Basics of Joints
Design & Layout

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Outline

• Jointing Basics
  ▶ Why joint concrete pavements?
  ▶ Types of joints & function
• Jointing & Reinforcing Requirements
• Resources & Tools Available
• Questions???
Jointing/Reinf. Basics

- Key Design & Construction Item (can’t stress enough)
  - Significant impact on long-term pavement performance
  - Significant impact on potential for random cracking (risk)
    - During Construction (Contractor & Designer)
    - During Performance Life (Owner)
  - Significant impact on contractor’s ability to pave efficiently
    - Production
    - Cost $$$$$
Jointing

Purpose:

• Control natural transverse & longitudinal cracking from internal slab stresses.
• Divide pavement into construction lanes or increments.
• Accommodate slab movements.
• Provide load transfer.
• Provide uniform sealant reservoir.
Why Does Concrete Crack after Placement?

- Concrete drying shrinkage (hydration)
- Changes in temperature and moisture
  - Ambient (contraction)
  - Gradient (curling)
- Subbase restraint (friction or bond)
- First applied loads (construction loads)
Natural Crack Development

- Volume loss
- Thermal Contraction

Usually within first 12-24 hours
Natural Crack Development

- Temperature Gradients
- Moisture Gradients
- Thermal Cycles
- Loading

Usually occurs sometime after 12 hours and may take months.
Natural Crack Development

- Proper jointing provides a series of saw cuts (joints) spaced to control crack formation.

GOAL!
Concrete Pavement Types

Principles of Design

- **JPCP** - control cracking so that it occurs only at designated locations (joints)
- **JRCP** - extend joint spacing to reduce number of joints, and provide light reinforcement to hold intermediate cracks
- **CRCP** - confine uncontrolled cracking to acceptable spacing, and widths, so slab performs as if no cracks exist.
Plan

JPCP

Profile

or

8–15 ft (typ.)

max.

12 ft
Main Jointing Considerations

- Joint Spacing
- Reinforcing (Dowels & Tie Bars)
- Joint Saw Depth (timing)
- Orientation (Intersections, inlets, etc.)
Joint Types

- Transverse Contraction
  - Undoweled or Doweled
- Transverse Construction (headers)
- Longitudinal Contraction
- Longitudinal Construction
- Isolation/Expansion
Jointing Details

General Guidelines (transverse):

- 24 x (slab thick. in inches) rule (maximum)
  - Maximum of 15’ (transverse)
  - Design shorter (8’ to 14’)
    - Minimizes random crack risk
    - Allows for adjustment in field (match)
    - Limits warping & curling
    - Reduces individual joint movement

- Limit length:width ratio (1.5 max.)

- Shorter joint spacing more critical as subgrade & subbase stiffness increase
Shorter is Better!
Joint Spacing Recommendation

Maximum Joint Spacing: 14 ft

Note: The ratio of transverse joint spacing to longitudinal joint spacing should not exceed 1.
Formula for Maximum Joint Spa.

\[ ML = T \times C_s \]

- **ML** = Maximum length between joints (in.)
- **T** = Slab thickness (in.)
- **\(C_s\)** = Support constant

Use 24 for subgrades or unstabilized [granular] subbases;

Use 21 for stabilized subbases (ATB, CTB, lean concrete) or existing concrete or asphalt pavement;

Use 12 to 15 for thin bonded overlays on asphalt
Maximum Joint Spacing Calculator

Concrete Pavement Structure Details

Concrete Pavement Thickness (in.): 7
Layer Immediately Below Concrete Surface Course:
- Subgrade
- Stabilized Subbase
- Unstabilized (Granular) Subbase
- Existing Asphalt Pavement
- Existing Concrete Pavement

Calculate

Joint Spacing Recommendation

Maximum Joint Spacing: 12.25 ft

Note: The ratio of transverse joint spacing to longitudinal joint spacing should not exceed 1.0

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Have a question about concrete pavements?
Want guidance from a professional engineer?
Need assistance with inputs?
Click here to contact your local ACPA Chapter or State Paving Association.

go to APP HOME
CONTACT
Transverse Contraction Joints

Doweled

Undoweled

0.75 – 1.50 inch. dia. Smooth Dowel

Reservoir 1/4 inch. (typ.)

