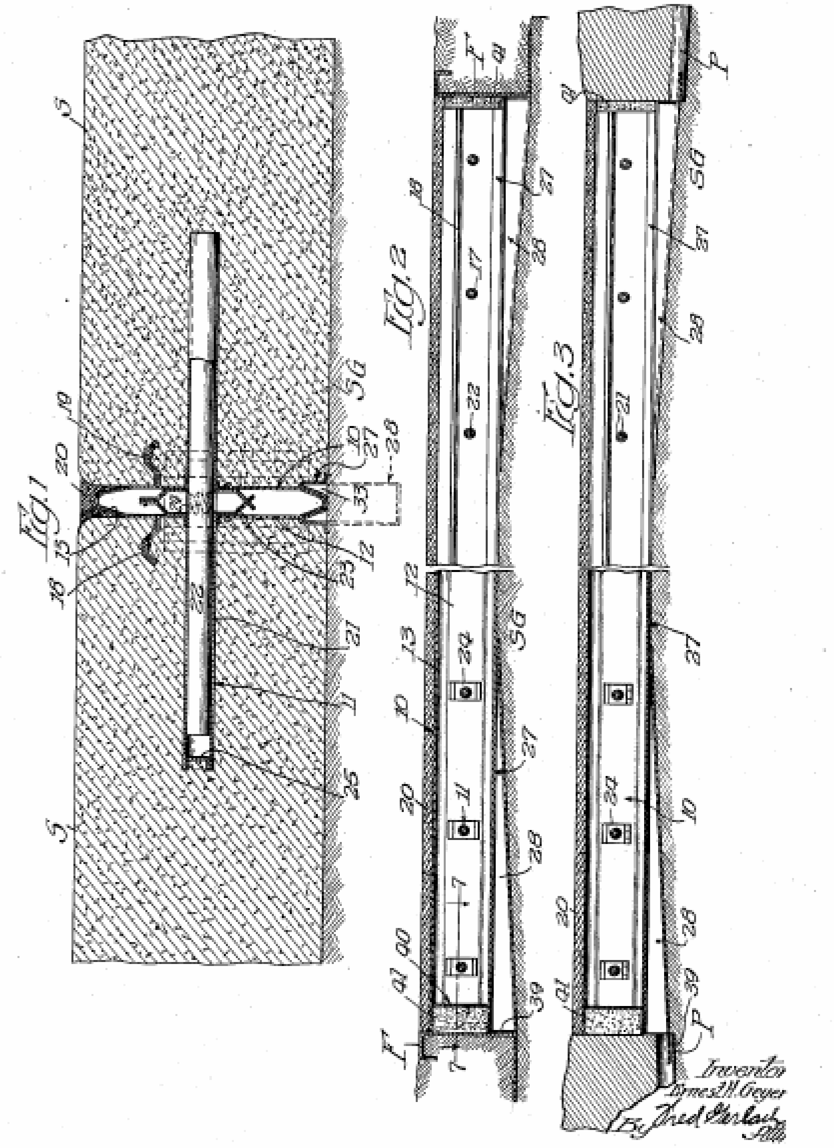
Inventor: John E. Carter
Materials: Metal for most of the joint and rubber blocks to fill the space at #33.

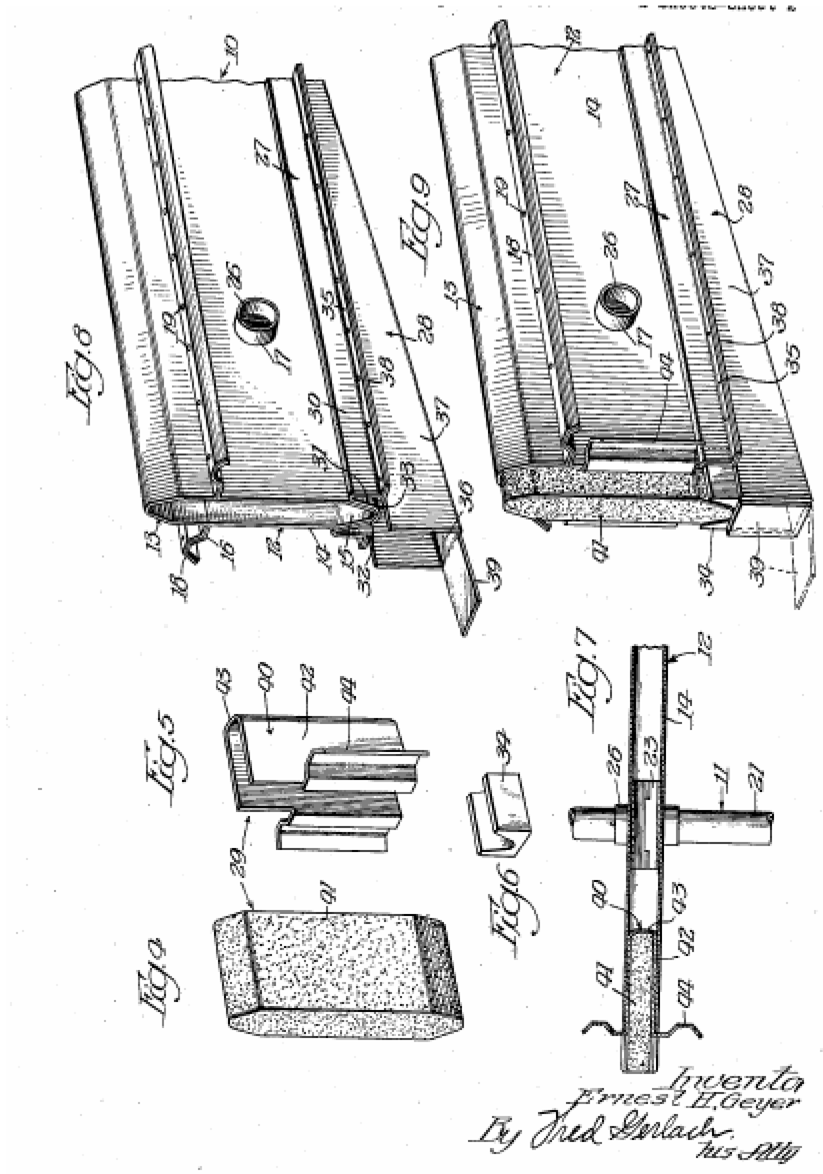
#2208000

July 16, 1940. E. H. GEYER 2,208,000

JOINT FOR CONCRETE SLABS

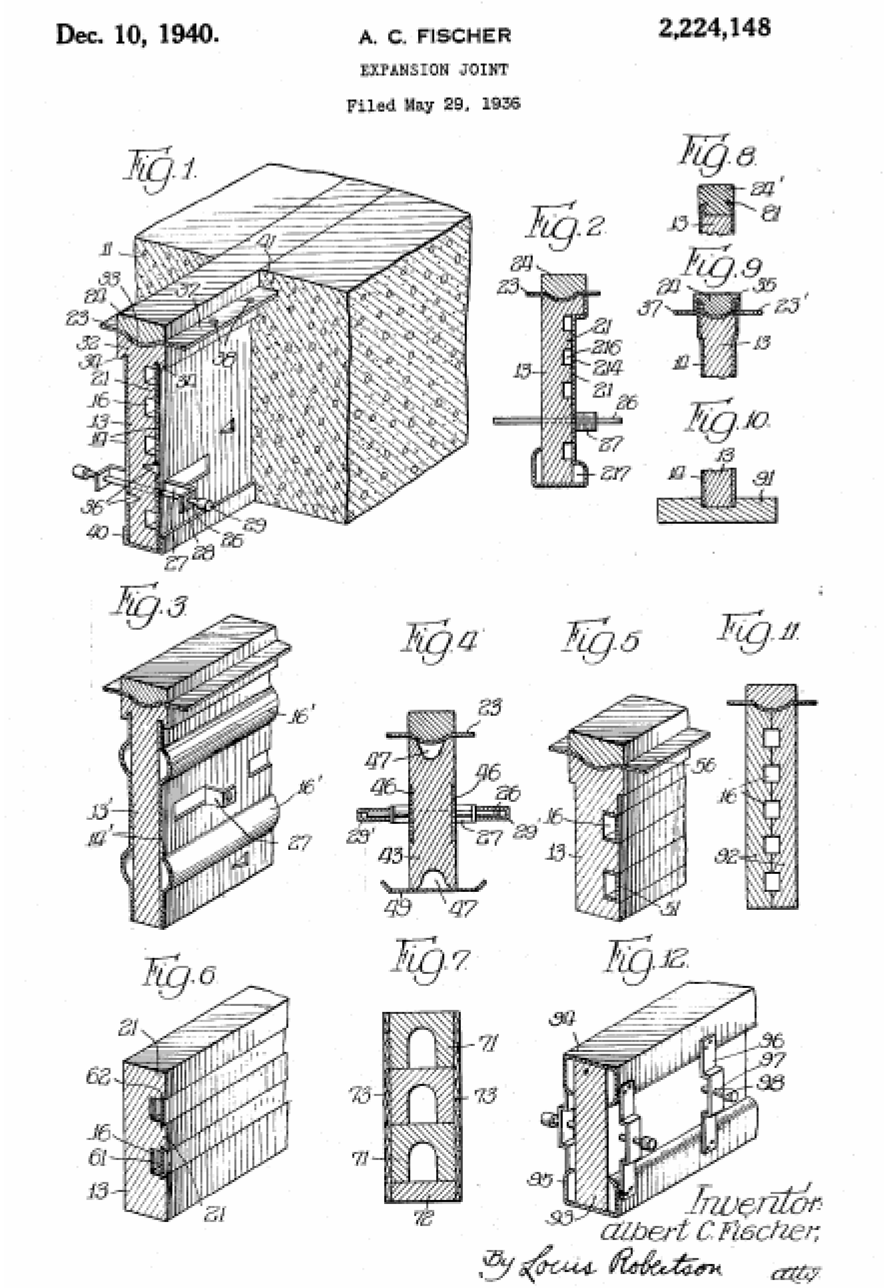
Filed Sept. 30, 1937 2 Sheets-Sheet 1





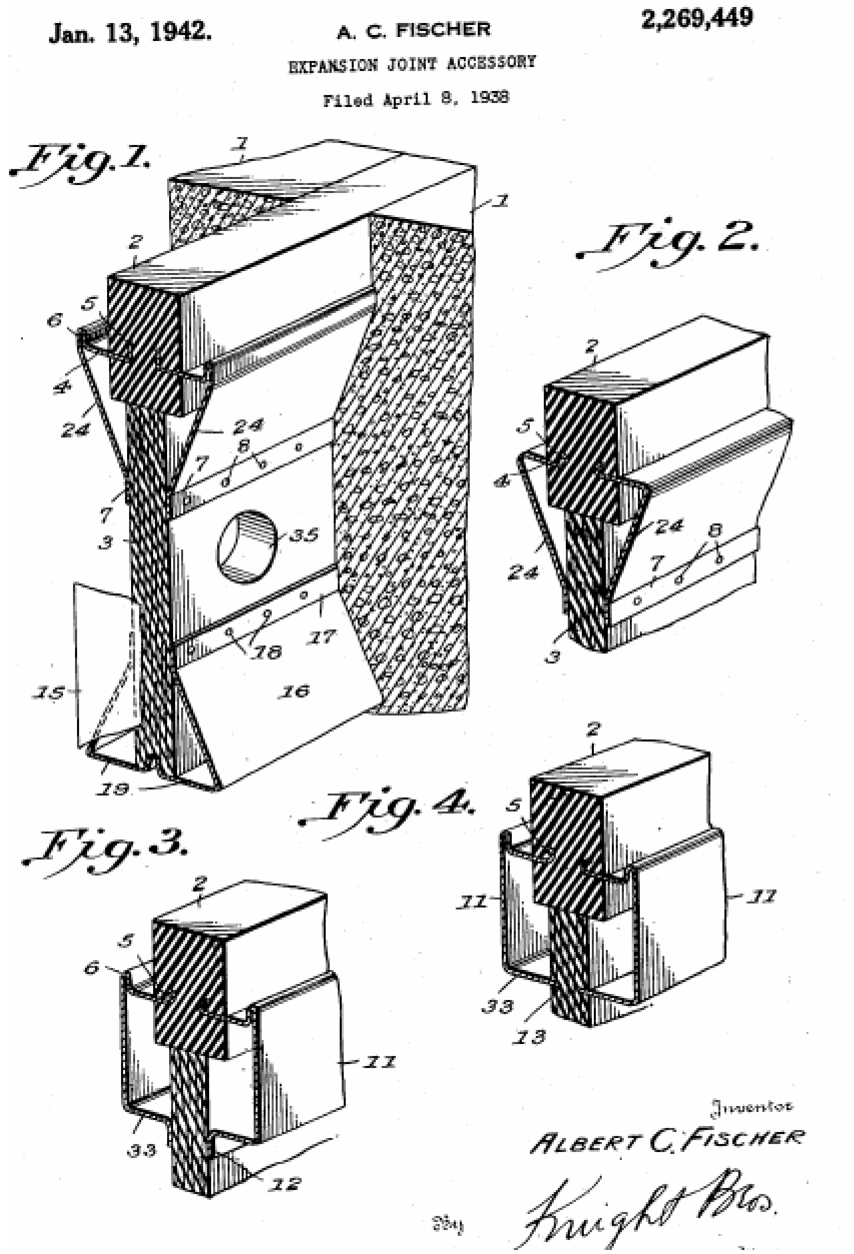
Inventor: Ernest H. Guyer
Materials: Metal, 16 & 18 are metal flanges to keep water out, 20 is a plastic material, 41 is a compressible plug with no specific material stated

#2224148



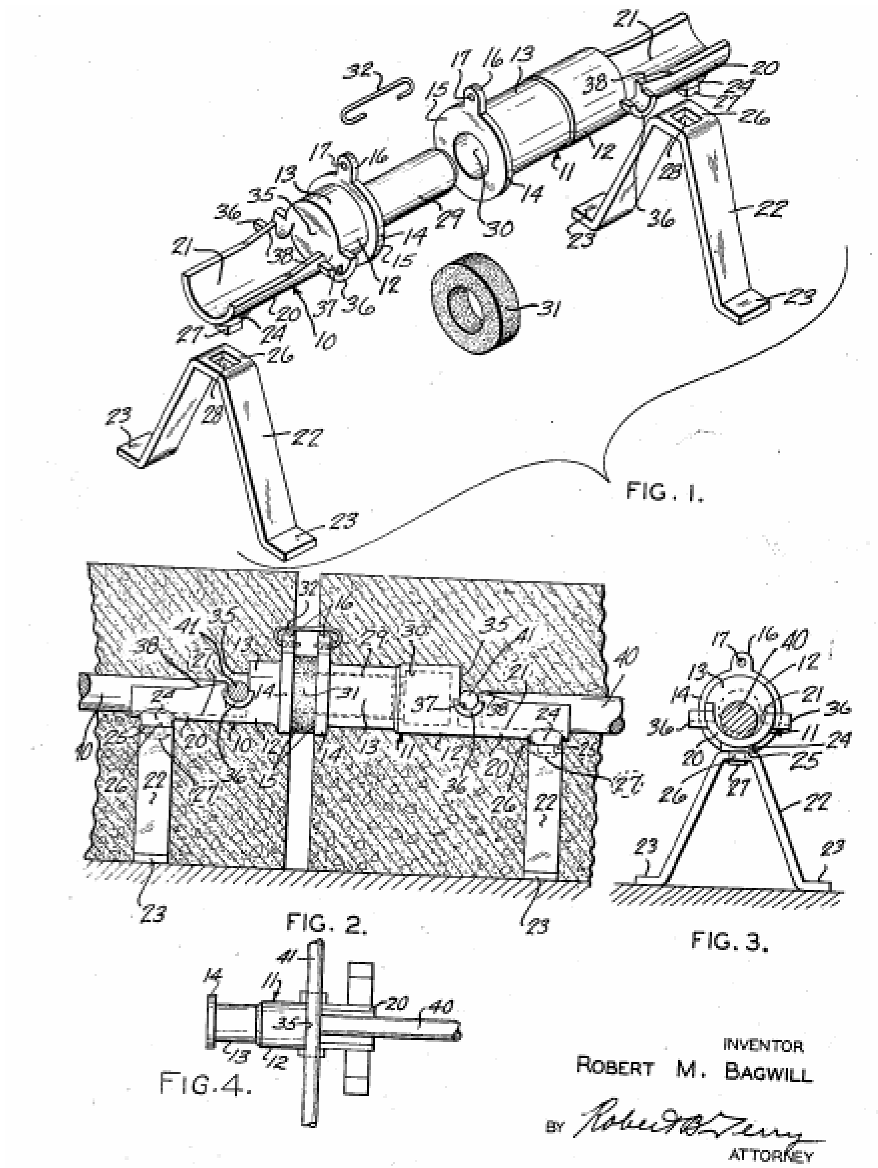
Inventor: Albert C. Fischer
Materials: Metal, 23 & 24 are made of a flowable filler or rubber used to seal out concrete when it's being poured

