Placing Embedded Steel
Embedded Steel – Pre-Placed
## Dowel Alignment in Joint

<table>
<thead>
<tr>
<th>Range of Dowel Alignment</th>
<th>No. of Dowel Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment &lt; 0.6 in.</td>
<td>12</td>
</tr>
<tr>
<td>0.6 in. &lt; Alignment &lt; 0.8 in.</td>
<td>2</td>
</tr>
<tr>
<td>0.8 in. &lt; Alignment &lt; 1 in.</td>
<td>1</td>
</tr>
<tr>
<td>1 in. &lt; Alignment &lt; 1.5 in.</td>
<td></td>
</tr>
<tr>
<td>1.5 in. &lt; Alignment</td>
<td></td>
</tr>
</tbody>
</table>

**Calculate**

**Calculated Details**

- Calculated Joint Score (JS): 9
- Total Number of Dowels in Joint: 15

There is low risk of this joint locking.
Leave Tiebar Out Near Dowel

- If a tiebar is placed too close to a transverse joint, it may interfere with joint opening and closing and the effectiveness of the dowels to transfer loads.
- No tiebar should be placed within 6 inches of the tip of the nearest dowel bar in a transverse joint.
Leave Tiebar Out Near Dowel

PROBABLY TOO CLOSE!
Location Identification
When Do You Saw the Joints?
Crack Control Window

Too Early: Raveling

Sawing Window

Too Late: Cracking

Internal Stress Equals Concrete Strength

Minimum Strength to Avert Excessive Saw Cut Raveling
Factors that Shorten Sawing Window

Weather
- Sudden temperature drop or rainshower
- Sudden temperature rise
- High winds and low humidity
- Cool temperatures and clouds
- Hot temperatures and sunny

Subgrade/Subbase
- High friction/bond between slab and subgrade/subbase
- Dry subgrade/subbase surface during construction
- Stabilized free-draining (permeable) subbases
Factors that Shorten Sawing Window

**Concrete Mixture**
- High water demand
- Rapid early strength
- Retarded set
- Fine aggregate (fineness & grading)
- Coarse aggregate (maximum size and/or percentage)

**Miscellaneous**
- Paving against or between existing lanes
- Saw blade selection
- Delay in curing protection or improper curing

See ACPA’s TB016P and IMCP

---

**CONCRETE PAVING Technology**

Early Cracking of Concrete Pavement—Causes and Repairs

Purpose
The ability to adequately saw concrete pavement with a recessive surface crack to facilitate crack healing, depends upon design features, concrete material properties, jointing techniques and environmental conditions. Minimizing the potential for unrestrained crack development is critical, especially when the design and construction of the concrete pavement is such that surface cracks are likely to develop. This publication provides recommendations on how to achieve the necessary construction and material selection to ensure crack healing.

Introduction
Cracks in concrete cause water to penetrate the pavement, damaging the integrity of the pavement. A fundamental goal of concrete pavement design is to introduce a paving system that controls the potential for surface cracking. This goal cannot be achieved if concrete pavement is designed to crack at all regular intervals. It is therefore important to consider the factors that influence cracking, as well as the potential for crack development. This publication provides guidance on how to prevent crack formation and control crack growth, while also addressing the repair of existing cracks.
Definition of Curing

Maintenance of a satisfactory moisture content and temperature in concrete during some definite period immediately following placing and finishing so that the desired properties are developed.
IMPORTANCE OF CURING!

Proper curing fosters increased strength development and delays the development of internal stresses. Internal temperature and moisture are of utmost importance!

Graph: Longer sawing window with proper curing showing increased strength development and delay in internal stresses.

Internal Temp and Moisture of Utmost Importance!
**Evaporation Rate Calculator**

This evaporation rate calculator, based on the equations in ACI 305R, Hot Weather Concreting, allows you to quickly calculate the evaporation rate at hourly intervals based on the concrete temperature, the air temperature, the ambient relative humidity and the wind velocity. Data is provided for each time and also is presented on a chart alongside recommended caution and upper limits.

**Terms of Use**

The user accepts ALL responsibility for decisions made as a result of the use of this design tool. The American Concrete Pavement Association, its Officers, Board of Directors and Staff are absolved of any responsibility for any decisions made as a result of your use. Use of this design tool implies acceptance of the terms of use.

**Please Select A Project Start Time:** 8:00 AM

Note: Data does not need to be entered for each time to run the application. Only the fields that you supply values for will be plotted on the chart.

