Construction and Jointing of Local Concrete Roads: State of the Practice

Amanda Hult, P.E.

***N**ational **R**eady **M**ixed **C**oncrete **A**ssociation*

Acknowledgements

Slides compiled from ACI, NRMCA, ACPA, and PCA documents.

American Concrete Institute

NRMCA

ACPA

PCA
Portland Cement Association

ACI 325.12R: Streets and Roads

ACI 325.12R-02

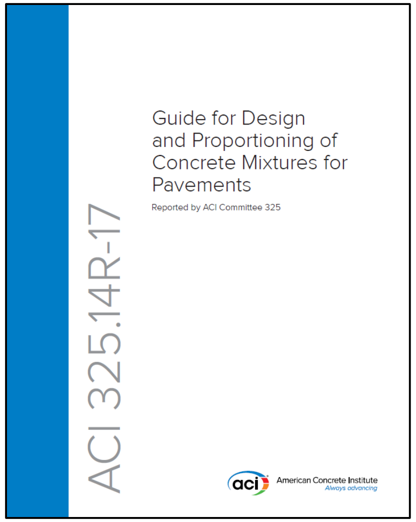
Guide for Design of Jointed Concrete Pavements for Streets and Local Roads

Reported by ACI Committee 325

Jack A. Scott, Chairman
Norbert J. Delatte, Secretary

David J. Akers	W. Charles Greer	Robert W. Piggott
Richard O. Albright	John R. Hess	David W. Pittman
William L. Arent	Mark K. Kaler	Steven A. Ragan
Jamshid M. Armaghani	Roger L. Larsen*	Raymond S. Rollings
Donald L. Brogna	Gary R. Mass	Kieran G. Sharp
Neeraj J. Buch*	William W. Mein	Terry W. Sherman
Archie F. Carter	James C. Mikulanec	James M. Shilstone, Sr.
Lawrence W. Cole*	Paul E. Mueller	Bernard J. Skar
Russell W. Collins	Jon I. Mullarky	Shiraz D. Tayabji
Mohamed M. Darwish	Theodore L. Neff	Suneel N. Vanikar
Al Ezzy	Emmanuel B. Owusu-Antwi	David P. Whitney
Luis A. Garcia	Dipak T. Parekh	James M. Willson
Nader Ghafoori	Thomas J. Pasko, Jr.	Dan G. Zollinger*
Ben Gompers	Ronald L. Peltz	