#2269449



Inventor: Albert C. Fischer
Materials: Metal and 3 is made of cork or rubber

#2269703



Inventor: Robert M. Bagwill
Materials: Metal

#2316233

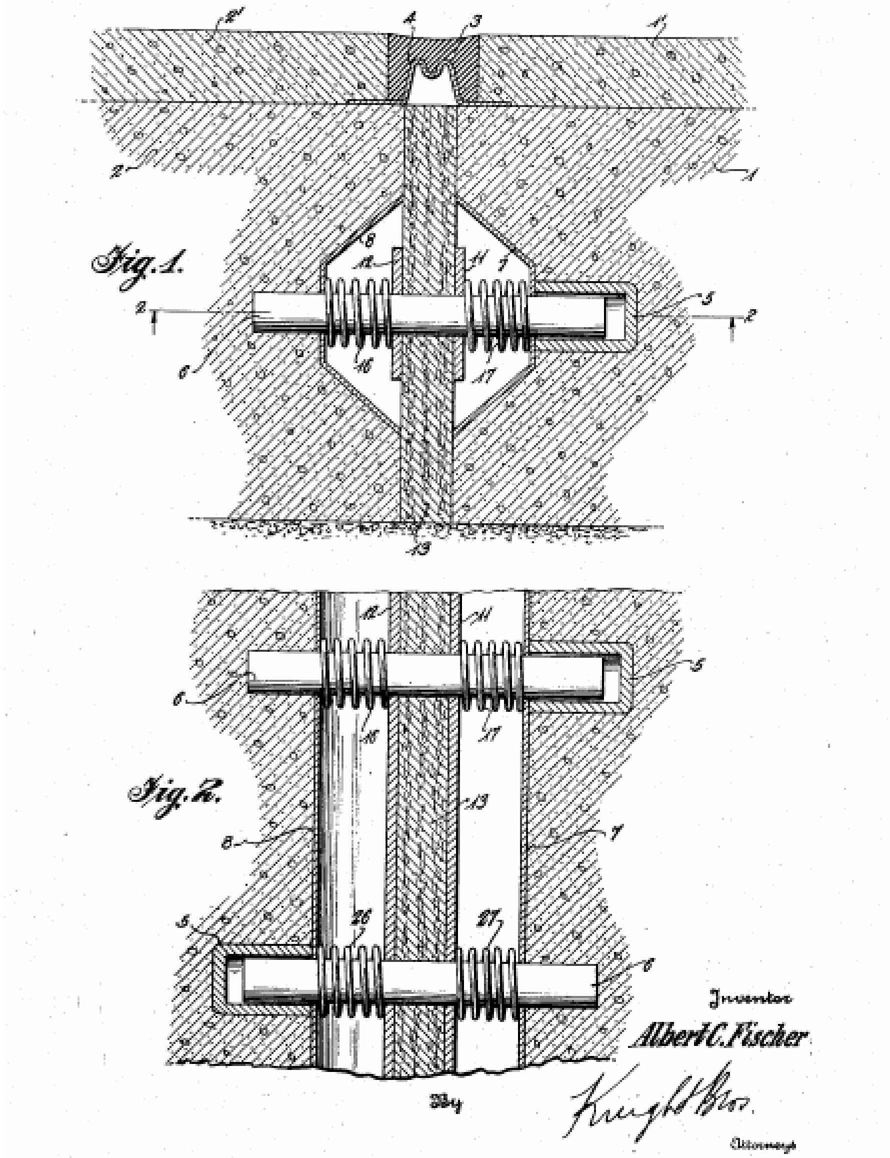
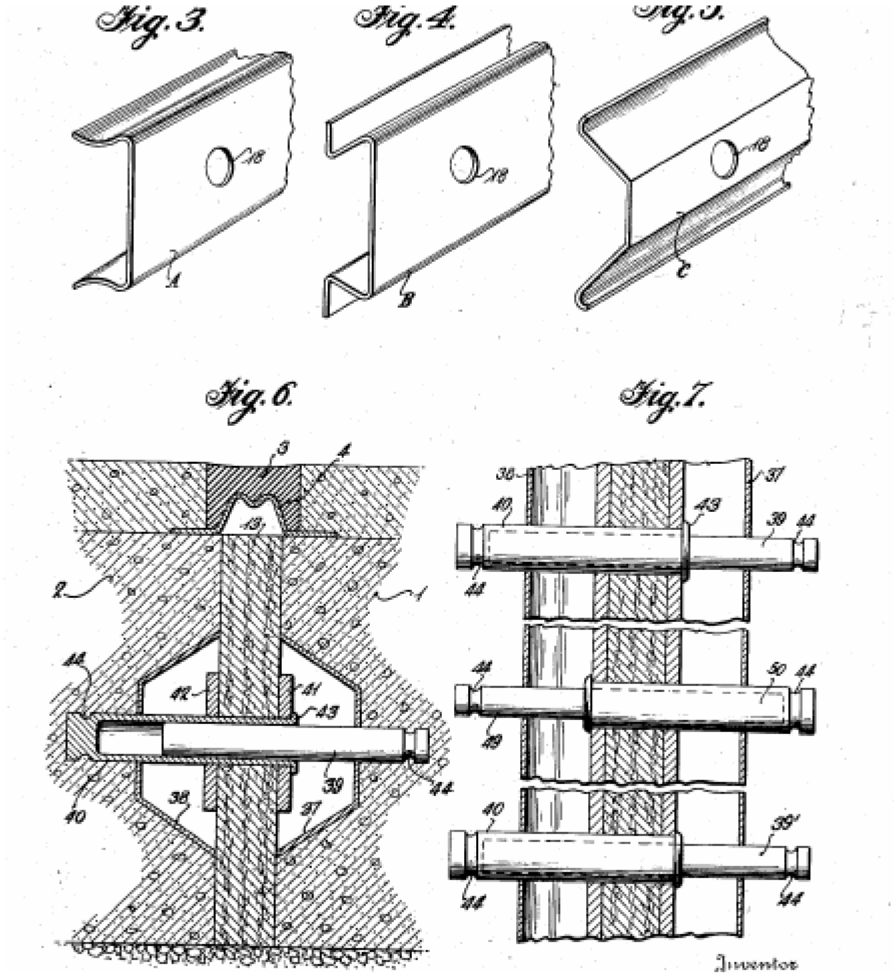
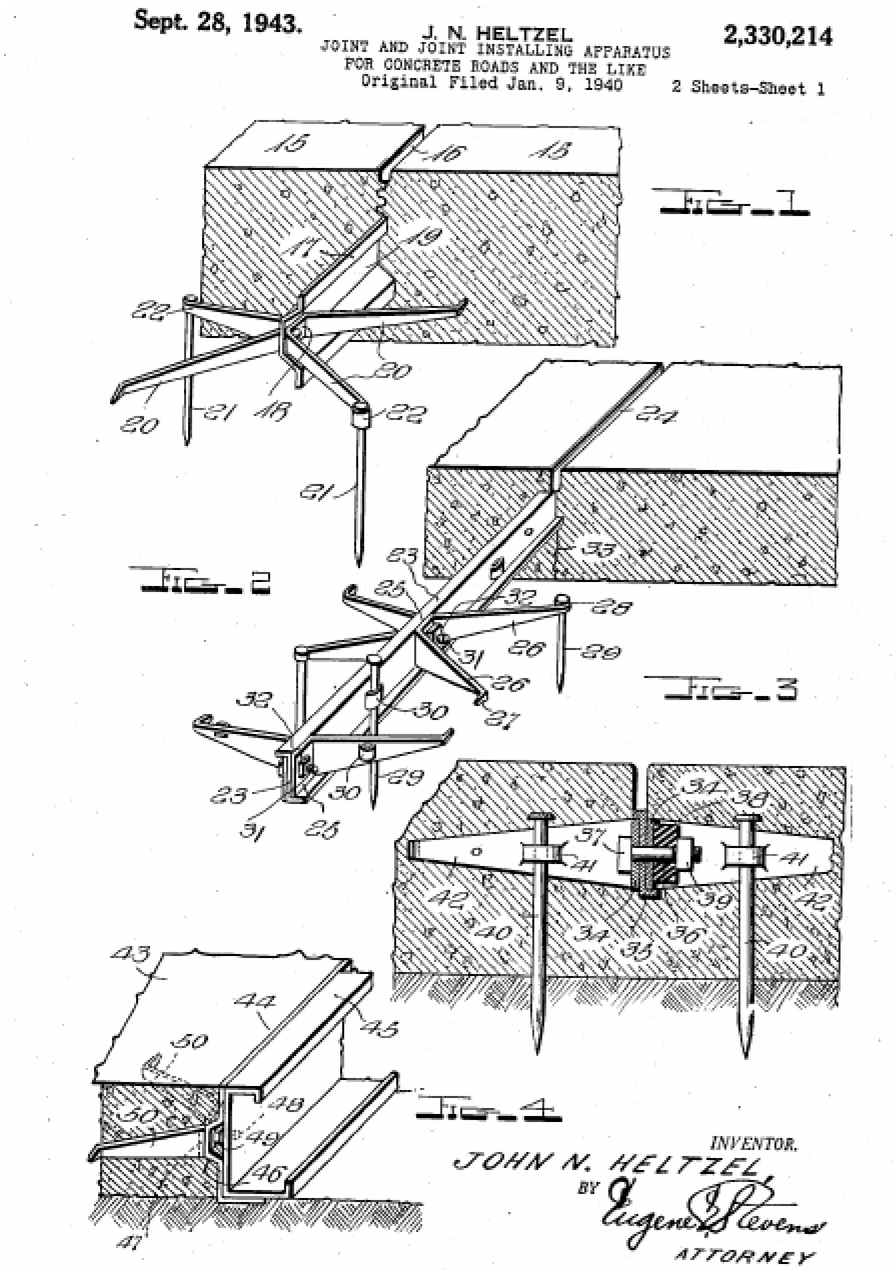


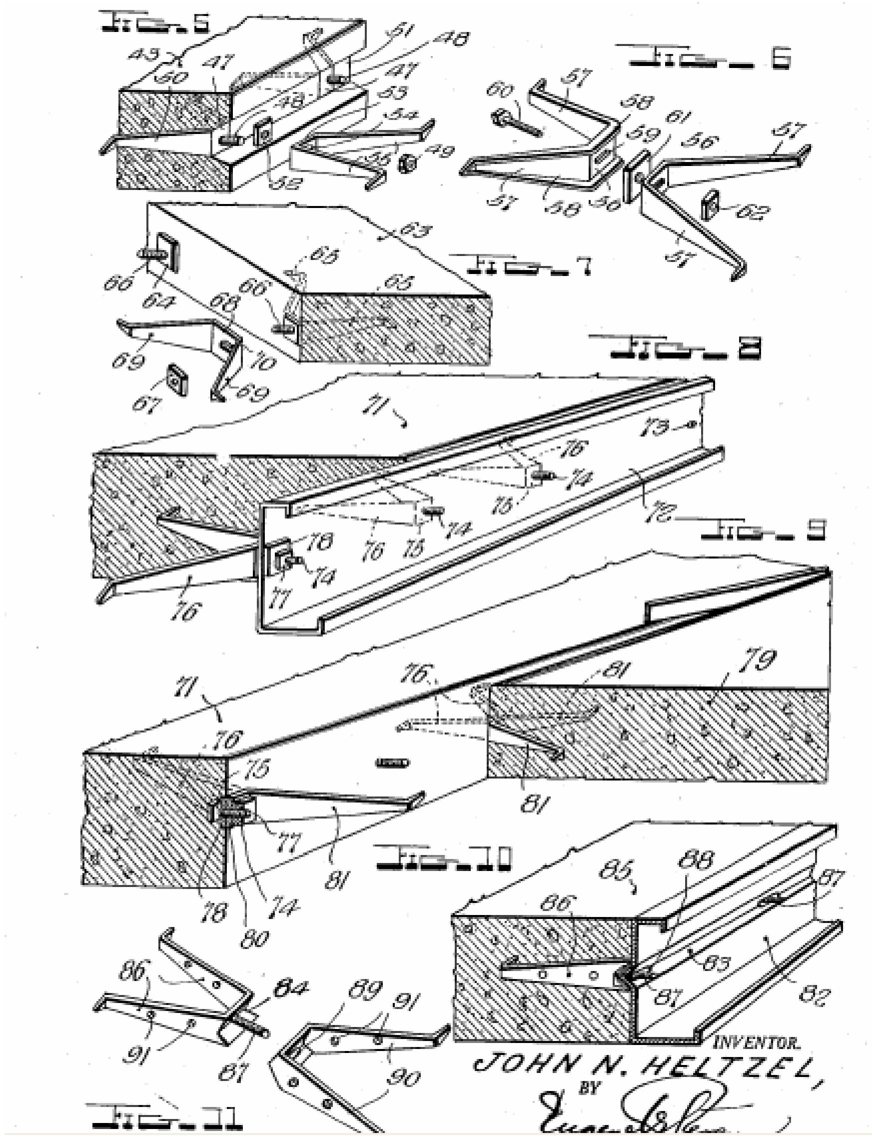
Fig. 1.
Fig. 2.
Inventor
Albert C. Fischer
By
Knight Bros.
Attorneys



Inventor: Albert C. Fischer
Materials: Note that cylinders in Figures 1 and 2 represent a vehicle driving over the road. This design didn't have much to say about the actual road. It talked about the car.

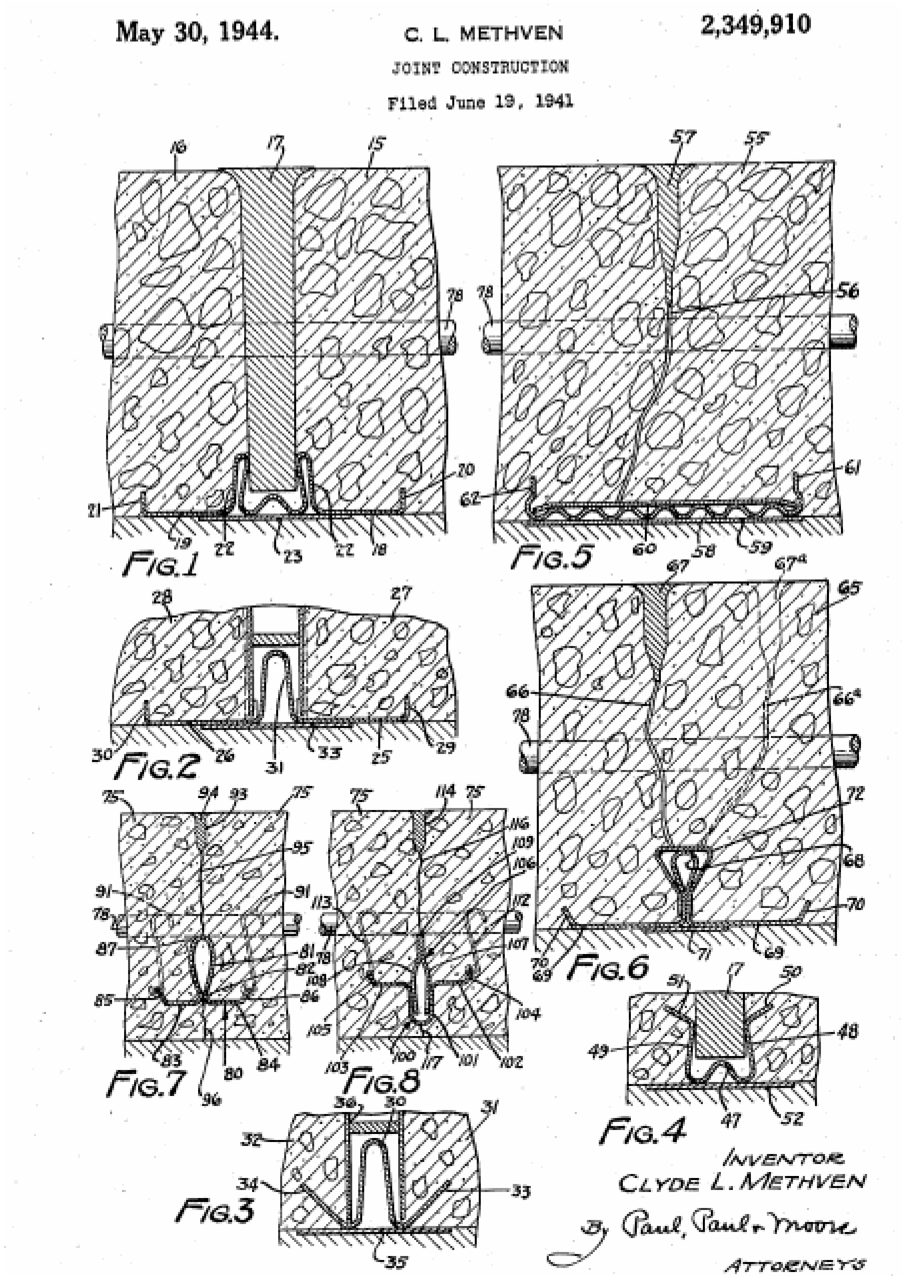
#2330214


Sept. 28, 1943.
J. N. HELTZEL
JOINT AND JOINT INSTALLING APPARATUS
FOR CONCRETE ROADS AND THE LIKE
Original Filed Jan. 9, 1940
2,330,214
2 Sheets-Sheet 1
INVENTOR.
JOHN N. HELTZEL
BY
ATTORNEY



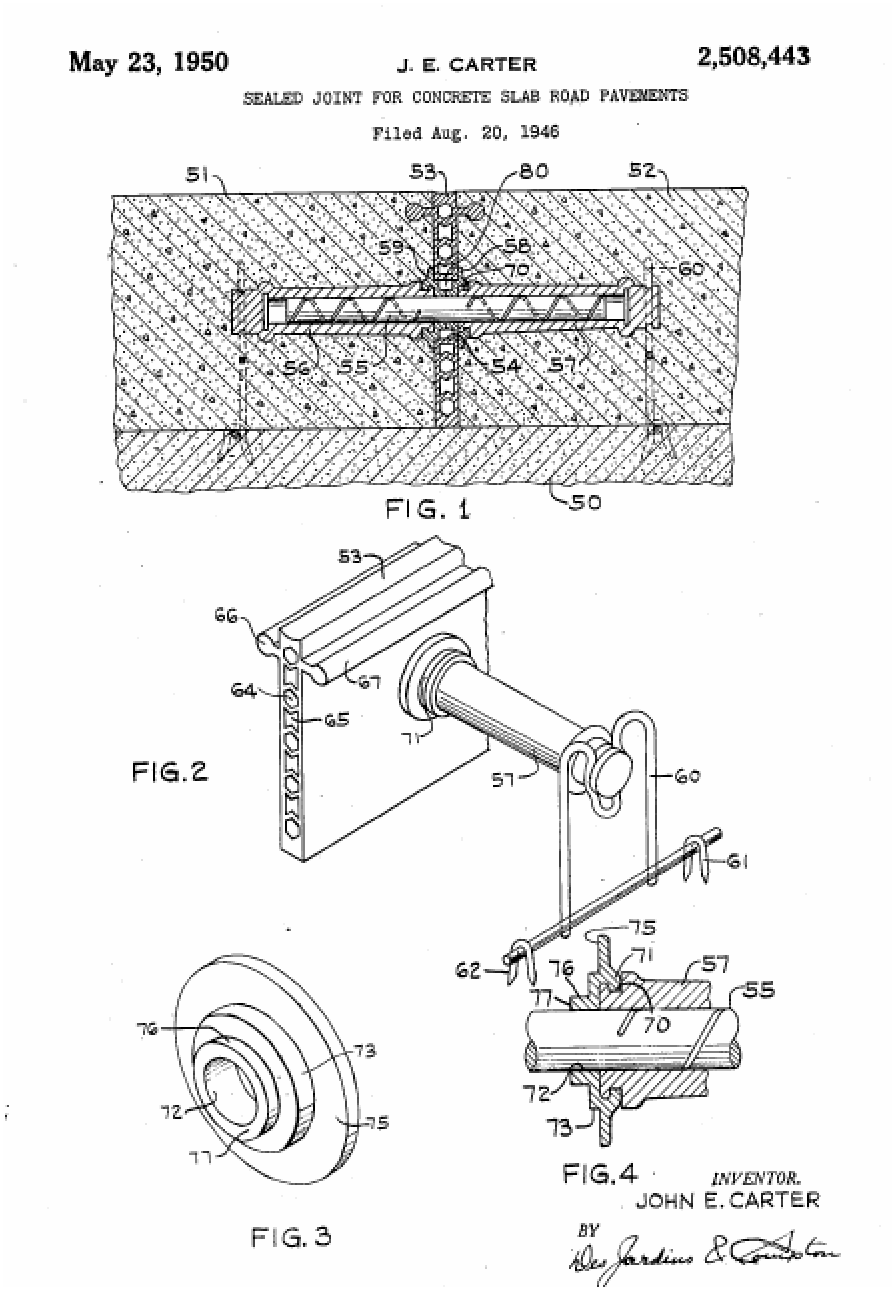
Inventor: John N. Heltzel
Materials: Metal

#2349910



Inventor: Clyde L. Methven
Materials: Metal, 17 is a bituminous material, 31 is a metal seal to keep water out, 80 is a thin flexible material such as copper.