<table>
<thead>
<tr>
<th>Time</th>
<th>Concrete Temp (°F)</th>
<th>Air Temp (°F)</th>
<th>Relative Humidity (%)</th>
<th>Wind Velocity (mph)</th>
<th>Evaporation Rate (lb/hr-ft²-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>85.0</td>
<td>80.0</td>
<td>50.0</td>
<td>19.0</td>
<td>0.33</td>
</tr>
<tr>
<td>9:00</td>
<td>89.0</td>
<td>84.0</td>
<td>50.0</td>
<td>12.0</td>
<td>0.25</td>
</tr>
<tr>
<td>10:00</td>
<td>76.0</td>
<td>71.0</td>
<td>50.0</td>
<td>15.0</td>
<td>0.22</td>
</tr>
<tr>
<td>11:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>12:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>1:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>3:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>5:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>6:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>7:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Switch Units: Metric

[apps.acpa.org](http://apps.acpa.org)
How to Test the Window...

ASTM C Now = “Alright, Start To Make Cut Now”
Levels of Raveling

Unacceptable:

Moderate:

None:

www.hiperpav.com
What About the Sawcut Depth?
Not Just Timing…DEPTH!
Joint Depth Recommendations

- **Transverse**
  - T/4 on unstabilized
  - T/3 on stabilized

- **Longitudinal**
  - T/3

Timing is a factor

Early-entry sawing may allow for sawing depths of T/6 to T/5, but at least 1.25 in. (32 mm) deep

If start to see dust from cut, consider reverting to a cut depth of T/4
Of Course It is More Complicated

Concrete Mix
- Aggregate size
- Cementitious content

FRACTURE PROPERTIES

Wedge Split Test

FEM Model

Crack Propagates

Saw Cut Depth Model

Tensile strength of the slab at 12 hours

Nominal strength MPa

- 688.38
- 688.38ST

Concrete Mix

Wedge Split Test

FEM Model

Crack Propagates

Saw Cut Depth Model
Making the Initial Saw Cut
Joint Formation/Sawing
Common Types of Pavement Saws

- Walk-Behind
- Span Saw
- Early Entry
Saw Blades

- Most common are industrial diamond (require water cooling) or abrasive (carborundum).
- Must match the saw blade to the concrete; based primarily on aggregate hardness but also depends on power output of saw.
Order of Saw Cuts

- Common practice to first cut transverse joints to alleviate internal stresses.
- However, best practice to keep all sawing as close to the paving operation as possible.
Proper Location, Time & Depth = Joint Activated Over Dowel Bars
Check the Depth!

- Too shallow = may not relieve stresses adequately; random cracking
- Too deep = additional effort and expense, unnecessary equipment wear, and reduce aggregate interlock
- As blade diameter decreases, the saw operator must adjust saw to ensure proper depth

What about concrete overlay on unmilled asphalt?
No Speeding!

- Sawing speed controls cut depth; hard aggregate might require a slower speed.
- Speed typically controlled by saw’s self-propelling mechanism.
- Saw operators that attempt to speed up cutting may tend to push a saw too fast, causing the blade to ride up out of its full cut… not cutting to proper depth = risk for cracking!
Starting and Stopping a Cut

- Cut start and stop requires special attention
- Early-entry saws may require the saw cut stop about ½ in. short of the pavement edge to prevent “blow out”
- In windy conditions, best to orient direction of sawing with wind; the slab face exposed to the wind will dry quicker
Joint Sealing
Joint Sealants

History & Background

Accepted definition: Sealants minimize infiltration of surface water & incompressibles into the joint system.

Erroneous definition: Sealants prevent infiltration of surface water & incompressibles into the joint system.
To Seal or Not to Seal?

Sealing joints & maintaining well-sealed joints may improve performance of the pavement; research into this topic is ongoing.

... however, some agencies and owners no longer require joints to be sealed under certain conditions.
Updated Joint Sealing Guidance – Coming Soon

Concrete Pavement Joint Sealing/Filling

INTRODUCTION

Joint sealant use dates back to the early 1900s. Through years of technical development and field application, two basic approaches emerged: joint filling and joint sealing. An additional approach of leaving pavement joints open has also been applied. This bulletin discusses the proper application of joint sealants and fillers, and provides details on proper installation.

Sealing or filling transverse and longitudinal joints in concrete pavements is an important consideration for long-term pavement performance. For most pavement applications, proactive sealing or filling of joints provides a measure of restraint protection against potential problems, such as spalling, bowing, and heaving, which can result in pavement joint blow-ups. However, to gain these benefits the installation and maintenance of the sealants/fillers must be performed with care.