Dowel
Transverse Contraction Joints

- **Dowels**
  - Typically used on pavement ≥8”
  - Not used on pavements <6”
  - May be used on pavements 6”-8”
  - Rule of thumb => 1/8” per inch of pavement (i.e. 8” pavement => 1” dia.)

- Epoxy coated
- Bond breaker (factory applied)
- Installed in baskets (stake down)
Description

DowelCAD was created to aid in the optimization of dowel bar design and, by using it, a pavement engineer can determine joint responses to varying dowel sizes or investigate the impact of various alternate dowel bar configurations.

For nearly one hundred years, dowel bars have been used in concrete pavements as a means to bridge vehicle loads across adjacent slabs. It is commonly known that dowels can increase pavement performance considerably, particularly in circumstances where heavy traffic or poor soils are present.

Given the increasing cost of construction materials—including steel—seemingly small measures such as the reduction of even one dowel per joint can compound into significant cost savings overall. As long as measures are taken to ensure that pavement performance is not compromised, these cost savings can benefit the owner-agency as they seek out the most efficient use of their budgets.
Dowel Bar Optimization

[Image showing DowelCAD software interface with options for Dowel Sizing, Dowel Spacing, and Dowel Selection. The interface includes options for Dowel Spacing Alternatives such as 12 Dowels, uniform (baseline), 11 Dowels (Alternate A), 9 Dowels (Alternate B), and 8 Dowels (Alternate C). The analysis type includes Corner Dowel Spacing, Center Lane Dowel Leave-Out, and Alternate Dowel Spacings. The software displays a comparison between baseline and alternative configurations, showing a steel savings of 25%. The Dowel Bearing Stress (psi) is compared between 12 Dowels (Baseline) and 9 Dowels (Alt. B), with the latter showing a -3% difference.]
Dowel Bar Optimization

Donahoo Road in KCK - 2010
Dowel Bar Optimization

Utah DOT Current Standard – 8 Dowels
Transverse Construction Joint

- 0.75” to 1.5” dia. Smooth Dowel
- Reservoir 1/4” (typ.)
- Smooth Face (Butt Joint)
Jointing Details

- Transverse Joint Spacing:
  - Keep as uniform as possible
  - Be sure to match adjacent joints
  - Add note allowing adjustment to include minimum and maximum spa.
Jointing Details

★ General Guidelines (longitudinal):

► Maximum of 12’ (longitudinal)
  ➢ Especially for thinner pavements (<8”)
    – Minimizes random crack risk
    – Limits warping & curling

► Limit length:width ratio (1.5 max.)
  ➢ 1.25 is better (square)

► Shorter joint spacing more critical as subgrade & subbase stiffness increase
  ➢ Fly Ash Treated vs. Granular Subbase

► Consider how pavement will be constructed
LEGEND

--- Longitudinal Joint

--- Transverse Joint

* Match Existing
  (Contractor Shall Verify Existing
  Elevations Prior to Trimming Subgrade)
Jointing Details

- Longitudinal Joints
  - Consider how the pavement will be constructed
    - Monolithic C&G
    - Paving width
    - Be careful of jointing slabs wider than 12’ well off center (i.e. 16’ paved width @ 12’ & 4’)


Pavement Section
Municipal Street Example

- 50’-0”
- 30’-0”
- 28’-0” B-B
- 14’-0”
- 7’-0”
- 6’-0”
- 4’-0”
- 14’-0”
- 20’-0”
- 6’-0”
- 4’-0”

- Profile Grade
  - 2%
  - 2%

- 4” Broken Yellow Centerline

- Type "A" Curb & Gutter

- 8” Concrete Pavement (NRDJ)

- 6” AB-3 (OP Modified)

- 6” Type AA(MR-3-3) Compaction

- Conc. Sidewalk

- 1”

- 1” (Typ.)

- 6” Min. (Typ.)