ACI 325.12R

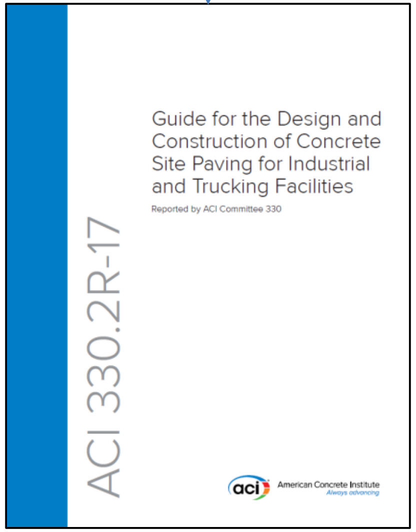

ACI 325.14R-17

Guide for Design and Proportioning of Concrete Mixtures for Pavements

Reported by ACI Committee 325

American Concrete Institute
Always advancing

Proportioning

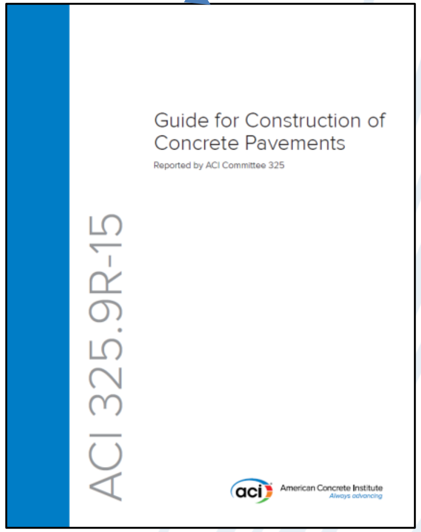

ACI 330.2R-17

Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

Reported by ACI Committee 330

American Concrete Institute
Always advancing

Industrial


ACI 325.9R-15

Guide for Construction of Concrete Pavements

Reported by ACI Committee 325

American Concrete Institute
Always advancing

Construction

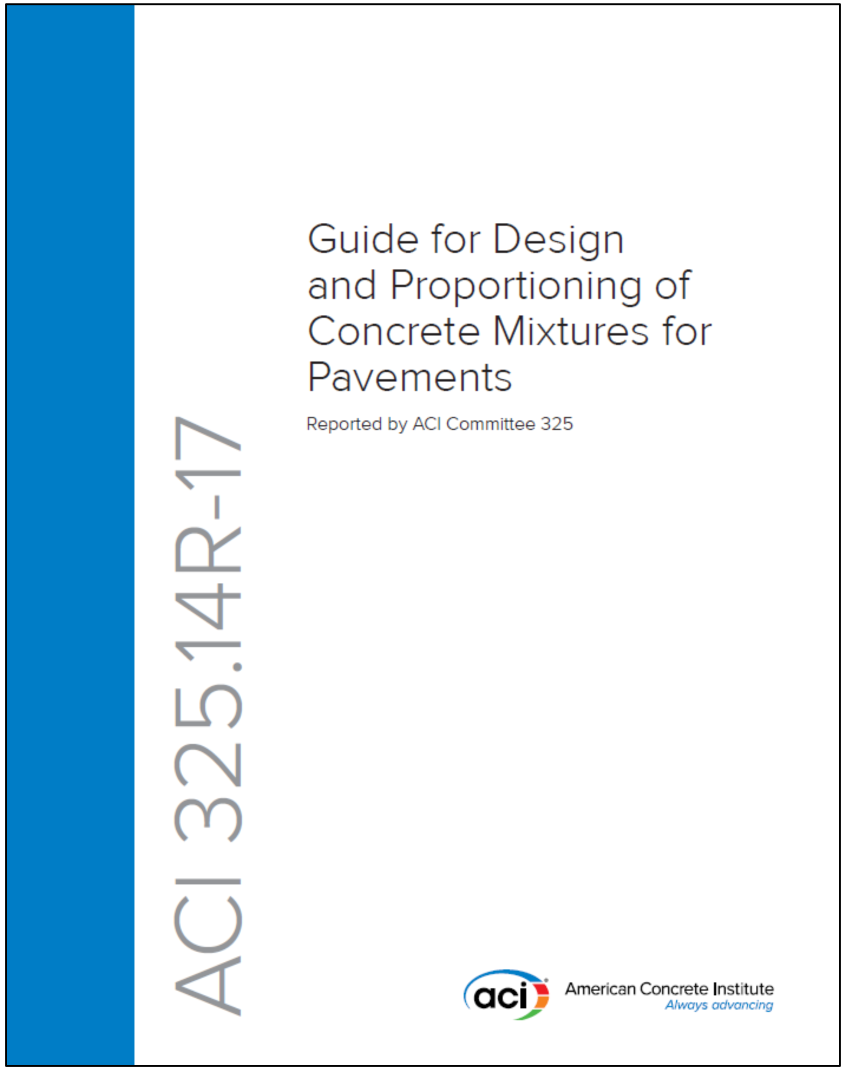
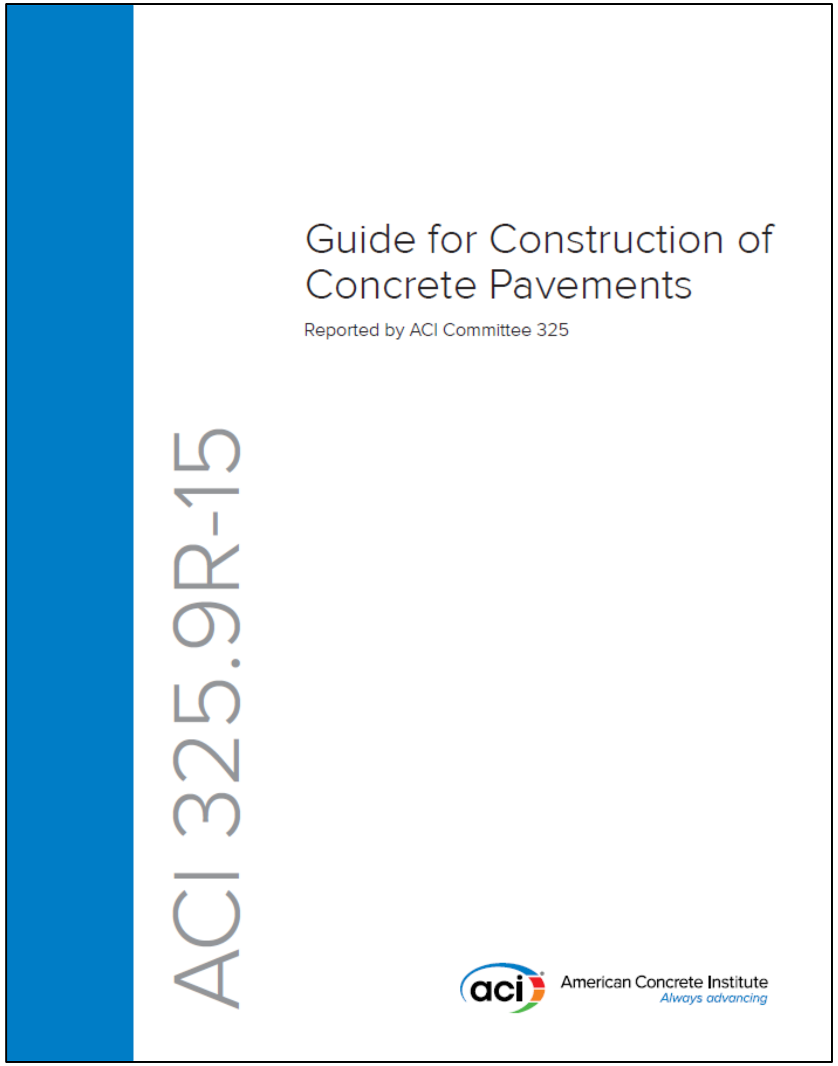