Joint sealing involves the insertion of a sealant, usually a rubber-based material, into the joints of concrete pavements. The purpose of joint sealing is to minimize infiltration of surface water, reduce the movement of moisture, and prevent the entry of debris. Joint sealing materials are typically applied in a liquid or gel form and then cured to form a solid seal. These materials are designed to resist the effects of weather, temperature, and traffic.

Basic Sealing Considerations – Water can contribute to subgrade or base layer softening, erosion, and pumping of subgrade or base lines. Such a degradation of support to pavement slabs causes higher load stresses in the concrete, pavement settlements, corner cracks and/or heaved transverse or longitudinal joints (3,6,7,9).

Unfortunately it is not practical to construct, and continually maintain, a completely watertight pavement. Therefore, the concrete pavement industry and concrete engineers have developed passive techniques to minimize passage of water through joints and reduce the impact of water in a concrete pavement system.

In addition to minimizing water passage, sealing joints also prevents incompressible, water-resistant materials from entering the joints. Incompressibles are known to contribute to spalling and in extreme cases may cause slab migration. In compressible joints, the excessive pressure due to spalling may cause pavement slab blow-ups (9). In some cases, excessive pressure along joint faces results when incompressible materials enter the joints and cause joint expansion in hot weather.

“Joint fillers” are sealants placed in the joints to resist surface water infiltration, joint movement, and separation of pavement slabs and joints. These materials are typically designed to be placed in the joints prior to or after the placement of the pavement slabs.
Creating the Sealant Reservoir
Joint Sealing

Often times, joints that are not sealed during the first construction may be sealed during maintenance and repair procedures.

**Notes:**
A - Initial cut to a depth of T/4 or T/3 as required for conventional sawing.
B - Initial cut to a depth of 1-1/4” (32 mm) minimum for early-entry sawing.
C - As required to accommodate sealant and backer rod.
D - As required by the manufacturer.

Field Poured Sealant

- Hot-Poured Sealant -- D/W = 1 (typical)
- Silicone Sealant -- D/W = 0.5 (typical)
- Two-Component Material Cold Poured -- D/W = 0.5 (typical)

W is 1” MAX!
Joint Sealing

Preformed Seal

- Initial cut to a depth of $T/4$ or $T/3$ as required for conventional sawing.
- Initial cut to a depth of $1-1/4''$ (32 mm) minimum for early-entry sawing.
- As required to accommodate sealant and backer rod.
- As required by the manufacturer.

Isolation Joint

Preformed Compression Seal -- W Sized for Slab & Climate
Description

This web applet, based on the total free strain calculations from the research report "Mechanistic-Empirical Tie Bar Design Approach for Concrete Pavements," allows you to estimate the maximum amount you should expect cracks beneath sawcuts in dowel- or dowelless transverse joints of in jointed plain (JPCP) or jointless reinforced concrete pavement (JRPC) to open due to the variables used as inputs here. This maximum joint movement estimate is useful when selecting suitable sealants for your planned or specified joint width.

Terms of Use

The user accepts ALL responsibility for decisions made as a result of the use of this design tool. American Concrete Pavement Association, its Officers, Board of Directors and Staff are absolved of any responsibility for any decisions made as a result of your use. Use of this design tool implies

Location Details

State: Arizona
Location: Flagstaff

Concrete Material Details

Cement Type: Type I
Cementitious Materials Content (lb/yd³): 550
Coefficient of Thermal Expansion (10⁻⁶/°F): 5.5

Concrete Pavement Structure Details

Concrete Pavement Thickness (in.): 8
Transverse Joint Spacing (ft): 15
Description

To size a preformed compression seal requires consideration of pavement temperature at installation and the joint movement range. The compression seal must work within the compression range (typically 20-50%). Cooler installation temperatures require less seal compression because the joints are not as open as they would be during a warmer installation. This tool calculates the required joint saw cut width necessary to ensure that the compression seal will remain in compression under the varying ambient temperature conditions.