- 2%

- 1.0%
Longitudinal Contraction Joint

- D/3
- Reservoir 1/4” (typ.)
- D/2
- Deformed Tie Bar
- D
Longitudinal Contraction Joint

- **Tie Bars**
  - Used to hold joints together (promote aggregate interlock)
  - Typically #4 to #5 bars x 30” long
  - Spaced at 24” to 48”
  - Keep away from transverse joints (18”)
  - Number not as critical for municipal pavements due to restraint and limited potential for movement
New Mechanistic-Empirical Tie Bar Design Approach
Mechanistic-Empirical Tie Bar Designer

Description

The mechanistic-empirical (M-E) technique is the most widely used tie bar design methodology for concrete pavements. However, the EOT™ service does not account for the effects of thermal shrinkage and leading conditions, variables that are critical in a tie bar design procedure. This mechanistic-empirical (M-E) concept. This new M-E tie bar design procedure balances the need to ensure joint integrity while reducing the length of the tie bar design with the process of extending the resultant caused by varying maximum stress together. Because this design tool is based on the latest tie bar design concepts, the design is limited to the various variables used in the design procedures conducted during the research project. Thus, only certain design assumptions are available for some variables, such as the type and size of the tie bar.

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Location Details

State: [Select State]
Location: [Select Location]

Concrete Material Details

Concrete Type: [Select Type]
Cementitious Materials Content (lbs): [Enter Value]
Coefficient of Thermal Expansion (EOT/°F): [Enter Value]

Concrete Pavement Structure Details

Concrete Pavement Thickness (in.): [Enter Value]
Lane Configuration: [Select Configuration]
Subgrade Type/Thickness: [Select Type/Thickness]

Construction Details

Month of Construction: [Select Month]
Curing Procedure: [Select Procedure]

Calculate Design

Submit: [Button]
MECHANISTIC-EMPIRICAL TIE BAR DESIGNER

LOCATION DETAILS

State: Iowa
Location: Des Moines

CONCRETE MATERIAL DETAILS

Cement Type: Type III
Cementitious Materials Content (lb/yd^3): 520.0
Coefficient of Thermal Expansion (10^(-6)F): 6.00

CONCRETE PAVEMENT STRUCTURE DETAILS

Concrete Pavement Thickness (in.): 9.00
Lane Configuration: Two Tied 12-ft Lanes
Subbase Type/Thickness: Unstabilized (Granular) Subbase - 0 in.

CONSTRUCTION DETAILS

Month of Construction: August
Curing Procedure: Curing Compound

Submit  Save Inputs
**CALCULATED DESIGN**

**OPTION 1:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Free Strain</td>
<td>800 Rounded up from 779.9</td>
</tr>
<tr>
<td>Tie Bar Size</td>
<td>#5 Tie Bar Spacing*: 45</td>
</tr>
<tr>
<td>Tie Bar Length</td>
<td>24 Steel Grade: 40</td>
</tr>
</tbody>
</table>

THE LONGITUDINAL JOINT IN THIS DESIGN CONTAINS 0.082 IN.² OF STEEL PER FOOT; THIS VALUE MAY BE USED TO DETERMINE EQUIVALENT DESIGNS FOR ALTERNATE TIE BAR SIZES.

**OPTION 2:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Free Strain</td>
<td>800 Rounded up from 779.9</td>
</tr>
<tr>
<td>Tie Bar Size</td>
<td>#4 Tie Bar Spacing*: 45</td>
</tr>
<tr>
<td>Tie Bar Length</td>
<td>24 Steel Grade: 60</td>
</tr>
</tbody>
</table>

THE LONGITUDINAL JOINT IN THIS DESIGN CONTAINS 0.052 IN.² OF STEEL PER FOOT; THIS VALUE MAY BE USED TO DETERMINE EQUIVALENT DESIGNS FOR ALTERNATE TIE BAR SIZES.

* The provided tie bar spacing shown is a maximum value. A slightly shorter tie bar spacing may be necessary, depending on slab length and the required distance between tie bars and dowel bars at transverse joints.

**NOTE:** The original research investigating the impact of cement type on ultimate shrinkage did not consider a Type I/II cement; because you have selected Type I/II cement, the cement type factor used in the calculation of ultimate shrinkage is assumed to be 1.0, comparable to that of Type I cement. See page 53 of "A Mechanistic-Empirical Tie Bar Design Approach for Concrete Pavements" for more details on the ultimate shrinkage calculation.
Longitudinal Construction Joints

Smooth Faced

Keyed

Reservoir 1/4” (typ.)