#2508443



Inventor: John E. Carter
Materials: Metal, 53 and 58 sealing materials made of electromeric material

#2649720

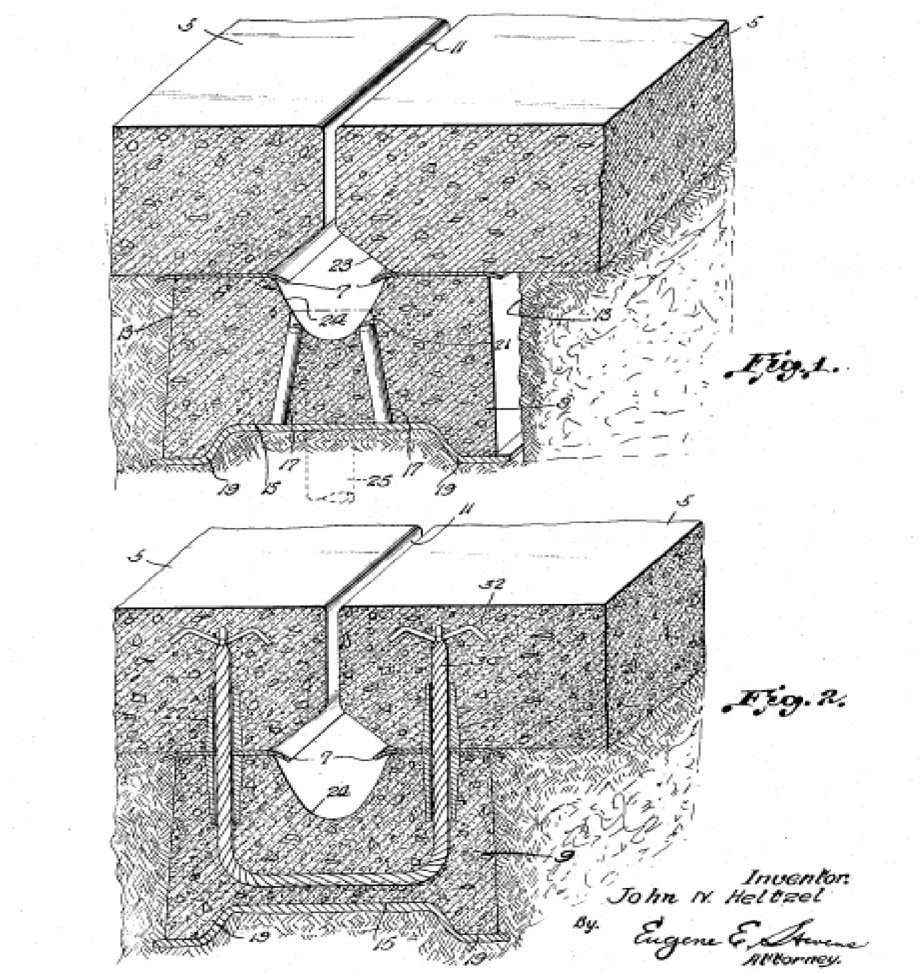
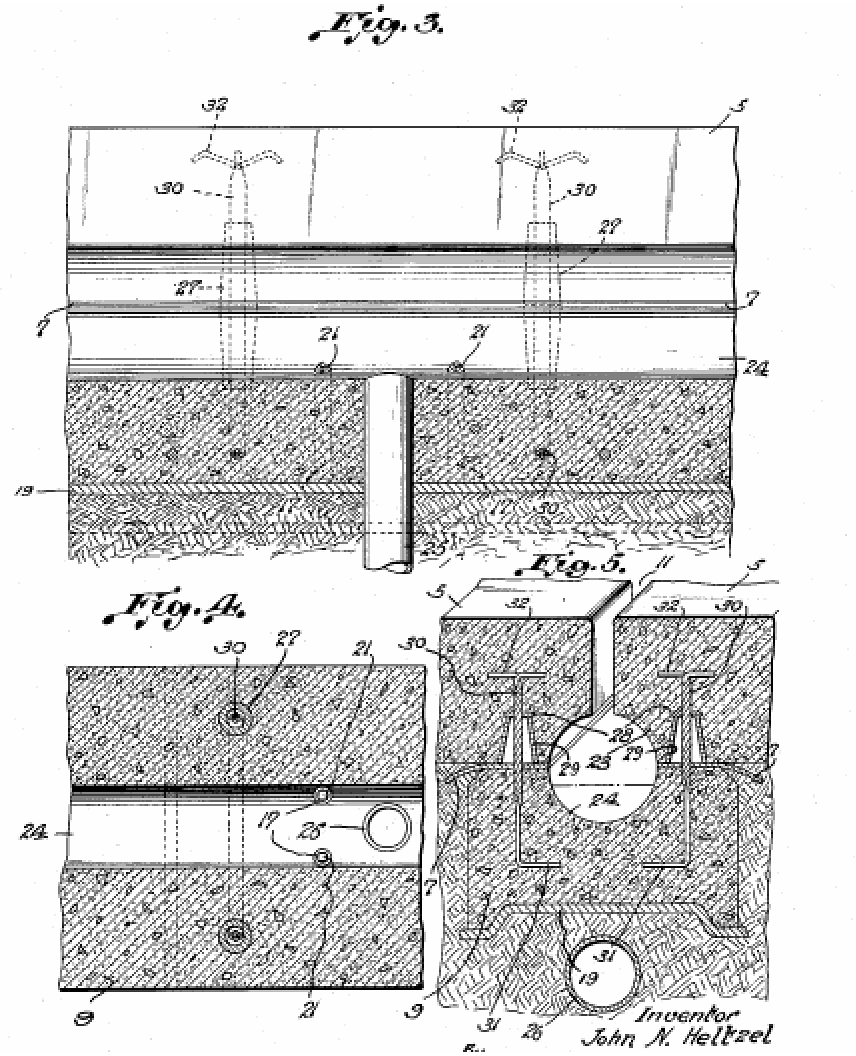


Fig. 1.
Fig. 2.
Inventor.
John N. Heltzel
By.
Eugene E. Stevens
Attorney.



Inventor: John N. Heltzel
Materials: Metal, 7 is an asphaltic impact strip

#2700329

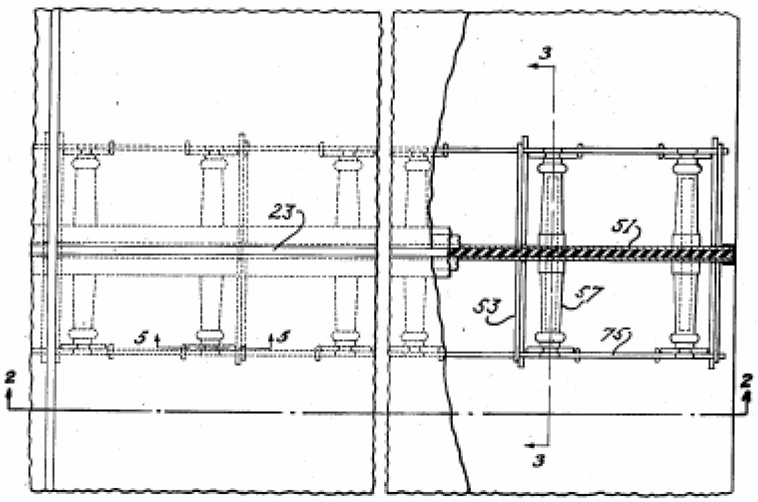


Fig. 1

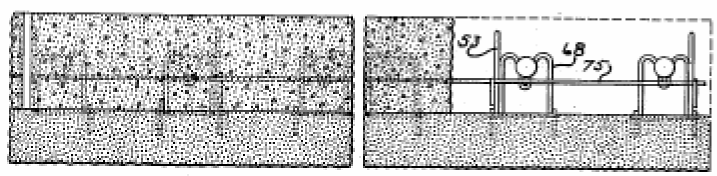


Fig. 2

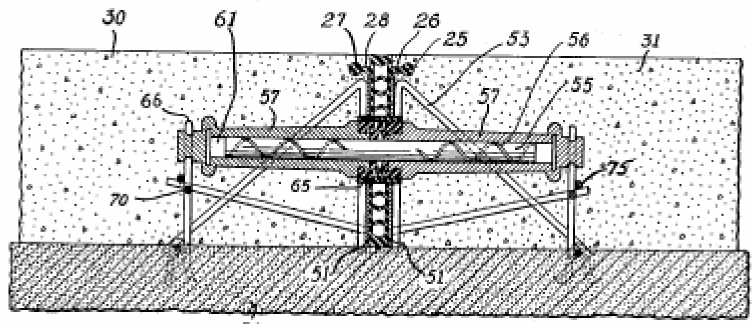


Fig.3

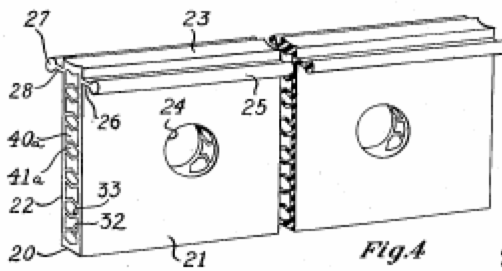


Fig.4

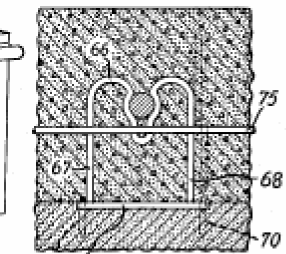


Fig. 5

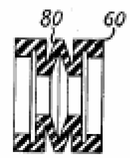


Fig. 6

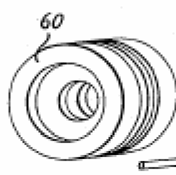


Fig.7

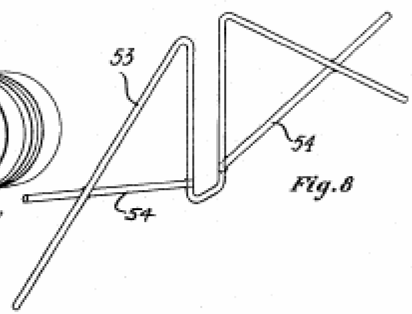


Fig.8

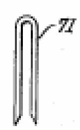
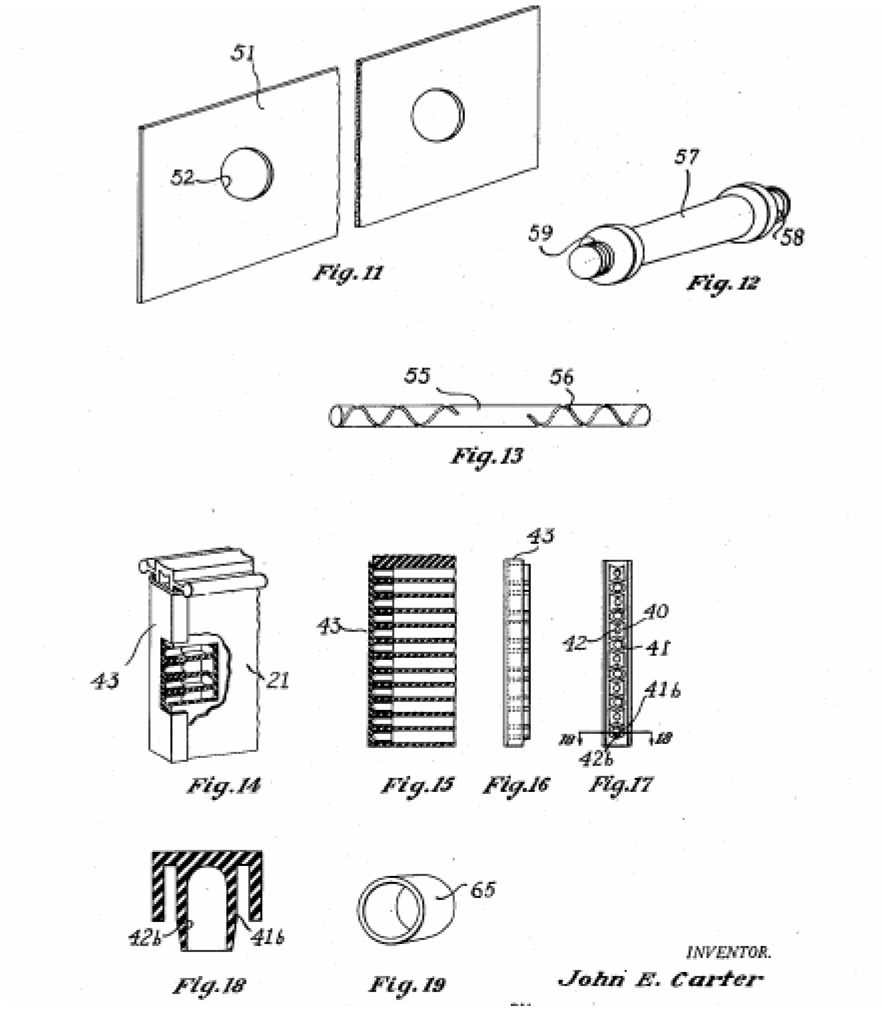


Fig.9

Fig.10

INVENTOR.
John E. Carter
BY



Inventor: John E. Carter
Materials: Metal, elastomeric materials (inventor suggested vulcanized rubber or butadiene-acrylonitrile co-polymers). Any of the black materials like 26-28 and 40-43 are examples of the elastomeric joint strips

#2839973

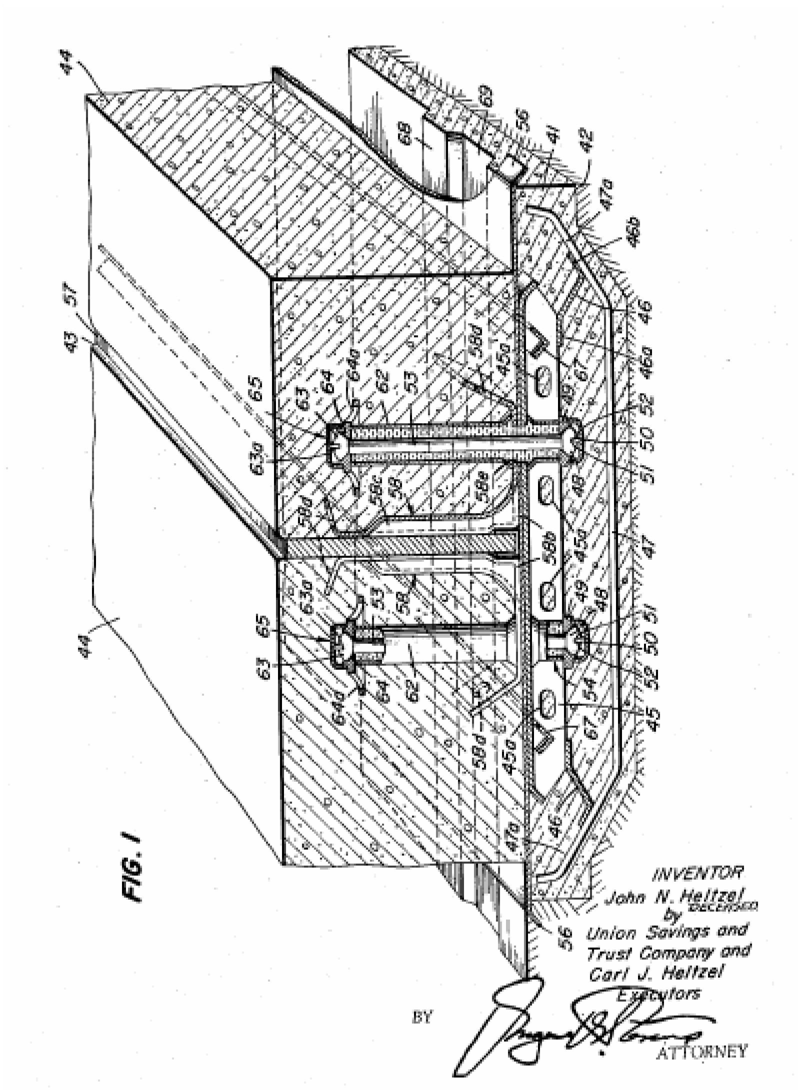
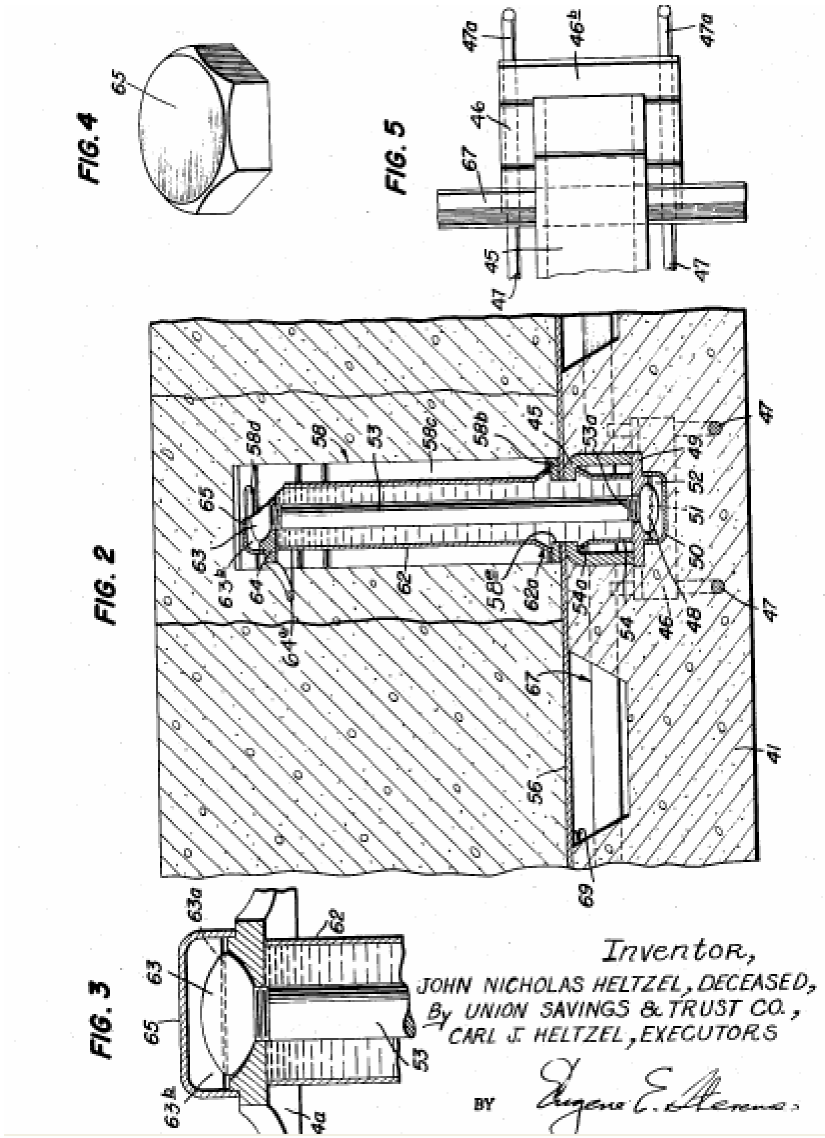
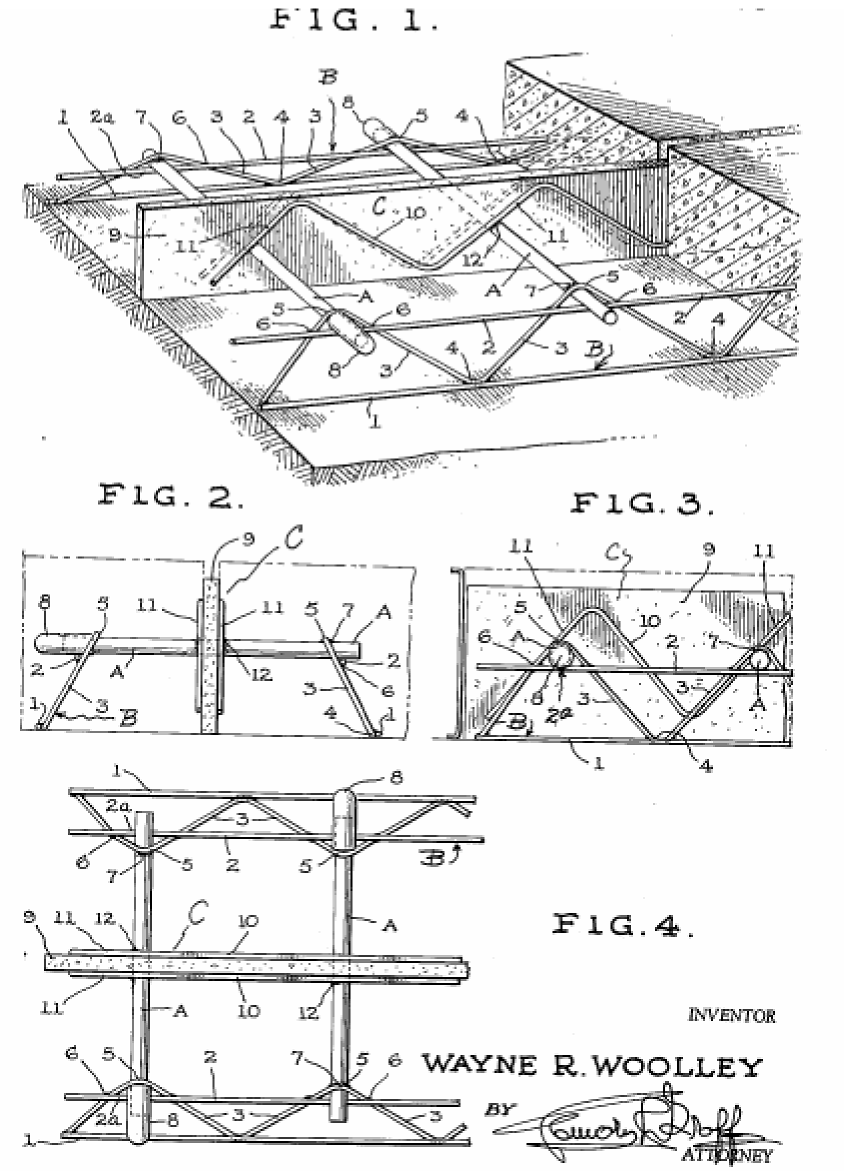