Of course, the actual installation temperature cannot be accurately known during the design process. Therefore, designers should calculate sizing for various potential installation scenarios (cool, moderate, and hot). The designer also should examine the influence of other design factors on seal sizing requirements. In particular, joint spacing significantly effects total joint movement (see the

Compression Seal Details

Width of Uncompressed Seal (in.): 0.5

Minimum Recommended Compression: 20%

Maximum Recommended Compression: 50%

Local and Construction Temperature Details

- Use Average Weather Data
- Input Weather Data

State: Indiana
Location: Fort Wayne
Month of Construction: July

Sawing Recommendation

Joint Saw Cut Width: 0.25 in.
Joint Noise Estimator

Description

For passenger cars, 70% to 90% of the traffic generated noise is produced by the tire-pavement interaction. Thus, additional traffic generated noise due to such vehicles is well characterized through evaluation of just the tire-pavement interaction. In the U.S., this is accomplished with the use of On-Board Sound Intensity (OBSI; see image on the right in the header) per AASHTO TP-76.

As a vehicle travels over joints in a jointed concrete pavement, there is a joint slap noise that contributes to the overall pavement noise. When evaluating pavements using OBSI techniques, it is generally only convenient to determine the overall pavement noise levels. These levels are a function of both the joint slap effect and the pavement texture effect.

This tool, based on the work of Dr. Paul Donavan, was developed to allow designers to estimate the

Concrete Pavement Details

Joint Spacing (ft):

Joints Sealed:

Yes
No

Joint Width (in.):

Joint Depth (in.):

0.5
0.25
CLEAN the Joint
Make Certain the Joint is Clean!

- All sealed joints must be cleaned immediately behind saw cutting or joint widening and immediately prior to sealing operations.
  - Removes saw-cut slurry, soil, sand, etc.
- Cleanliness of both joint faces is extremely important to concrete/sealant bond.
It’s not Hard to Check...

- If wiping a finger along the face picks up dirt or dust, recleaning should be done before sealing!
... and is not Expensive to Fix!
New Field Tests on Their Way!
Installing the Backer Rod
Backer Rod (if used)

- Minimizes excess stress on sealant material from improper shape factor
- Provides support for the tooling of the surface
- Prevents self-leveling mat’l from filling entire joint
- Prevents three-sided adhesion
Sealing the Joint
Sealing the Joint

- Only apply when temps are above min recommended by manufacturer
- Ensure joint faces dry before sealing
- Fill joint from the bottom up to prevent air from becoming trapped under the sealant
- Fill from beginning to end in one smooth operation
Hot-Pour Joint Sealants

KEY FACTORS:
- Field control of heating
  - 175-200°C (350-400°F)
- Double boiler
- Agitation
- Insulated hoses
- Shape factor (filler/sealant)
- **Clean** and dry sidewalls!!
Silicone Joint Sealants

KEY FACTORS:
- Pre-packaged in drums
  - Manufacturer controls properties
- Shape factor
- Concrete aggregate
- Clean sidewalls!!
- Weather conditions
  - Moisture in air aids curing
  - Moisture in concrete can deter bonding
Compression Seals

KEY FACTORS:

- Cell design
  - 5 to 6 cells standard in U.S.
- Uniform reservoir width
- Installation quality
  - Lubricant
  - Stretch
  - Twist
  - Debris
Sealant Use in Highways

- None: 5%
- Hot-Pour: 30%
- Silicone: 49%
- Preformed: 16%
Relative Cost of Sealants

<table>
<thead>
<tr>
<th>Sealant Type</th>
<th>Cost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp Seal 1/4 in.</td>
<td>107</td>
</tr>
<tr>
<td>Comp Seal 3/8 in.</td>
<td>112</td>
</tr>
<tr>
<td>Comp Seal 1/2 in.</td>
<td>115</td>
</tr>
<tr>
<td>Hot Pour 1/8 in.</td>
<td>104</td>
</tr>
<tr>
<td>Hot Pour 1/4 in.</td>
<td>105</td>
</tr>
<tr>
<td>Hot Pour 3/8 in.</td>
<td>106</td>
</tr>
<tr>
<td>Hot Pour 1/2 in.</td>
<td>107</td>
</tr>
<tr>
<td>Non Sag Silicone 3/8 in.</td>
<td>110</td>
</tr>
<tr>
<td>Non Sag Silicone 1/2 in.</td>
<td>111</td>
</tr>
<tr>
<td>Self Level Silicone</td>
<td>108</td>
</tr>
<tr>
<td>Self Level Silicone</td>
<td>108</td>
</tr>
<tr>
<td>Unsealed 1/8 in.</td>
<td>110</td>
</tr>
<tr>
<td>Unsealed 1/8 in.</td>
<td>100</td>
</tr>
<tr>
<td>Sealant Type</td>
<td>Duration</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Hot-pour</td>
<td>4-7 yr.</td>
</tr>
<tr>
<td>Silicone</td>
<td>8-15 yr.</td>
</tr>
<tr>
<td>Preformed</td>
<td>15-25 yr.</td>
</tr>
</tbody>
</table>
Joint Sealing Research