Butt Joint

Keyway

D/2

D
Keyways

1:4 Slope

Trapezoidal

Half-Round
Isolation (Expansion) Joints

- Used to isolate pavement from in-pavement objects and objects which extend below frost line
  - Manholes
  - Drainage inlets
  - Buildings
  - Etc.
- Not used to accommodate pavement expansion
Pavement Movement

Length while concrete fresh

After drying shrinkage

Full Temp. Contraction

Full Temp. Expansion

Isolation/Expansion Joints

Doweled Expansion Joint

Thickened Edge Expansion Joint

Isolation Joint
Isolation (Expansion) Joints

- Also used to isolate one pavement from another (situations)
  - Differing joint spacings (eliminate sympathy cracking)
  - Pavements moving in different directions
    - Legs of intersection
    - Sideroads
    - Etc.
Things to Avoid

- Slabs < 1 ft. wide (rectangular slabs)
- Slabs > 15 ft. wide (12 ft. wide)
- Angles < 60° (<90° is better)
- Creating interior corners
Things to Ensure

- Match existing joints or cracks
  - Includes curb joints
- Reduce/eliminate crack risks
  - Develop a jointing plan
  - Watch timing (saw on time)
  - Understand joint location (make adjustments!)
Intersection Jointing

CONCRETE PAVING Technology

Concrete Intersections
A Guide for Design and Construction

TB019P
Examples of Locations
Examples of Locations

EB237P
Jointing a Roundabout
Adjust to Meet Utilities!

- Blockout with perimeter isolation joint
- Optional reinforcement
- Adjust joint to meet inlet
- Adjust joint
- Telescoping manhole no boxout
Proper Boxouts

Box Out Fixture Details

Square Manhole Boxout:
- Reinforcing bars recommended to hold cracks tight
- Isolation joint

Diagonal Manhole Boxout:
- Isolation joint

Circular Manhole Boxout:
- Isolation joint

Square Boxout with Fillets:
- Isolation joint

Manhole (No Boxout):
- Isolation joint/bond breaker around perimeter

Telescoping Manhole:
- No boxout or isolation joint necessary

Square Inlet (no boxout):
- Isolation joint

Round Inlet Boxout:
- Isolation joint
If You DO Box Out Properly…
If You DON’T Box Out Properly…
Design of Concrete Pavement for Streets and Roads

Design and construction standards for streets and roadways should provide for pavements with both long service life and low maintenance. As a guide in achieving this goal, this publication provides designs that meet traffic requirements and will result in the lowest annual cost when considering both initial construction cost and pavement maintenance.

Following are the factors involved in the design process for concrete streets and roads:

1. Street classification and traffic
2. Geometric design
3. Subgrades and subbases
4. Concrete quality
5. Thickness design
6. Jointing
7. Construction specifications

Several other ACPA publications, Subgrades and Subbases for Concrete Pavements(1), Design and Construction of Joints for Concrete Streets(2), and Construction Specification Guideline for Concrete Streets and Local Roads(3), discuss the details of subgrades and subbases, jointing practices, and specifications in much greater detail.

Street Classification and Traffic

Comprehensive traffic studies have shown that streets of similar character have essentially the same traffic densities and axle load intensities. A practical approach to thickness design is to establish a street classification system that provides an axle load distribution for the various categories of streets. This information sheet has divided street pavements into six different classifications. Descriptions for each classification include traffic volumes, types of vehicles, and maximum axle loadings. These classifications are listed in the Thickness Design section of this document.

Design Considerations

Utilities

During the construction of new subdivisions and commercial developments, utilities are commonly placed in the right-of-way outside the pavement area to facilitate maintenance, possible additions, and upgrades to utility systems. Present and future needs must be evaluated and provisions made for utilities. Forethought can eliminate the tearing up of existing pavements for work on utilities. In some instances, particularly for older infrastructure, underground utilities must be located within the paved area. In these cases, it is usually recommended to incorporate the pavement construction project with utility replacement, such as sewers, water mains, gas lines, and electrical and communications conduits.

Integral Curbs

A practical and economical way to build concrete pavements for streets is with an integral curb section. An integral curb is constructed with the pavement in a single operation—all concrete work being done simultaneously. When using forms, the curb is easily shaped with a template and straightedge as the pavement is placed. Integral curbs can also be constructed to almost any desired cross section using a slipform paver.
ACPA Tools & Resources

Resources:

- www.moksacpa.com
- www.iowaconcretepaving.org
- www.acpa.org
- www.wikipave.org

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  Username: MOKS
  Password: CSLIC-MOKS0721
Additional Questions???

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