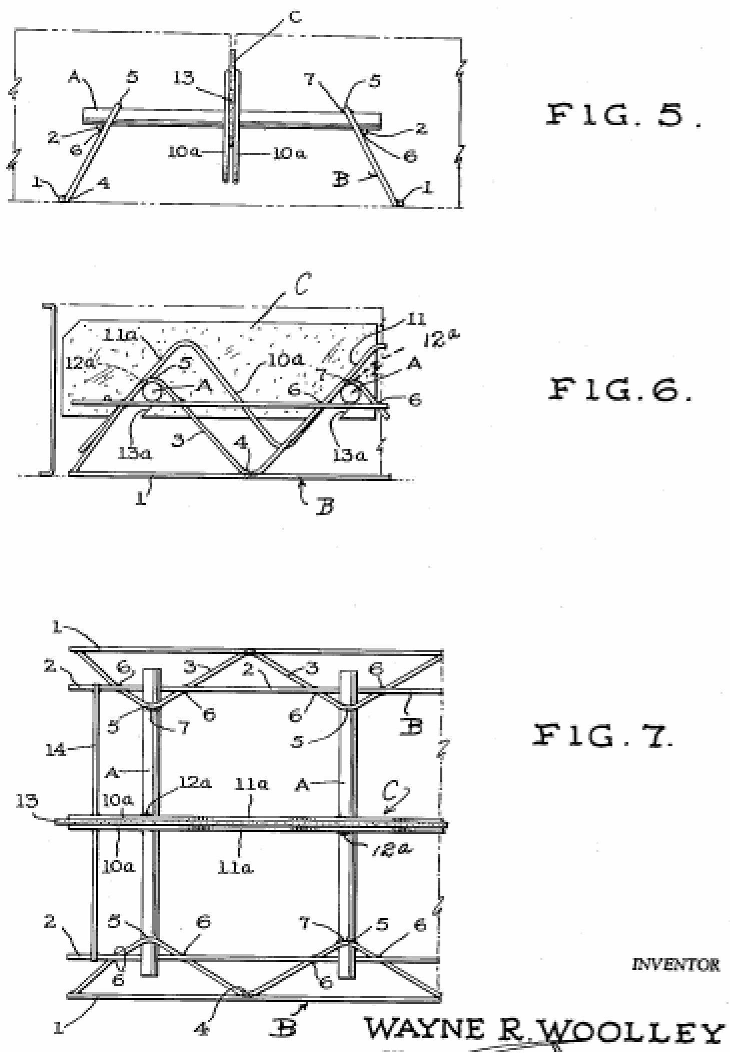
FIG. 1
INVENTOR
John N. Heltzel
DECEASED
by
Union Savings and
Trust Company and
Carl J. Heltzel
Executors
BY
ATTORNEY



Inventor: John N. Heltzel
Materials: Metal

#3059553





Inventor: Wayne R. Woolley
Materials: Metal, 9 is wood filler

#4522531

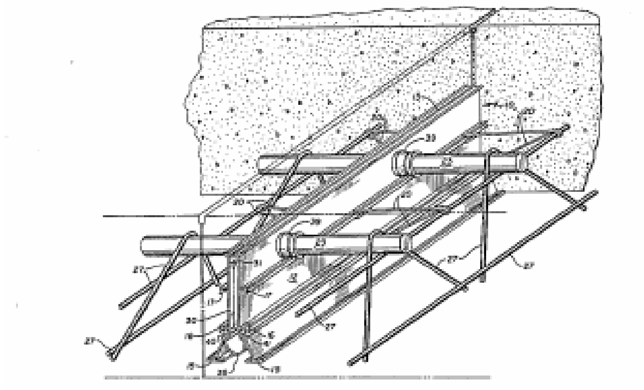


Figure 1

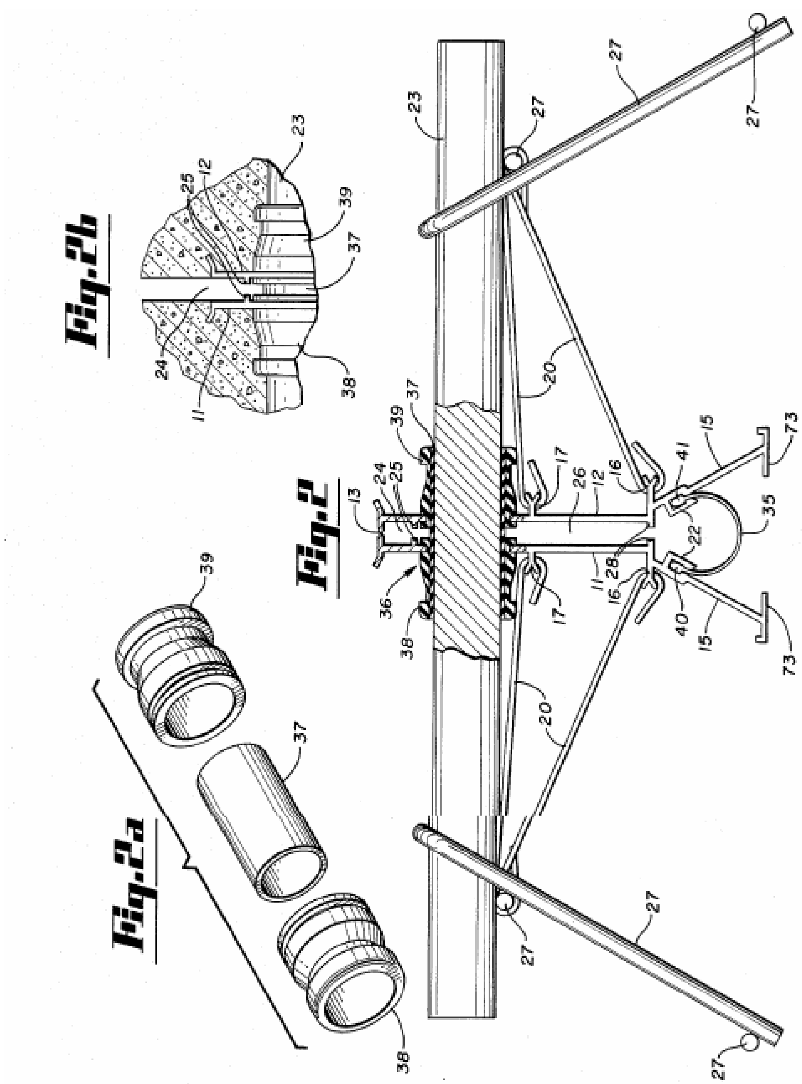


Fig.3

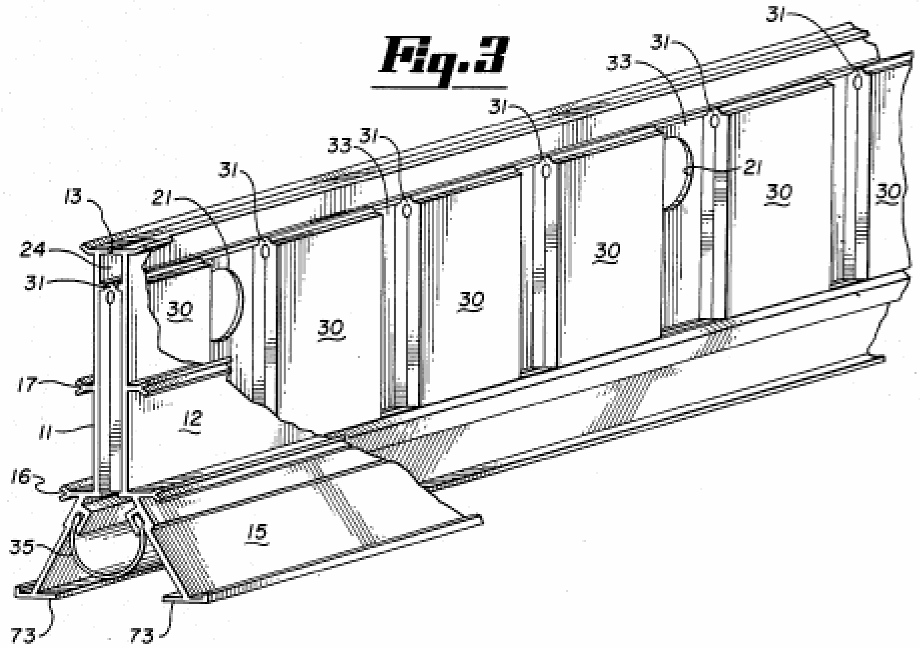

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Fig.4

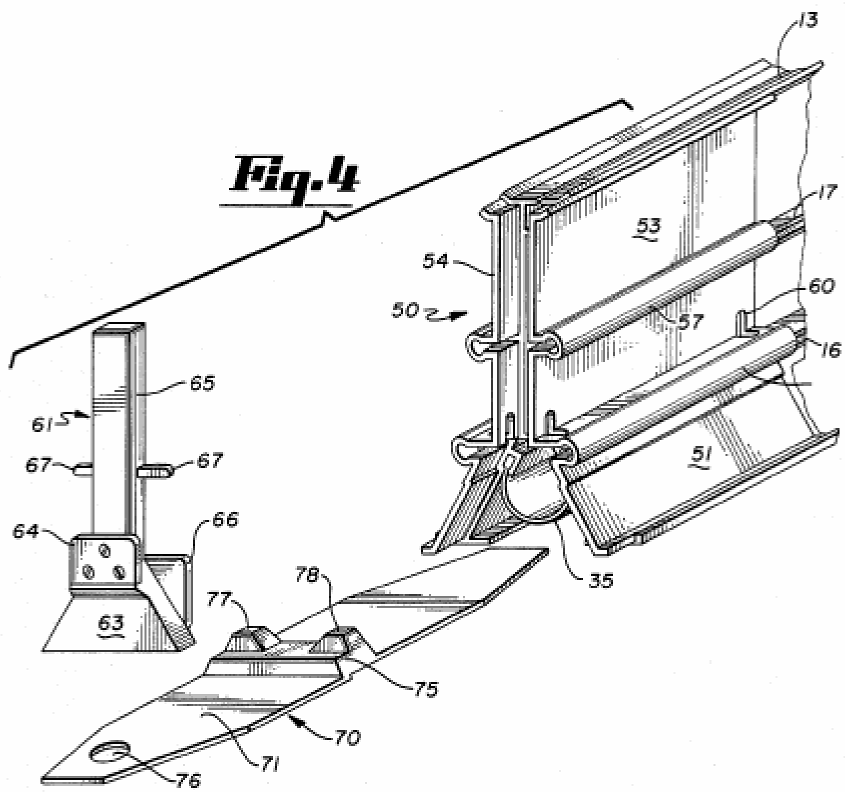
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Fig. 5

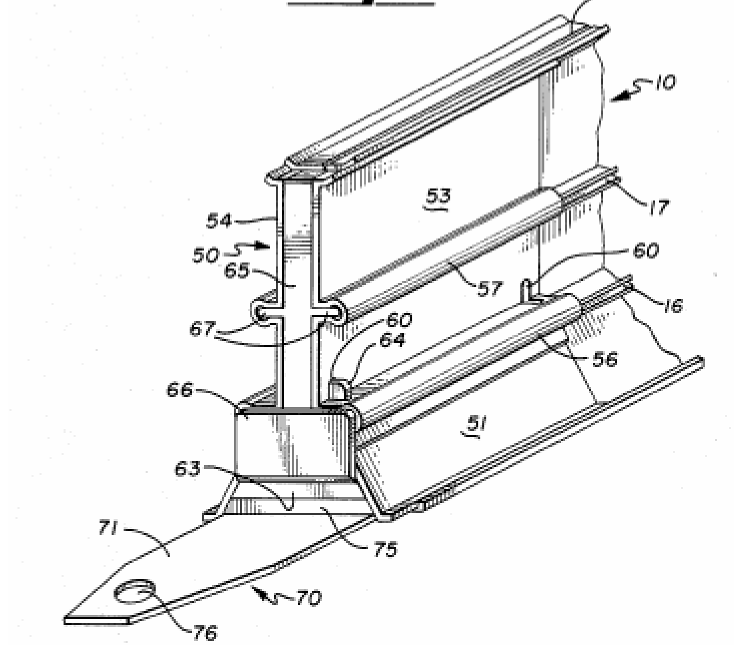
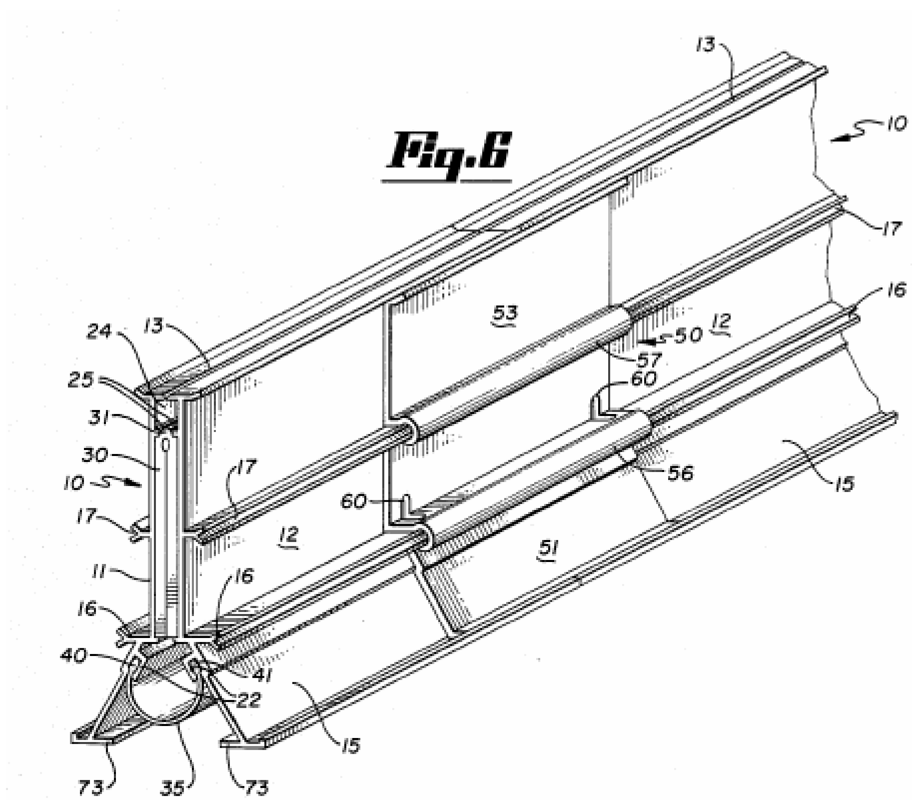
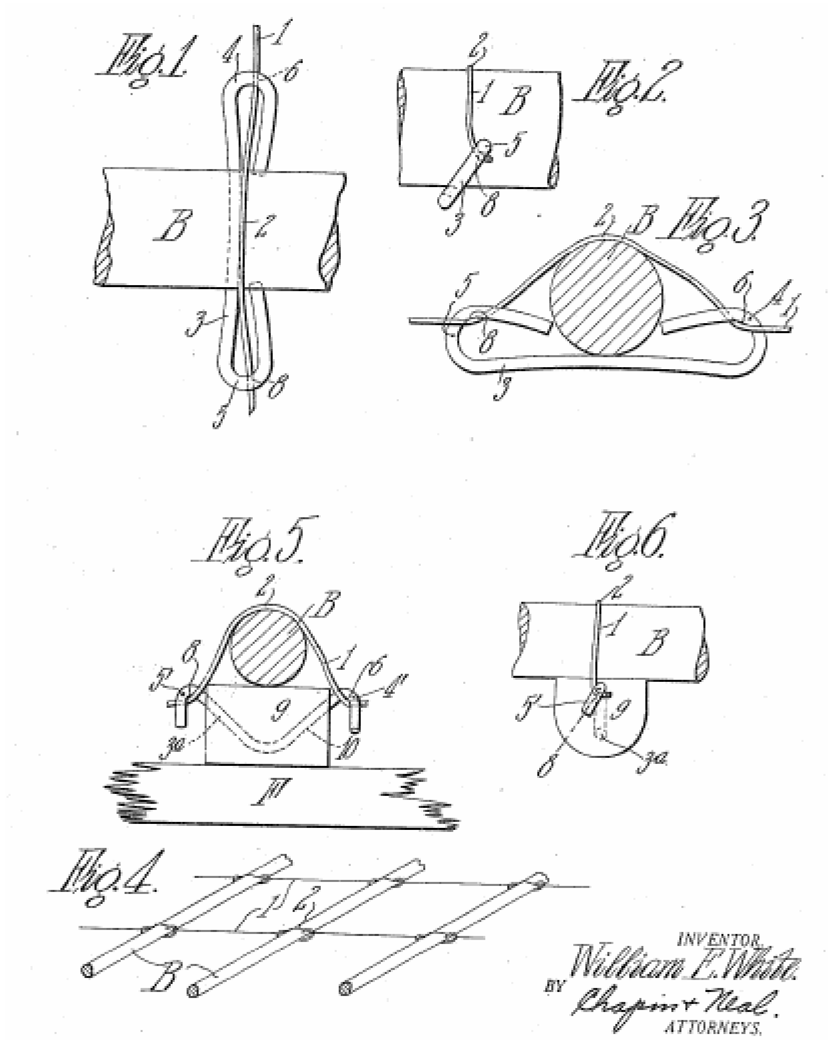