![Joint Sealing Image](image)

**Water Infiltration Rate**

- No seal
- Silicon
- Hotpour
- Compression

**Graph Details**

- **Y-axis**: Flow rate (gal/min/ft)
- **X-axis**: Joint Opening width (mm)
- **Legend**:
  - Base Curve
  - Poor Drainage & Poor Installation
  - Good Drainage & Good Installation
  - No Sealant

**Base Curve**

- Poor Drainage & Poor Installation
- Good Drainage & Good Installation
- No Sealant
Transverse Construction Joints
Construction Joints (Headers)

- Header joints (also known as transverse construction joints) are built at the end of a section of pavement
  - Must be constructed at the end of a day’s run
  - Constructed due to significant paving delays
- Either formed or sawed
- No way to account for in layout planning
- If next to previously placed pavement, best to match header with existing transverse joint
Either two-part form with dowels or tiebars protruding through form or false-dowels attached to form face and dowels inserted upon form removal; consolidate concrete well at form.
Formed Header
Sawed Header

Paving continued through of header, pavement sawed back, dowel/tiebar holes drilled, and dowels/tiebars installed.
Resuming Paving at Header

- If formed header, wait at least 6 hours before resuming paving
- Paving equipment is repositioned over the joint to start the next placement
- Some hand placement and hand vibration will be necessary on the start-up side of the header
- Use previously-placed header as a guide for surface finishing to ensure a smooth transition
Sources of Roughness from Steel

- Lack of Consolidation
  - Non-uniform consolidation within dowel basket can create roughness; adjust concrete mixture

- Reinforcement Ripple
  - Steel limits restitution of surface behind the profile pan, causing surface ripple; adjust concrete mixture or pitch of pan

- Spring-Back
  - Dowel basket deflects and rebounds as profile pan passes overhead, causing hump in the surface; adjust pitch of pan or do not cut shipping tie wires on dowel basket assembly
Cracking During Sawing

If uncontrolled cracking occurs:
- Omit the saw cut if a crack forms at or near the planned location for a joint before sawing starts.
- Stop sawing the joint upon noticing a pop-off crack (to prevent creation of a potential spall between the saw cut and crack).
- Saw every third transverse joint (skip-sawing) if uncontrolled cracking is imminent (for example, in the event of unexpected weather changes like storms or cold fronts); HAVE ENOUGH SAWS ON HAND!
- Switch to early-entry saws in the event that extreme conditions make it impractical to prevent uncontrolled cracking with conventional saws.
Repairing Issues from Sawing

Recommend: Saw & Seal Crack - Epoxy Saw Cut

- Cracks fully penetrate slab depth
- Joints not cracked where cracks exist
- If crack beyond dowel embedment requirements then DBR can be done between existing dowels
Troubleshooting?

- Raveling or spalling is occurring due to sawing too soon or equipment problems.
- Early-age cracking is occurring due to sawing too late, insufficient joint depth, excessive joint spacing, excessive warping, excessive curling, too many lanes tied together, too much edge restraint, excessive slab/subbase bonding or restraint, misalignment of dowel bars, paving in cold weather, or paving in hot/dry weather.
- Sealant not adhering to joint.
- Sealant picks up or pulls out when opened to traffic.
- Sealant gelling in melting chamber (melter).
- Sealant cracking or debonding.
- Voids or bubbles in cured sealant.
- Etc…

... see ACPA literature of IMCP

... Contact ACPA or local ACPA Chapter
110th Street & Lamar Avenue
Overland Park, Kansas
110th Street & Lamar Avenue
Overland Park, Kansas
110th Street & Lamar Avenue
Overland Park, Kansas
Rough Grading
Grading of Subgrade
Subbase & Curb Const.
Curb Placement – Widened Gutter
Field Joint Layout Plan
Inner Pavement Ring Formed
Inner Pavement Ring Formed
Dowel Basket Placement
Start Concrete Placement
Hand Placement with Roller Screed
Hand Finishing
Half Way Done!
Outer Ring...
Outer Ring...
1 inch Isolation Joint
Approach Lane Sequence
Finishing Approach Lanes
Open to Traffic!
Next up: Troubleshooting Joint Design/Construction Issues