Fig. 6



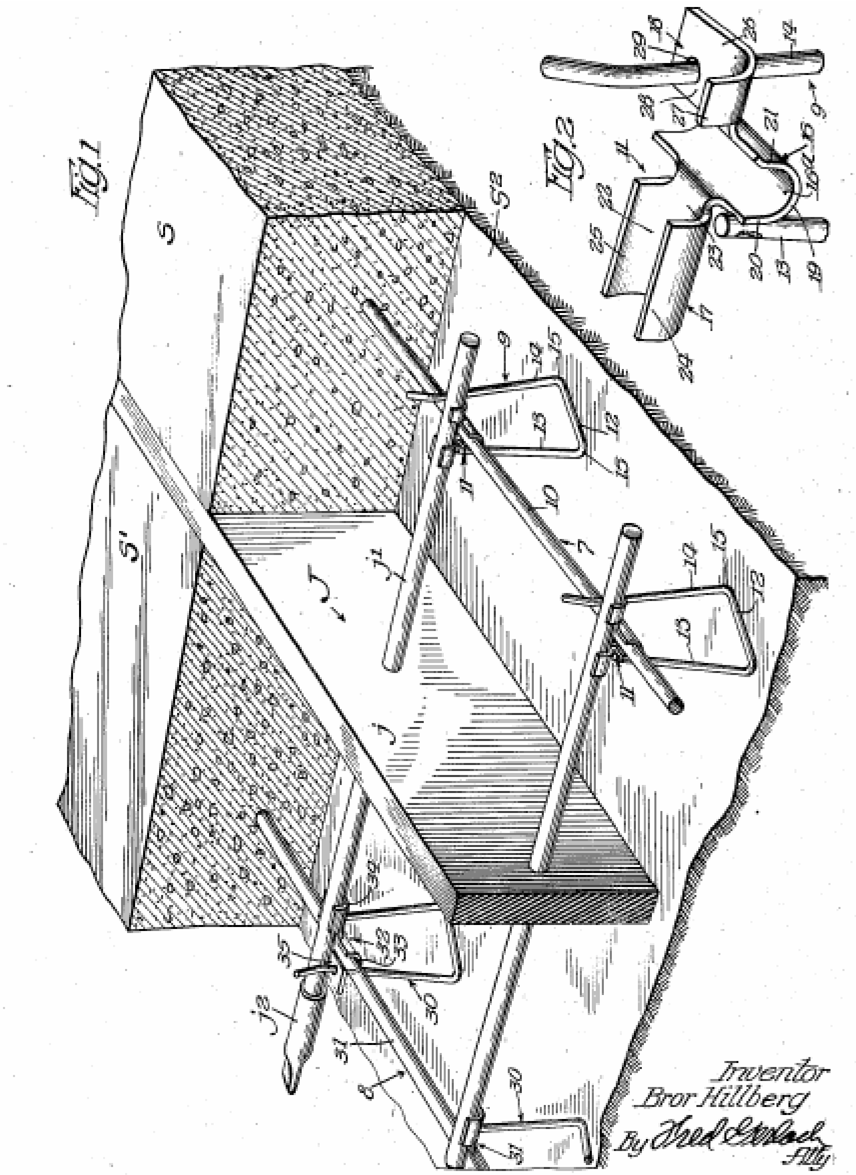
Inventor: Bernard D. Thomsen, Kenneth L. Thomsen
Materials: Metal, 10 is a plastic wall liner, 30 is made of thermoplastic blocks, 36-38 are seals, but the material is not given

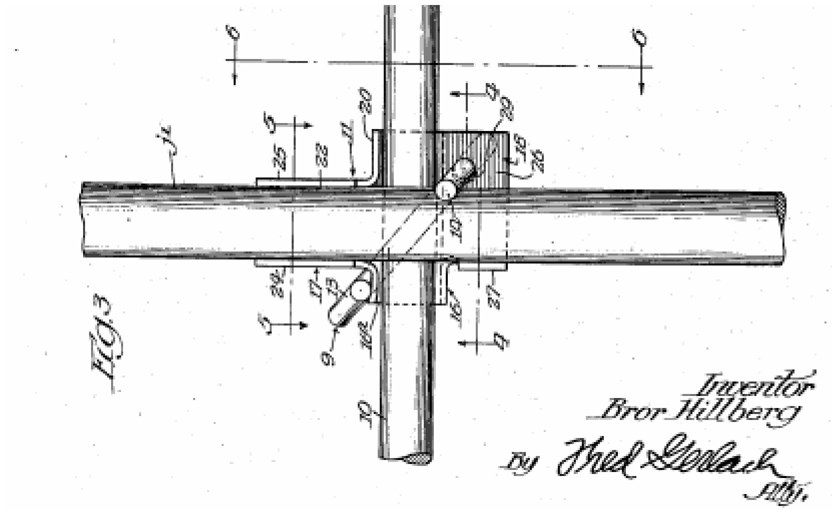
#1306984

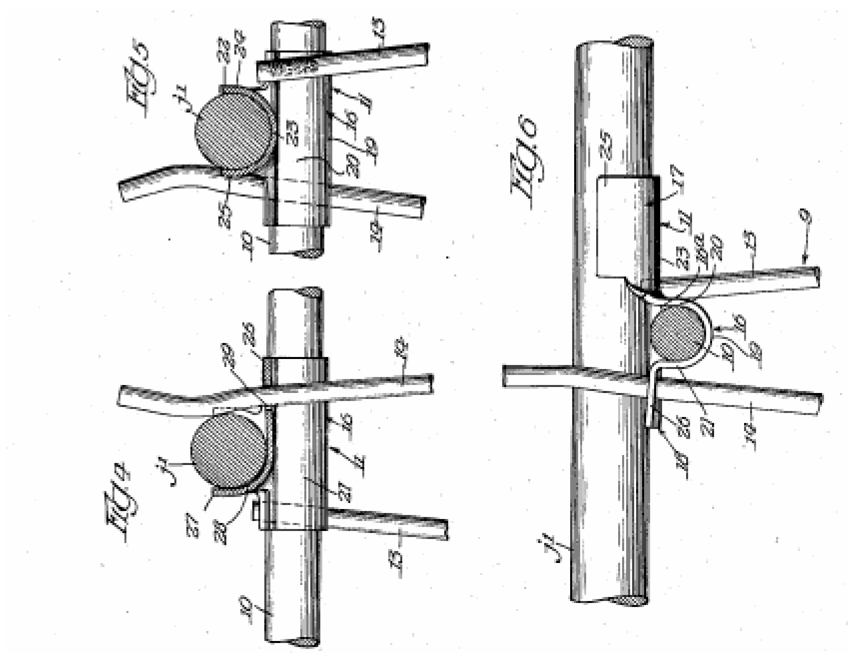


Inventor: William E. White
Materials: Metal

#2375361

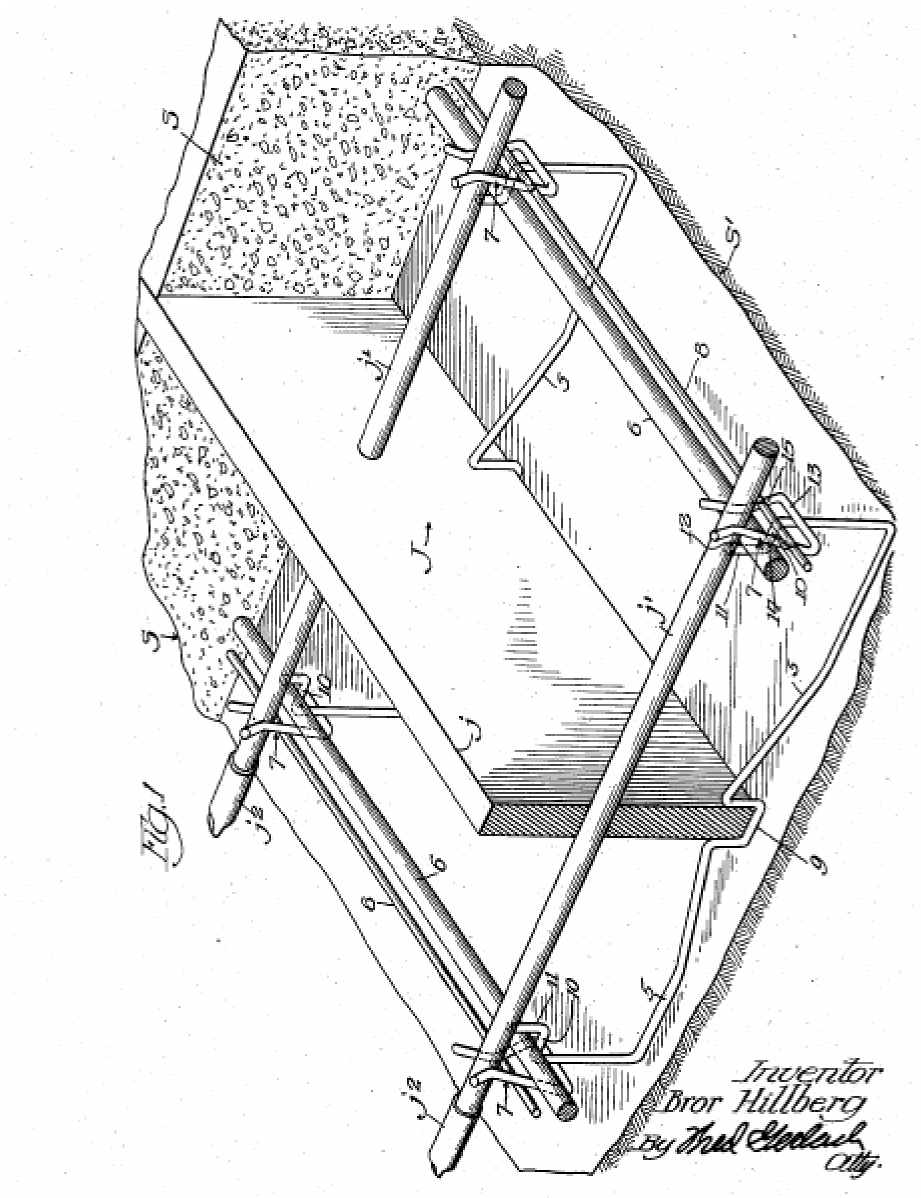


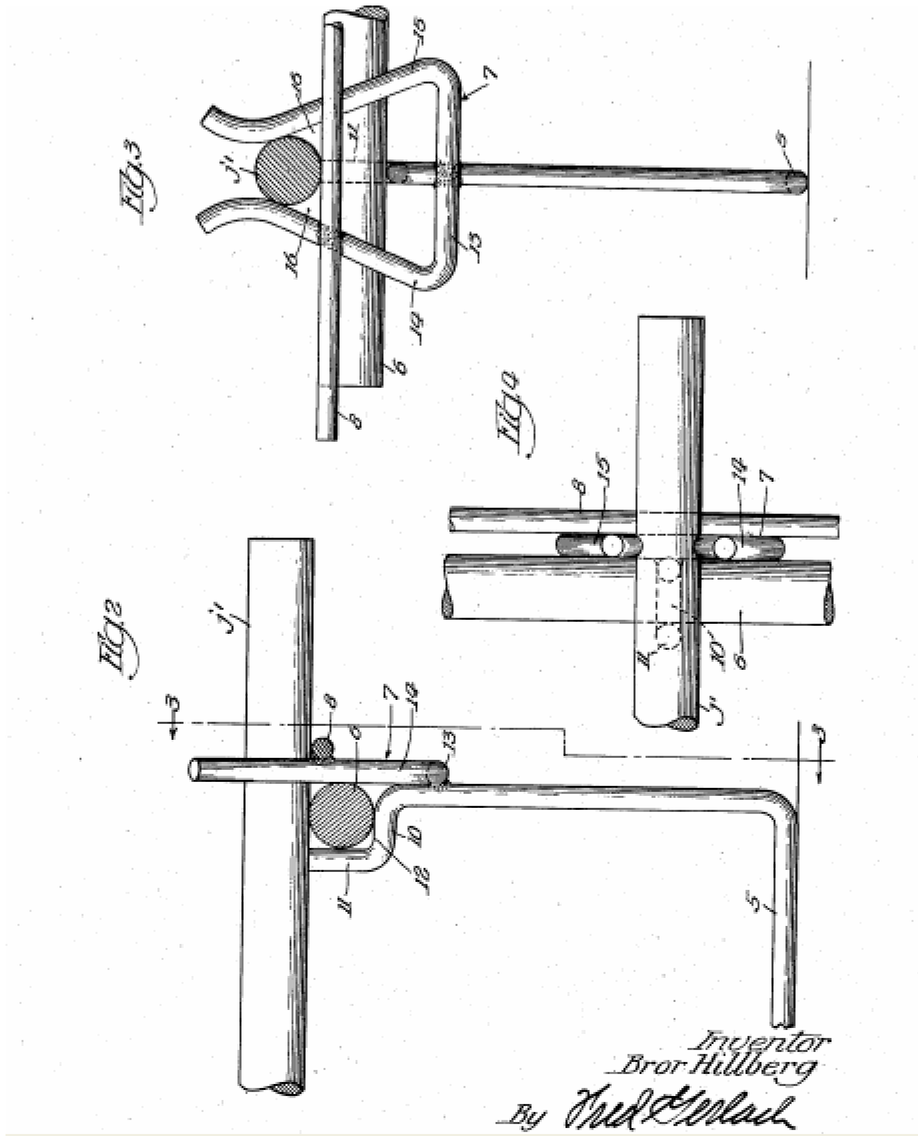




Inventor: Bror Hillberg
Materials: Metal

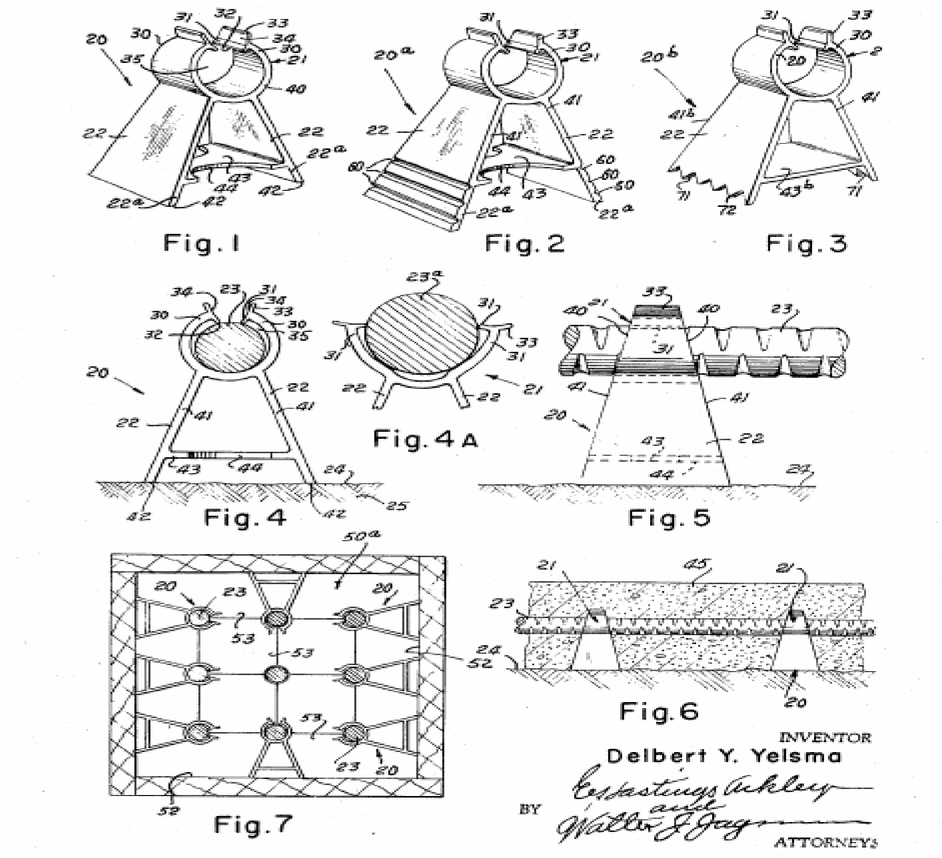
#2439428





Inventor: Bror Hillberg
Materials: Metal, compressible filler strip ***j***

#3471987



Inventor: Delbert Y. Yelsma
Materials: Metal, 45 represents the concrete poured around the design

#3694989

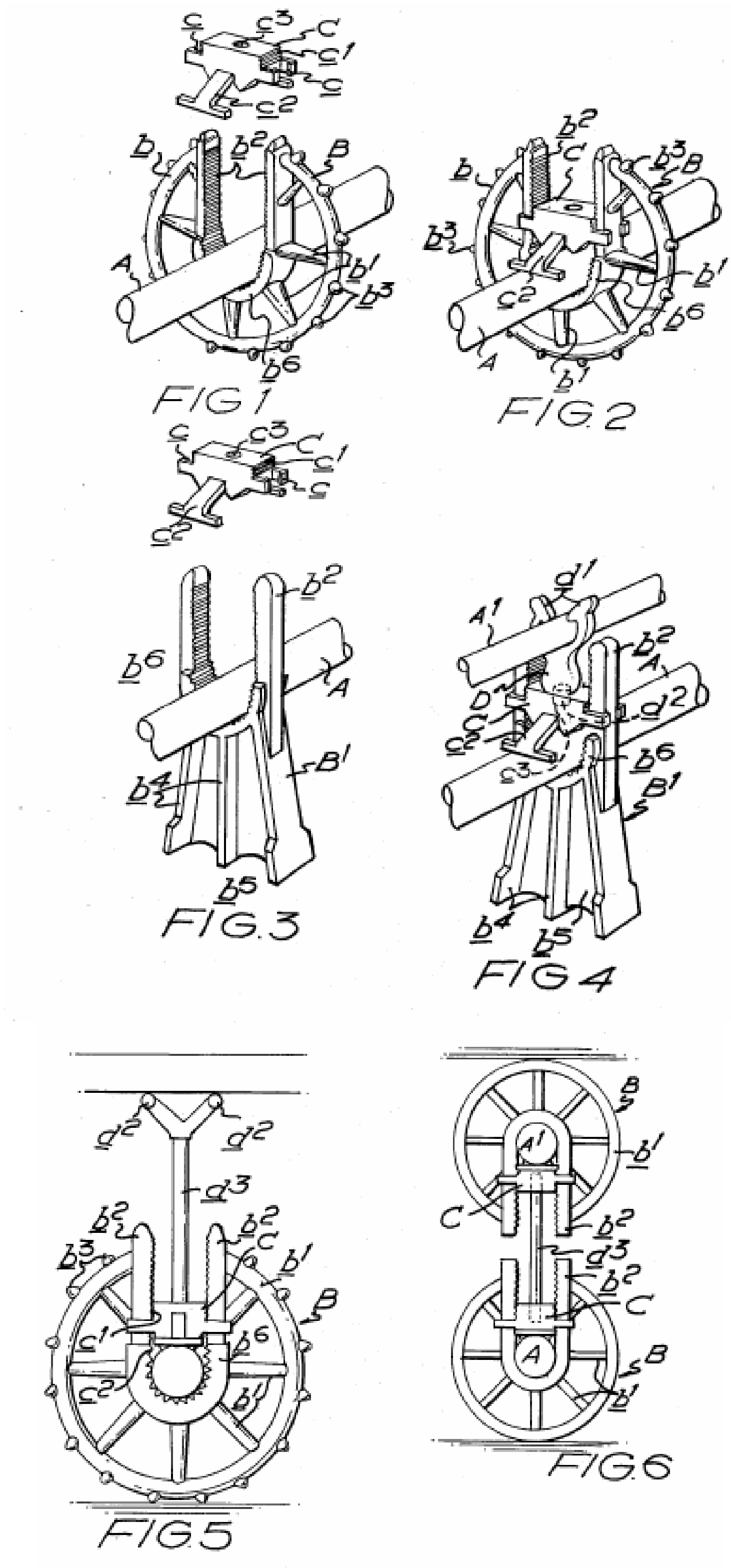


FIG 1

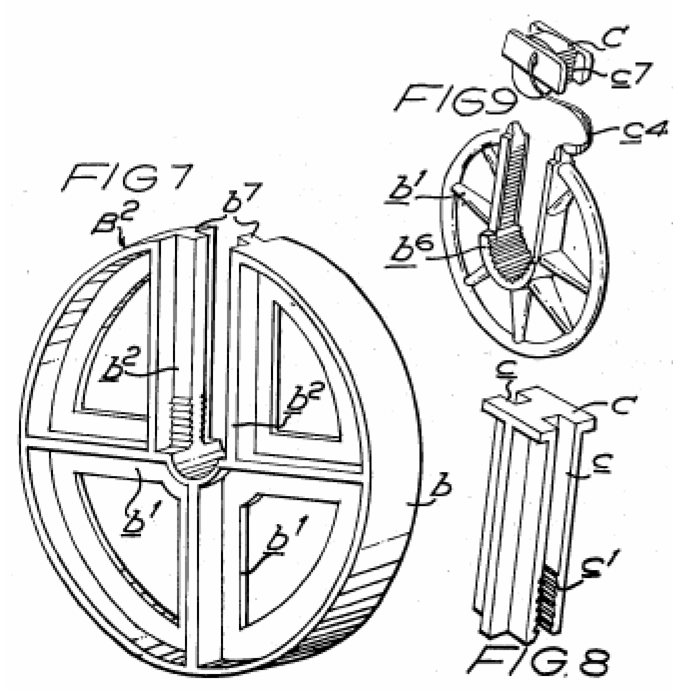
FIG. 2

FIG. 3

FIG 4

FIG 5

FIG. 6



Inventor: Keith W. Oliver, Donald Taylor
Materials: Metal

#1536178

Fig.1.

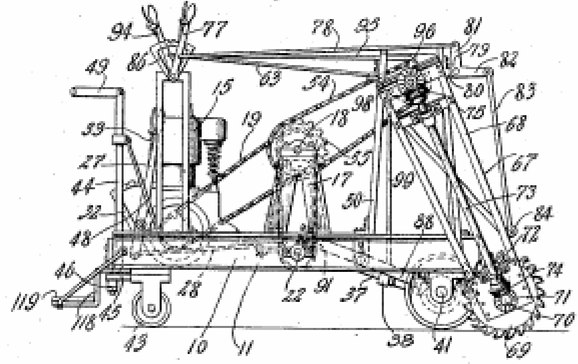
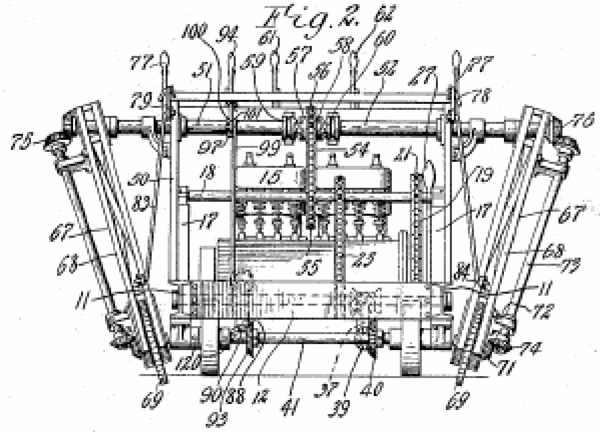


Fig.2.



Inventor
WILLIAM J. HACKETT
by
Attorney

Fig. 3.

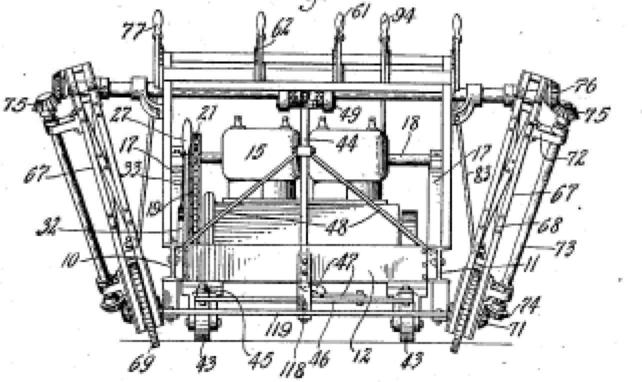
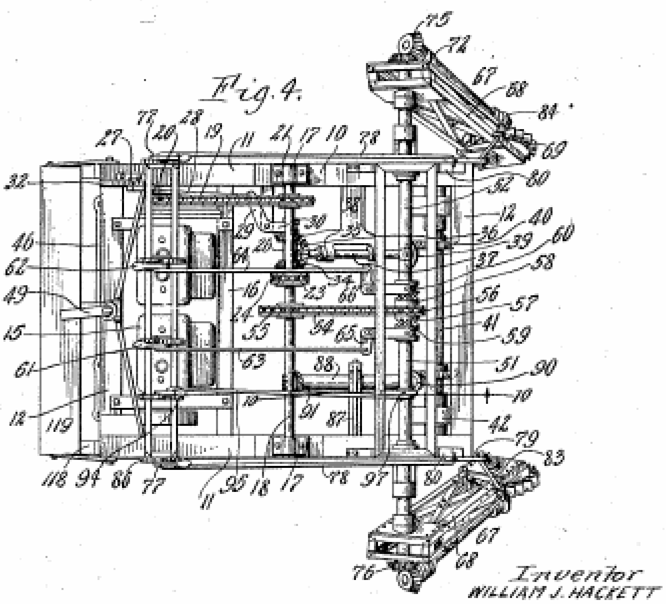


Fig. 4.



Inventor
WILLIAM J. HACKETT

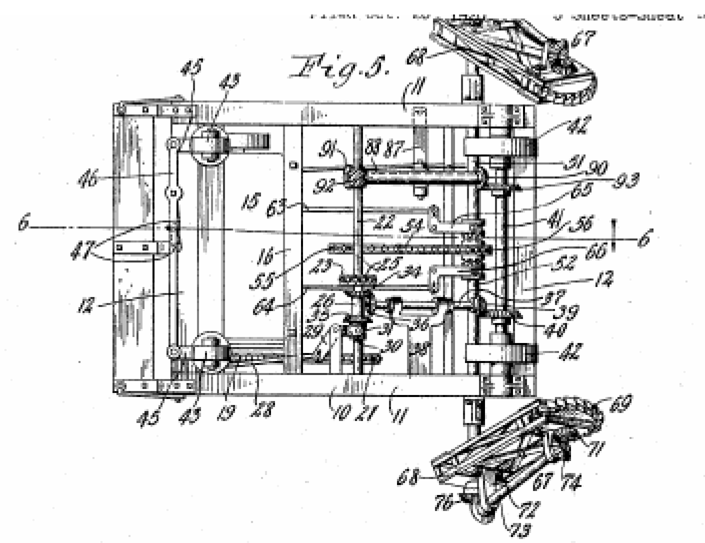


Fig. 5.

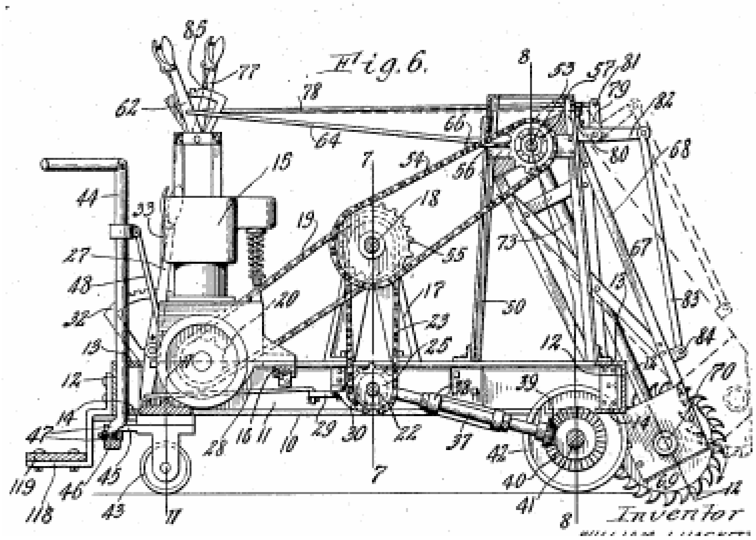


Fig. 6.

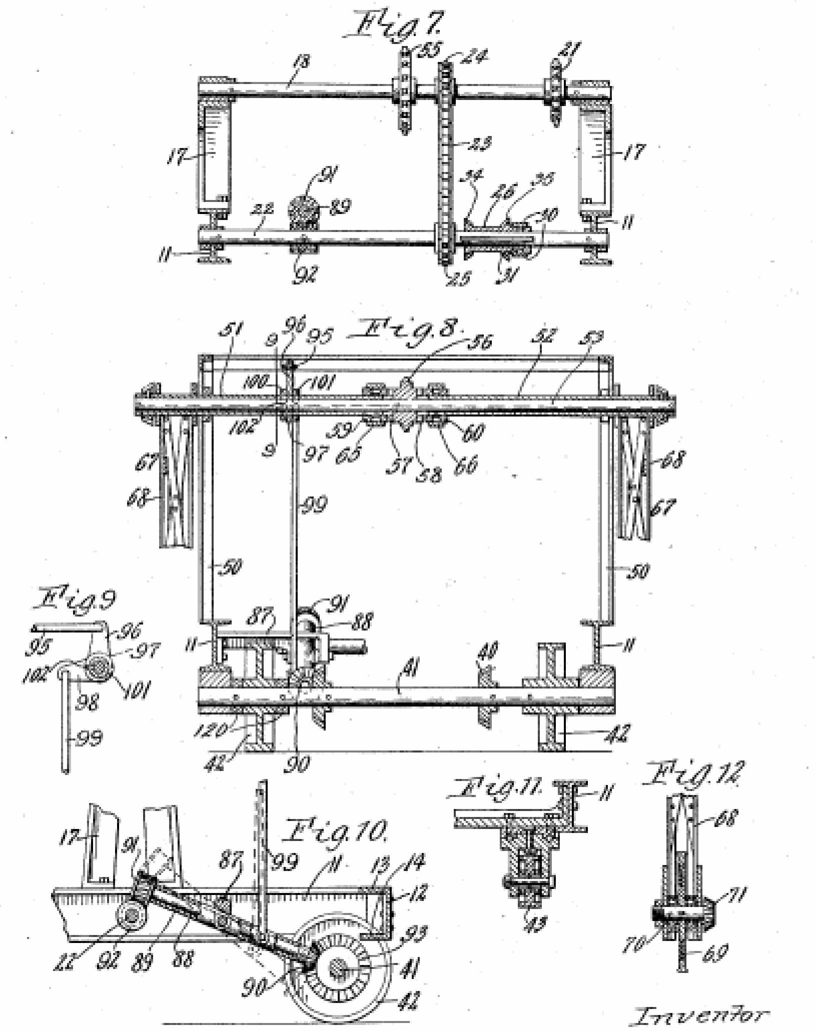
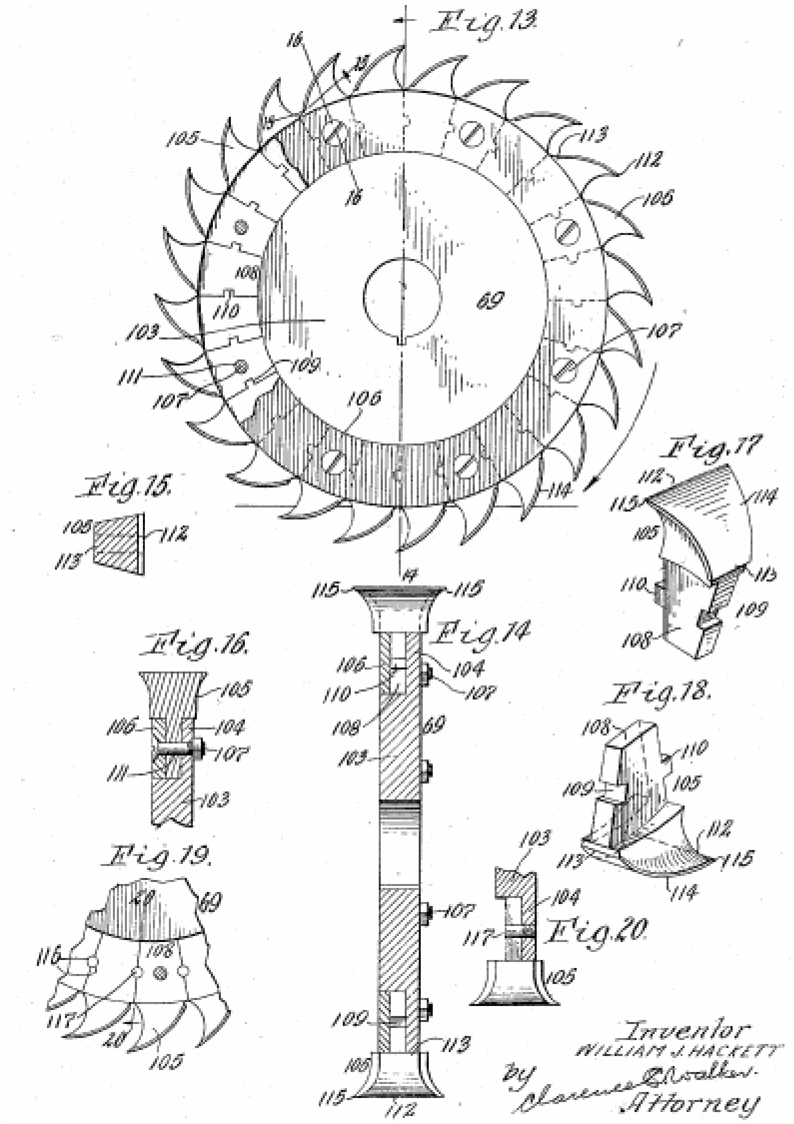


Fig. 7.
Fig. 8.
Fig. 9
Fig. 10.
Fig. 11.
Fig. 12.
Inventor



Inventor: William J. Hackett
Materials: Metal, all of this is part of an asphalt cutting machine

#3321250

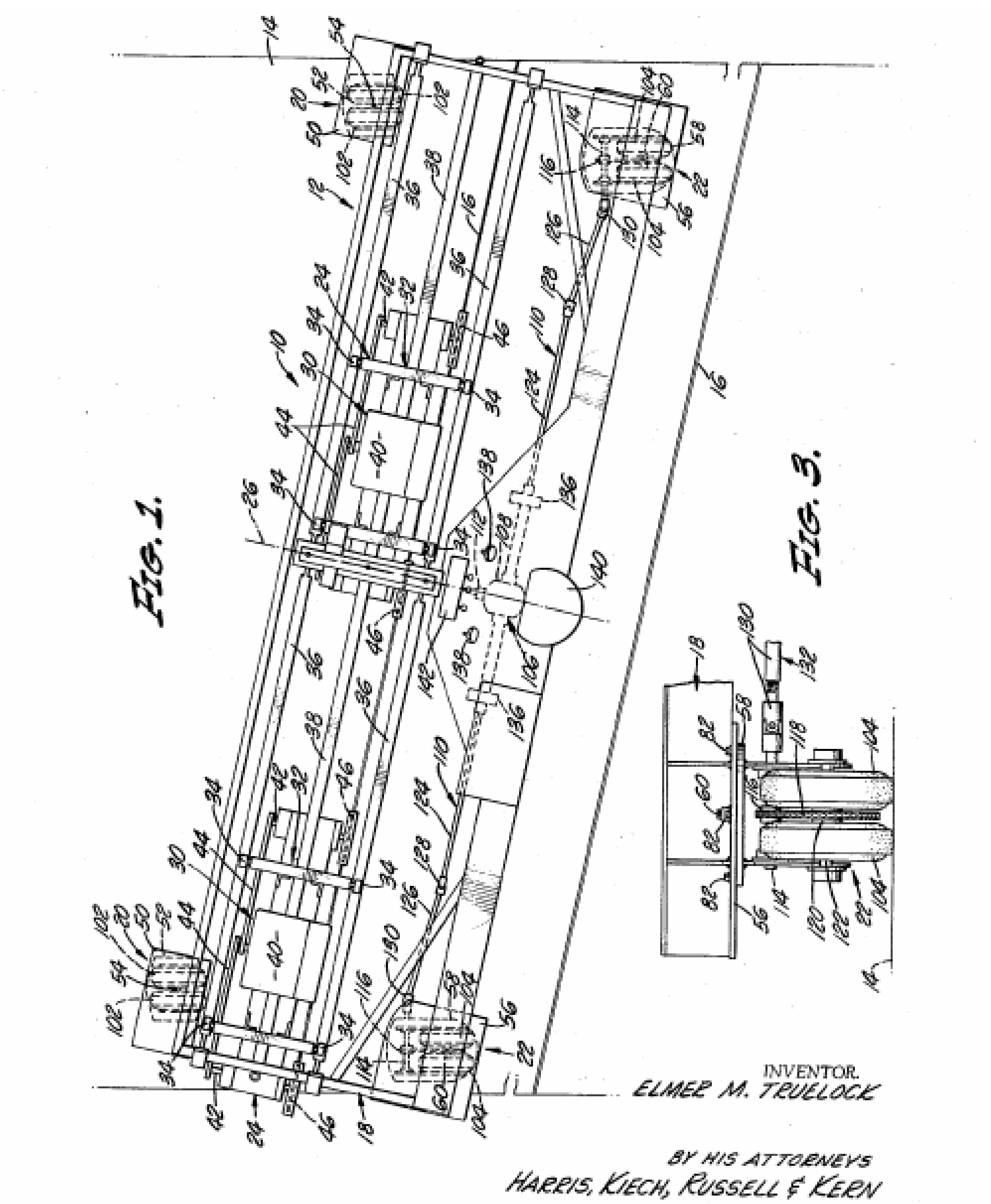
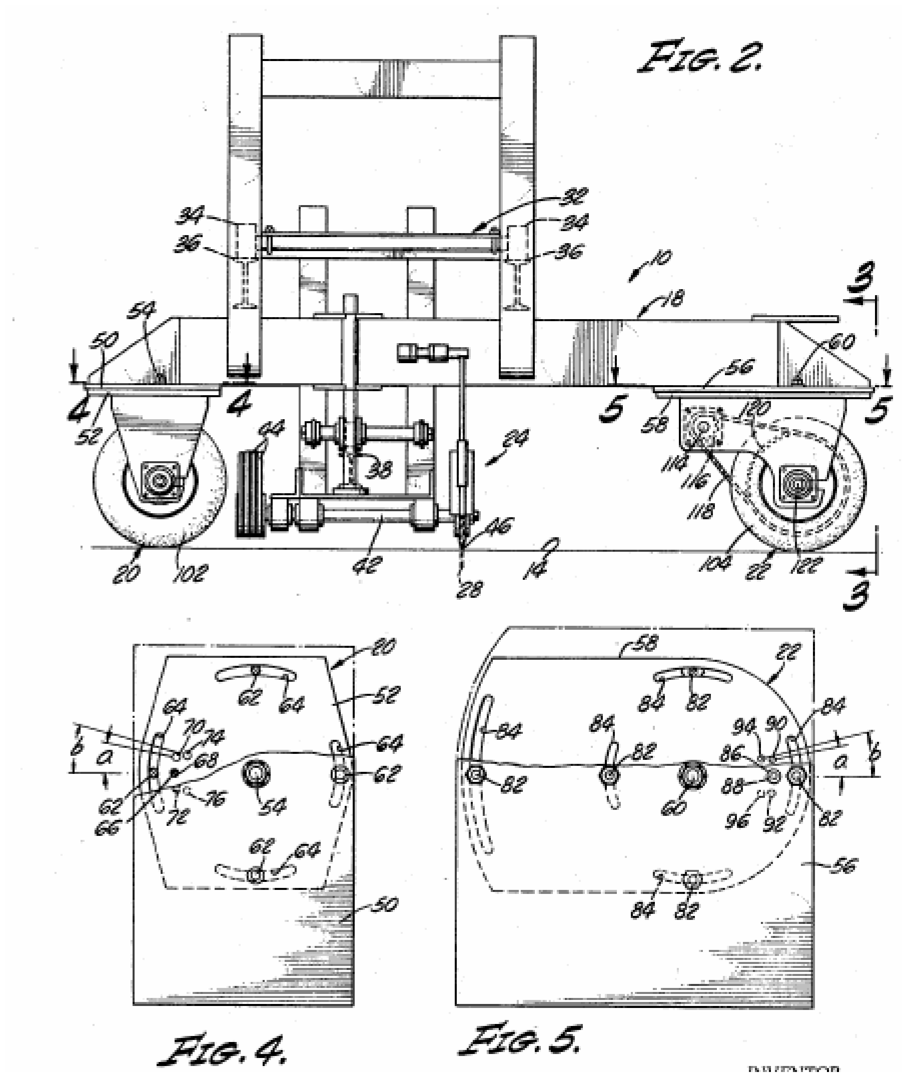
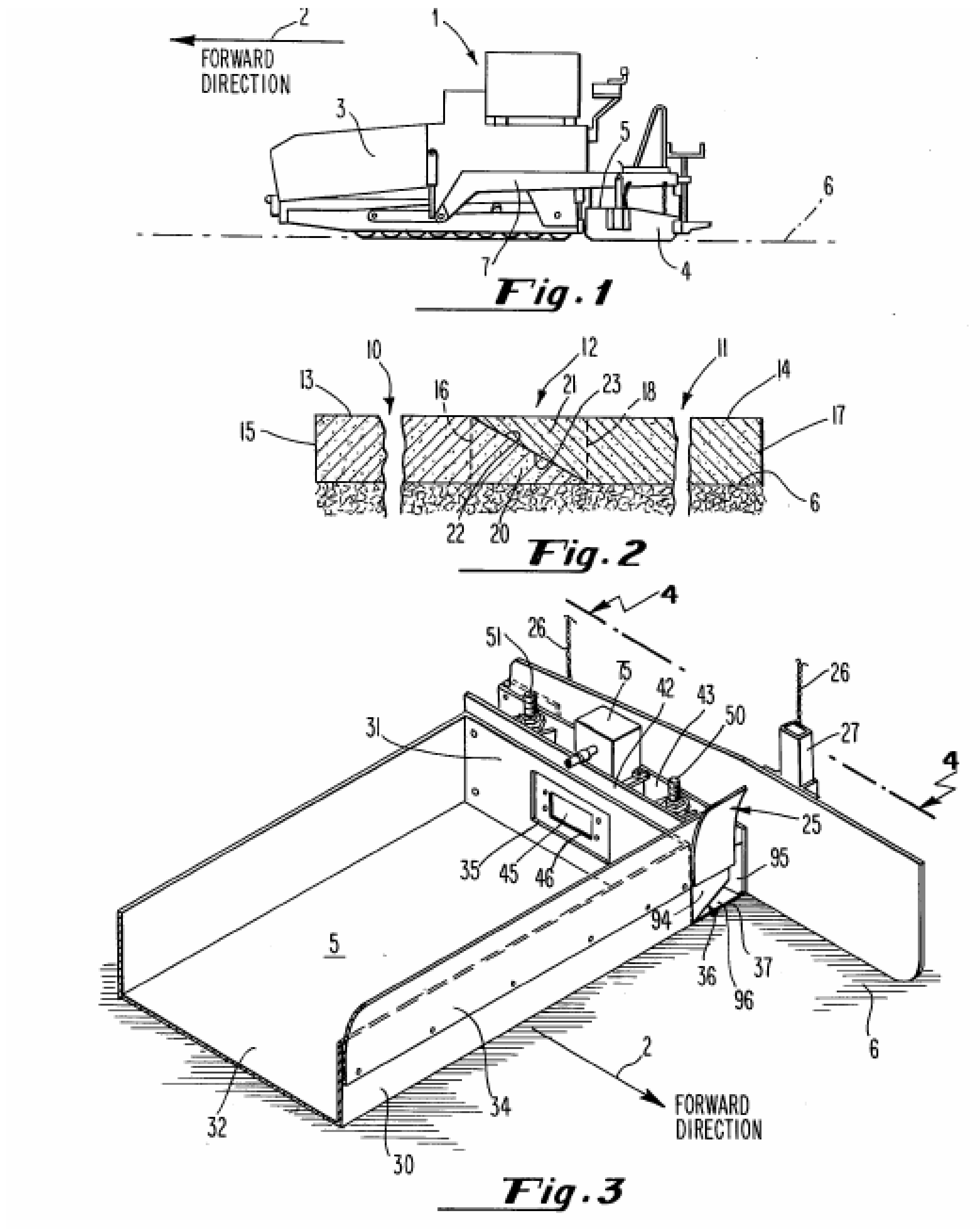


FIG. 1.
FIG. 3.
INVENTOR.
ELMER M. TRUELOCK
BY HIS ATTORNEYS
HARRIS, KIECH, RUSSELL & KERN



Inventor: Elmer M. Truelock
Materials: Metal, the material of the wheels is not given for this machine of slotting strips of concrete pavement

#4181449



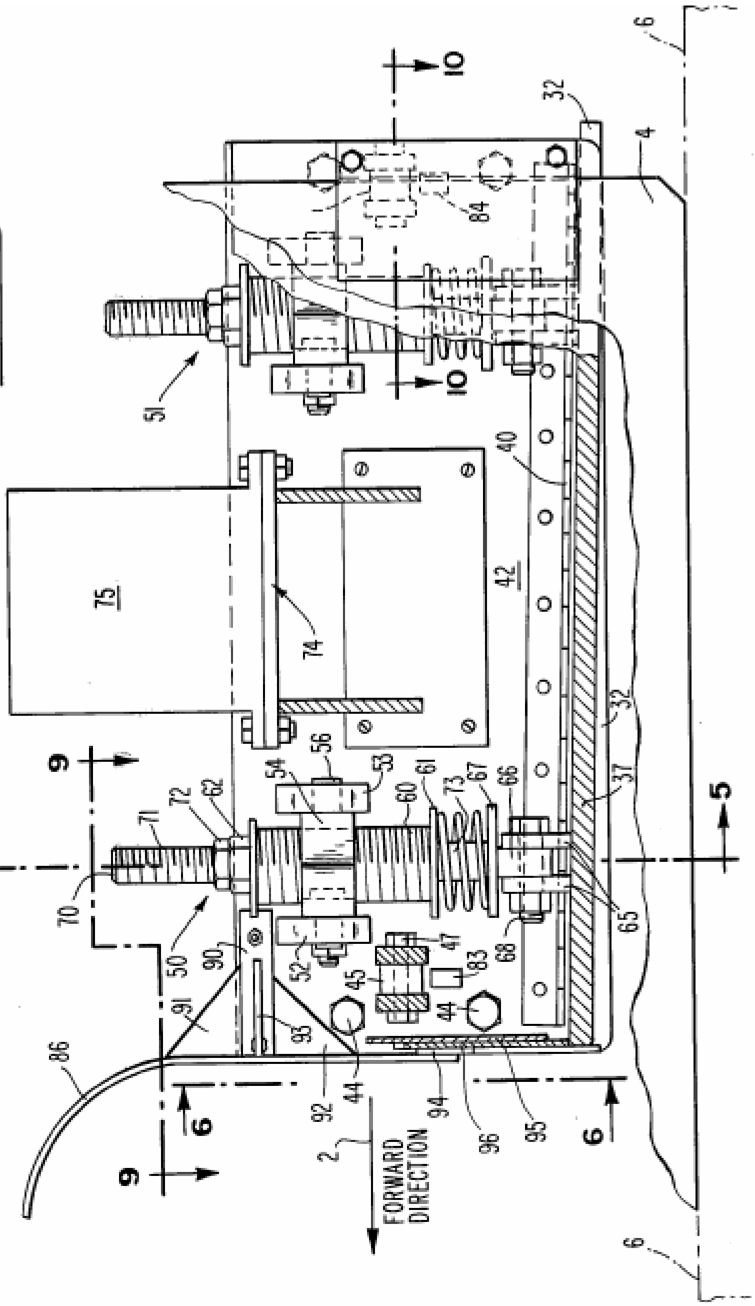


Fig. 4

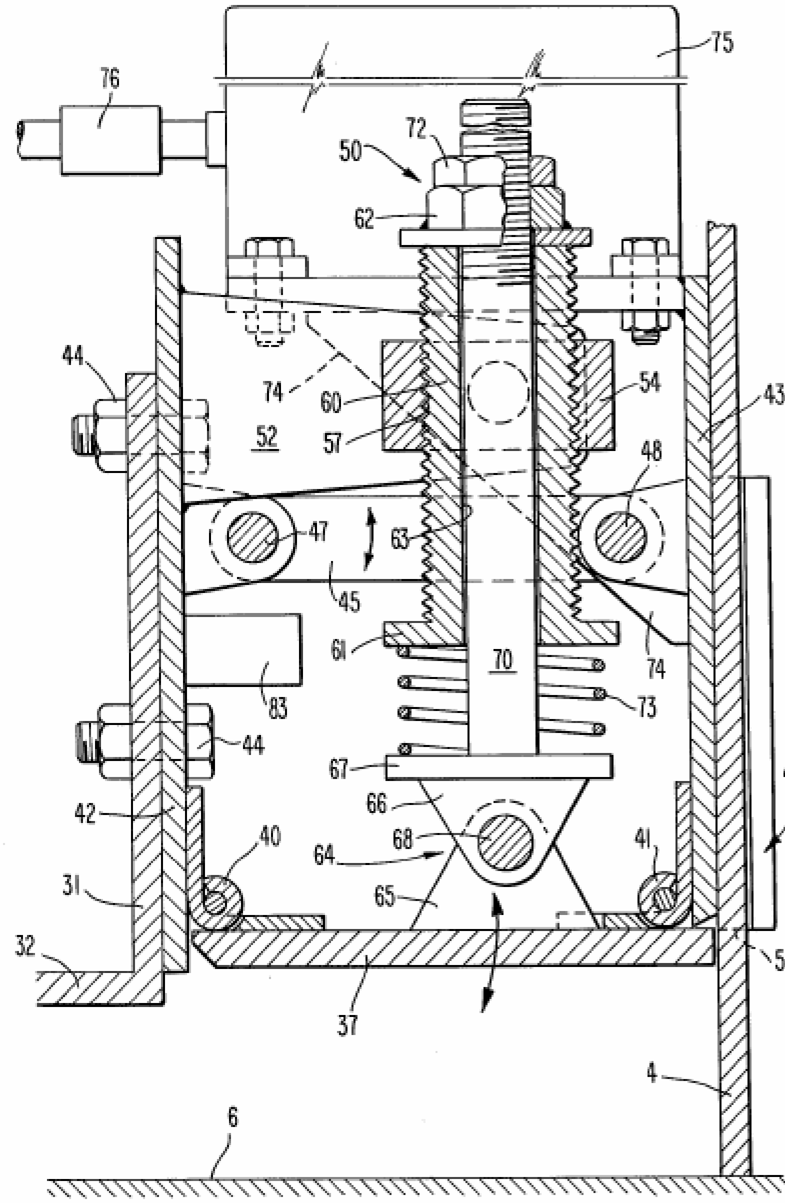

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Fig. 5

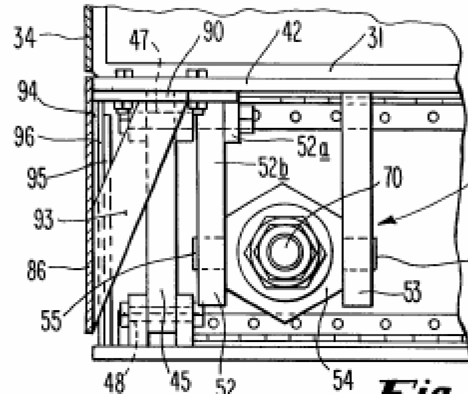

Fig. 9

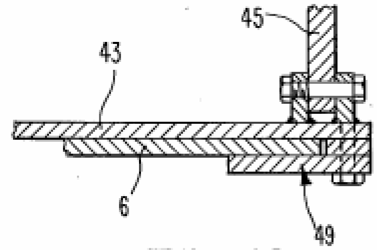

Fig. 10

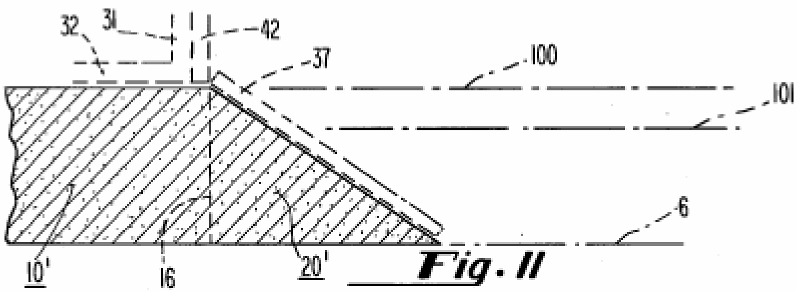

Fig. 11

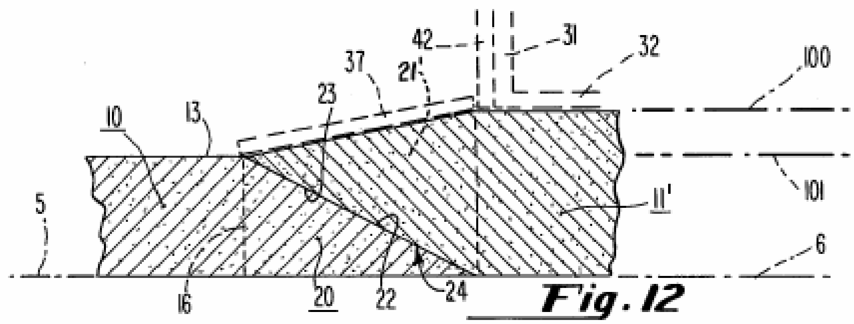

Fig. 12

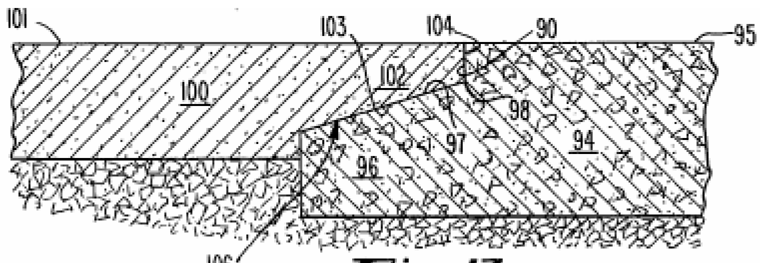

Fig. 13

Inventor: Earl Lenker
Materials: Paving machine made from metal

APPENDIX C. JOINT SPACING DATA

Table C1. Preliminary joint spacing measurements for US 520 transverse joint research

	Measurement from previous plate (m)			
Station	**South edge**	**South mid.**	**North mid.**	**North edge**
941+80, 64-mm (2.5-in.) plate, bottom				
	6.0 (236 in.)	6.0 (235.25 in.)	6.0 (234.75 in.)	6.0 (235.5 in.)
	6.0 (235 in.)	6.0 (236 in.)	6.0 (237 in.)	6.1 (239.5 in.)
	6.0 (237.75 in.)	6.1 (239.5 in.)	6.1 (239 in.)	6.0 (237.75 in.)
	6.0 (235.25 in.)	6.0 (235.5 in.)	6.0 (235 in.)	6.0 (236.5 in.)
	6.1 (240 in.)	6.0 (236.5 in.)	6.0 (237.5 in.)	6.0 (237.5 in.)
938+00, 70-mm (2.75-in.) plate, bottom				
	6.2 (246 in.)	6.2 (244.75 in.)	6.2 (244.25 in.)	6.2 (244 in.)
	6.1 (239 in.)	6.1 (240 in.)	6.1 (241.5 in.)	6.2 (245 in.)
	6.2 (242.25 in.)	6.1 (240.25 in.)	6.0 (234.5 in.)	6.0 (237 in.)
	6.2 (243.25 in.)	6.2 (243.75 in.)	6.2 (244 in.)	6.2 (243.5 in.)
	6.2 (242.25 in.)	6.2 (244.25 in.)	6.2 (244.75 in.)	6.2 (244.5 in.)
937+00, 76-mm (3.0-in.) plate, bottom				
	6.1 (241 in.)	6.1 (241.25 in.)	6.1 (241.5 in.)	6.2 (245 in.)
	6.0 (238 in.)	6.1 (241.5 in.)	6.1 (241.5 in.)	6.1 (241 in.)
	6.3 (247.75 in.)	6.2 (243 in.)	6.2 (243 in.)	6.1 (239.5 in.)
	6.1 (240 in.)	6.1 (242 in.)	6.1 (244 in.)	6.2 (242.25 in.)
	6.3 (246.5 in.)	6.2 (242.5 in.)	6.2 (242.75 in.)	6.1 (239 in.)
936+10, 38-mm (1.5-in.) plate, top				
	6.1 (239.75 in.)	6.1 (240.25 in.)	6.1 (240.5 in.)	6.1 (240 in.)
	6.2 (244.5 in.)	6.1 (241.5 in.)	6.1 (240.5 in.)	6.1 (240 in.)
	6.1 (238.5 in.)	6.1 (241.5 in.)	6.2 (242.75 in.)	6.2 (242.5 in.)
	6.2 (243 in.)	6.2 (243.75 in.)	6. 2 (243 in.)	6.2 (244 in.)
	6.2 (243.25 in.)	6.1 (240.5 in.)	6.1 (241 in.)	6.1 (239.5 in.)
935+10, 45-mm (1.75-in.) plate, top				
	6.1 (242 in.)	6.1 (241 in.)	6.1 (241 in.)	6.1 (241 in.)
	6.1 (241 in.)	6.1 (241 in.)	6.1 (240 in.)	6.1 (240.75 in.)
	6.1 (240 in.)	6.1 (240 in.)	6.1 (239.75 in.)	6.0 (237.25 in.)
	6.0 (232.5 in.)	6.0 (235 in.)	6.0 (236 in.)	6.1 (240 in.)
	6.1 (241.5 in.)	6.1 (238.75 in.)	6.0 (238 in.)	6.0 (237 in.)
934+10, 51-mm (2.0-in.) plate, top				
	6.2 (244.5 in.)	6.1 (242 in.)	6.1 (241.5 in.)	6.1 (241.5 in.)
	6.1 (239 in.)	6.1 (239 in.)	6.1 (239.25 in.)	6.1 (239.5 in.)
	6.1 (239.5 in.)	6.2 (243.75 in.)	6.2 (243.5 in.)	6.2 (242.5 in.)
	6.1 (240 in.)	6.1 (239.5 in.)	6.1 (239 in.)	6.1 (240 in.)
	6.1 (242 in.)	6.1 (241 in.)	6.1 (241.5 in.)	6.1 (241.5 in.)

APPENDIX D. PAVING NOTES

Table D1. Photo records for US 520 transverse joint research

Station	Sect.	Photos before paving*	Photos during paving*
941+85	1	1 angle, 2 side, 3 CL	1 front, 2 side, 3 side bf. ss, 5 no trail
64 mm (2.5 in.)	2		9 after ss
	3		
	4		
	5		
	6		6 side, 7 side before ss, 8 side before ss
938+00	1		1 side
70 mm (2.75 in.)	2		2 side
	3		3 front
	4	1 over CL, 2 endshot	4 side
	5		5 side
	6		6 side angle
937+10	1		1 side, 3 top before ss
76 mm (3.0 in.)	2		2 side
	3		
	4		
	5	1 full length, 2 angle	
	6		
936+10 38 mm (1.5 in.)	1	1 CL, 2 full length, 3 end tie, 4 tie, 5 end macro	1 side, 2 side, 4 during ss, 6 after ss, 7 after ss
	2		3 side
	3	6 half length showing extra pins	
	4		5 side, 8 before ss
	5		9 end before ss
	6		
935+100	1	1 extra piece, 2 extra piece	10 side, 11 side during ss
45 mm (1.75 in.)	2		
	3		
	4		12 side angle
	5		
	6		13 side angle
934+10	1	1 unique double tie	14 side
51 mm (2.0 in.)	2	2 both sides twist	
	3		15 side, 20 after ss
	4		16 side
	5		17 side
	6		19 before ss

*Photos in this table are available in the project file.
Note: ss=super slicker; NP=no problems; CL=center line

Table D2. Paving notes and comments for US 520 transverse joint research

Station	Sect.	Comments before paving	Comments during/after paving
941+85 64 mm (2.5 in.)	1	curved at middle on each plate, all 4 ends fine	slight flexing when pushed
	2	very straight	1 & 2 had thin form oil application
	3	middle offset ~25 mm	NP
	4	pretty straight	creaking sound when paved; probably paver, not joint
	5	pretty straight, middle offset ~25 mm	NP
	6	bend around CL, 2 endpoints partially out	NP
938+00 70 mm (2.75 in.)	1	slight twist & offset @ CL	NP
	2	some twist, slightly crooked	NP
	3	very straight, little twist	NP
	4	pretty straight, little twist	NP
	5	pretty straight	NP
	6	pretty straight	NP
937+10 76 mm (3.0 in.)	1	some twist, mostly straight	NP
	2	some twist, 51-mm offset on north end	NP
	3	little twist, 51-mm offset on south end	no form oil
	4	little twist, very straight	no form oil
	5	some twist, pretty straight	NP
	6	some twist, offset ~25 mm @ CL, offset 51 mm @ south end	NP
936+10 38 mm (1.5 in.)	1	pretty straight, offset ~25 mm @ CL	thick oil on east end
	2	pretty straight	thick oil on east end, may have shifted in middle
	3	extra plate piece slightly offset	NP
	4	~25 mm offset @ CL	looked twisted on north end
	5	some ties had slack on south end, slight offset @ CL	looked twisted on north end
	6	very straight	NP
935+100 45 mm (1.75 in.)	1	pretty straight, slight offset @ CL	slightly pushed in middle, twist on north end
	2	pretty straight, slight offset @ CL	NP
	3	pretty straight, no offset	NP
	4	pretty straight, no offset	NP
	5	pretty straight, no offset	CL rod set slightly west
	6	twist on extra piece, 51-mm offset on north end	NP
934+10 51 mm (2.0 in.)	1	pretty straight, slight offset @ CL	CL rod set slightly west
	2	straight, twist on both center ends	twist on north end
	3	very straight, slight offset @ CL	NP
	4	very straight	slight flex
	5	very straight, slight offset @ CL, twist on north end	possibly pushed during pave
	6	very straight, slight offset @ CL	CL rod set slightly east

Note: ss=super slicker; NP=no problems; CL=center line

Table D3. Cracking data for US 520 transverse joint research

Station	5/18 and 5/19/2005	Check, 5/31/2005	Final check, 6/14/2005
941+85	Started checks @ 9:30 am, 5/18/05 & no cracks		No transverse cracks, only CL
938+00	Started checks @ 9:30 am, 5/18/05 & no cracks	CL cracked completely	No transverse cracks, only CL
937+10	Started checks 5/19/05		No transverse cracks, only CL
936+10	Started checks 5/19/05		No transverse cracks, only CL
935+100	Started checks 5/19/05		No transverse cracks, only CL
934+10	Started checks 5/19/05		No transverse cracks, only CL

APPENDIX E. WEATHER DATA

Table E1. Weather data for US 520 transverse joint research

Date (2005)	Time checked	Notes and cracking data	Temperature °C (°F) Min	Mean	Max	Dew pt. (%)	Precip. in mm (in.)	Vis. in km (mi)	Wind sp. in kph (mph) Mean	Sus-tained	Max gust
Tues. 5/17		941+80 & 938+00 paved	14.0 (57.2)	18.6 (65.5)	26.0 (78.8)	47.7	0.00 (0.0)	16.0 (9.9)	22.0 (13.7)	29.1 (18.1)	51.9 (32.2)
Wed. 5/18	5am-7:30pm	Start checks on first 2 sets; final 4 sets paved	14.0 (57.2)	17.8 (64.1)	26.0 (78.8)	52.1	1.02 (0.04)	16.0 (9.9)	21.3 (13.2)	27.2 (16.9)	46.5 (28.9)
Thurs. 5/19	8:20am-11:45am	Start checks on the last 4 sets	9.0 (48.2)	17.8 (64.1)	27.0 (80.6)	53.6	1.78 (0.07)	12.9 (8)	10.0 (6.21)	22.5 (14)	37.1 (23.0)
Fri. 5/20	7am-10am		12.0 (53.6)	16.8 (62.3)	25.0 (77)	54.4	0.00 (0.0)	13.5 (8.4)	12.2 (7.6)	19.3 (12)	29.5 (18.3)
Sat. 5/21		Weekend	12.0 (53.6)	15.5 (59.9)	22.0 (71.6)	52.8	0.76 (0.03)	14.5 (9)	17.2 (10.7)	32.2 (20)	55.4 (34.4)
Sun. 5/22		Weekend	11.0 (51.8)	19.6 (67.3)	25.0 (77)	48.8	1.02 (0.04)	16.1 (10)	14.8 (9.21)	30.6 (19)	53.5 (33.3)
Mon. 5/23	5:30pm-8pm		11.0 (51.8)	19.4 (66.9)	27.0 (80.6)	43.6	0.00 (0.0)	16.1 (10)	10.0 (6.21)	22.5 (14)	42.4 (26.4)
Tues. 5/24	12:40pm-2:50pm		9.0 (48.2)	18.6 (65.5)	27.0 (80.6)	48.1	0.00 (0.0)	16.1 (10)	12.4 (7.71)	17.9 (11.1)	27.8 (17.3)
Wed. 5/25	6:15pm-8:35pm		14.0 (57.2)	17.7 (63.9)	25.0 (77)	49.6	0.00 (0.0)	15.0 (9.3)	11.3 (7.02)	17.9 (11.1)	35.2 (21.9)
Thurs. 5/26	2:40pm-5pm		8.0 (46.4)	14.2 (57.6)	22.0 (71.6)	47.8	12.95 (0.51)	15.5 (9.6)	15.6 (9.67)	29.1 (18.1)	51.9 (32.3)
Fri. 5/27		Roofing	7.0 (44.6)	13.4 (56.2)	22.0 (71.6)	44.3	0.25 (0.01)	15.8 (9.8)	14.6 (9.09)	24.1 (15)	55.4 (34.4)
Sat. 5/28		Weekend	9.0 (48.2)	14.4 (57.9)	23.0 (73.4)	43.5	1.02 (0.04)	16.1 (10)	13.7 (8.52)	22.5 (14)	40.8 (25.3)
Sun. 5/29		Weekend	NO DATA								
Mon. 5/30		Weekend	NO DATA								
Tues. 5/31	8:30am-12pm	whole CL cracked at station 938 + 00; no cracked joints	NO DATA								

APPENDIX F. VISUAL DISTRESS AND JOINT OPENING SURVEY DATA

Table F1. Pavement distress records for June 7, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks or centerline longitudinal cracks
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is not cracked.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks, but centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is not cracked
4 control	Ten joints cracked on the south side but only eight are on the north side. Centerline is not cracked, but the surface shows of rock being drug across the surface
5	No transverse cracks. Centerline is cracked.
5 control	Six of the joints are cracked on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is not cracked.
6 control	Six joints are cracked through the pavement and four are not. Centerline is not cracked.

Table F2. Pavement distress records for June 14, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks or centerline longitudinal cracks.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is not cracked.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks, but centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Note: Only subgrade finishing of the shoulders is complete at this time.

Table F3. Pavement distress records for June 16, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks. Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is not cracked.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks, but centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Table F4. Pavement distress records for June 23, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks, Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is not cracked.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks, but centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Note: One new core hole in the slab 5 of test site 5 in the passing lane (2 foot right of the median edge)

Table F5. Pavement distress records for July 6, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks, Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is now cracked neat and straight.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks. Centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked neat and straight.
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Note: Test sites have now been referenced off the pavement to allow for future identification.

Shoulder rock operation completed July 9, 2005.
Ribbon cutting ceremony done on July 12, 2005.

Table F6. Pavement distress records for July 25, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks, Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is now cracked neat and straight.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks. Centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked neat and straight.
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Note: Test sites have now been referenced off the pavement to allow for future identification.

Table F7. Pavement distress records for August 21, 2005

Test site	Visual Distress Survey Remarks
Control section	Eight of the 10 joints are cracked through the pavement. Two adjacent to the test site are not cracked and centerline is not cracked.
1	No transverse cracks, Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is now cracked neat and straight.
2 control	Nine joints cracked at the surface (number 2 is not). Centerline is not cracked.
3	No transverse cracks. Centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is not cracked.
4	No transverse cracks. Centerline is now cracked neat and straight.
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
5 control	Nine of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked. There is some spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked.

Note: Some sealant is depressed in the test site joints either through loss at the ends or penetration into the crack that has formed below the saw cut.

Table F8. Pavement distress records for September 13, 2005

Test site	Visual Distress Survey Remarks
Control section	Ten joints are cracked through the pavement.
1	No transverse cracks, Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked.
2	No transverse cracks. Centerline is now cracked neat and straight.
2 control	Ten joints are now cracked at the surface. Centerline is now cracked neat and straight (10% shows minor spalling).
3	No transverse cracks. Centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is now cracked neat and straight (10% shows minor spalling).
4	No transverse cracks. Centerline is now cracked neat and straight.
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is now cracked neat and straight. There is some minor spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
5 control	Ten of the joints are cracked (number 7 is not) on both sides of the pavement and four are not. Centerline is cracked neat and straight.
6	No transverse cracks. Centerline is now cracked neat and straight. There is some minor spallling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked neat and straight.

Table F9. Pavement distress records for January 6, 2006

Test site	Visual Distress Survey Remarks
Control section	Ten joints are cracked through the pavement straight and tight.
1	No transverse cracks. Centerline is now cracked neat and straight.
1 control	Ten joints cracked at the surface. Centerline is cracked straight and tight.
2	No transverse cracks. Centerline is now cracked neat and straight.
2 control	Ten joints are now cracked at the surface. Centerline is now cracked neat and straight, except for the first 0.7 m that is offset 0.2 m north. Ten percent shows minor spalling and rock dragging due to dry mix.
3	No transverse cracks. Centerline is cracked neat and straight.
3 control	Ten joints cracked at the surface. Centerline is now cracked neat and straight (10% shows minor spalling due to dry mix and rock dragging).
4	No transverse cracks. Centerline is now cracked neat and straight.
4 control	Ten joints cracked on both sides of the pavement. Centerline is now cracked.
5	No transverse cracks. Centerline is now cracked neat and straight. There is some minor spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
5 control	Ten of the joints are cracked on both sides of the pavement and four are not. Centerline is cracked neat and straight. Contractor had two centerline cores cut.
6	No transverse cracks. Centerline is now cracked neat and straight. There is some minor spalling along the centerline (5% of length) due to dry materials in mix and dragging of rock.
6 control	Ten joints are cracked through the pavement on each side of the pavement. Centerline is now cracked neat and straight. Two cores cut in the driving lane in two consecutive mid-slab locations in the passing lane.

Note: All test sections have one core taken in joint 4 in the passing lane to verify the location of the joint-forming material. Additional cores were cut in sections 5 and 6 due to the relative location of the sawed joint and the joint-forming materials.

Table F10. Special survey of joint openings, September 13, 2005 (Section 1), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
1	1	9.53 (3/8)	9.53 (3/8)	12.7 (1/2)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
1 cont.	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	3	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	4	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	5	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	6	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	7	7.94 (5/16)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	8	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	9	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	10	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	6.35 (1/4)

Table F11. Special survey of joint openings, September 13, 2005 (Section 2), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
2	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
2 cont.	1	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	2	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	3	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	4	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	5	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	6	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	7	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	8	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	9	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	10	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	6.35 (1/4)

Table F12. Special survey of joint openings, September 13, 2005 (Section 3), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
3	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
3 cont.	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	7	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	8	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	9	7.94 (5/16)	7.94 (5/16)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	10	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)

Table F13. Special survey of joint openings, September 13, 2005 (Section 4), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
4	1	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	2	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
4 cont.	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	7	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	8	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	9	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	10	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)

Table F14. Special survey of joint openings, September 13, 2005 (Section 5), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
5	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
5 cont.	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	3	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	4	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	7	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	8	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	9	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	10	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)

Table F15. Special survey of joint openings, September 13, 2005 (Section 6), in mm (in.)

Test section	Joint number	Left edge	Qtr. point	Centerline	Qtr. point	Right edge
6	1	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	2	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	3	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	4	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	5	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
	6	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)	9.53 (3/8)
6 cont.	1	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	2	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	3	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	4	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	5	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)
	6	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)
	7	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)
	8	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)	6.35 (1/4)
	9	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)
	10	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)	7.94 (5/16)

APPENDIX G. CORE IMAGES

On June 16, 2005, with the aid of the Office of Special Investigations at the Iowa Department of Transportation, the research team obtained eight cores from the project site. Listed in Table G1 are the core sites by location and number for reference purposes. Photos of each core with the joint former and its location relative to the sawed joint are also shown in this appendix.

Table G1. Core sites by number and location

Test site/ core number	Core location
1/1	Joint number 4, passing lane, 90 inches north of pavement edge
2/2	Joint number 4, passing lane, 90 inches north of pavement edge
3/3	Joint number 4, passing lane, 84 inches north of pavement edge (note the anchor pin in photo)
4/4	Joint number 4, passing lane, 84 inches north of pavement edge (note the crack from joint former to saw joint)
5/5A	Joint number 4, passing lane, 84 inches north of pavement edge (missed vertical portion of joint former)
5/5B	Joint number 4, passing lane, 108 inches north of pavement edge and 3 inches west of saw cut (saw cut is 3 inches off the paint line on north side of pavement)
6/6A	Joint number 4, passing lane, 84 inches north of pavement edge (missed vertical section of joint former)
6/6B	Joint number 4, passing lane, 108 inches north of pavement edge and 4 inches west of saw cut

Note: All joints were sawed on June 15 and sealed on June 16, 2005.

Figure G1. Test section 1 core

Figure G2. Test section 2 core

Figure G3. Test section 3 core

Figure G4. Test section 4 core

Figure G5. Crack in test section 4 core

Figure G6. Close-up of crack in test section 4 core

Figure G7. Test section 5 core A

Figure G8. Test section 5 core B

Figure G9. Test section 6 core A

Figure G10. Test section 6 core B