TABLE OF CONTENTS



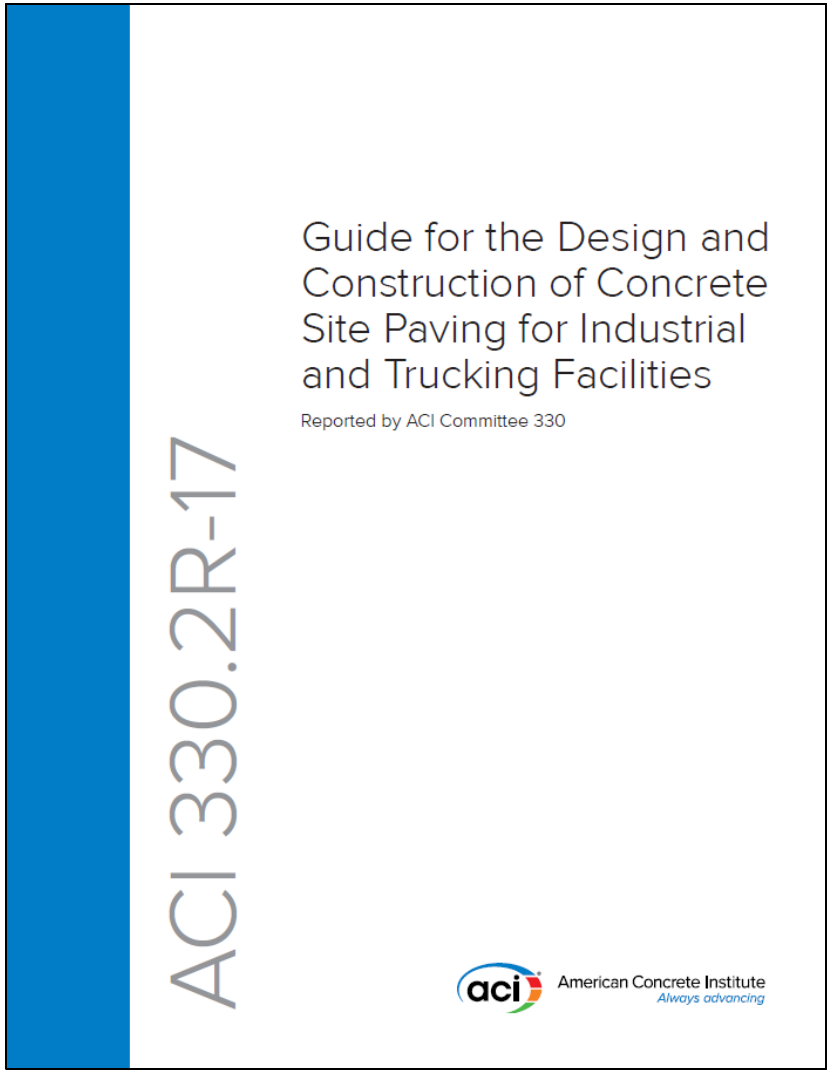
ACI 325.9R-15

Guide for Construction of Concrete Pavements

Reported by ACI Committee 325

American Concrete Institute
Always advancing

TABLE OF CONTENTS


Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities

Reported by ACI Committee 330

ACI 330.2R-17

American Concrete Institute
Always advancing

CHAPTER 1—GENERAL

CHAPTER 2—NOTATION AND DEFINITIONS

CHAPTER 3—SUBGRADES AND SUBBASES

3.1—Pavement support system
3.2—Subgrade/subbase failure modes
3.3—Subgrade considerations
3.4—Subbase considerations

CHAPTER 4—PAVEMENT DESIGN

4.1—Introduction
4.2—Loads
4.3—Concrete properties
4.4—Jointing
4.5—Reinforcement
4.6—Joint stability (load transfer)
4.7—Thickness design
4.8—Other design features

CHAPTER 5—CONCRETE MATERIALS AND MIXTURE PROPORTIONING

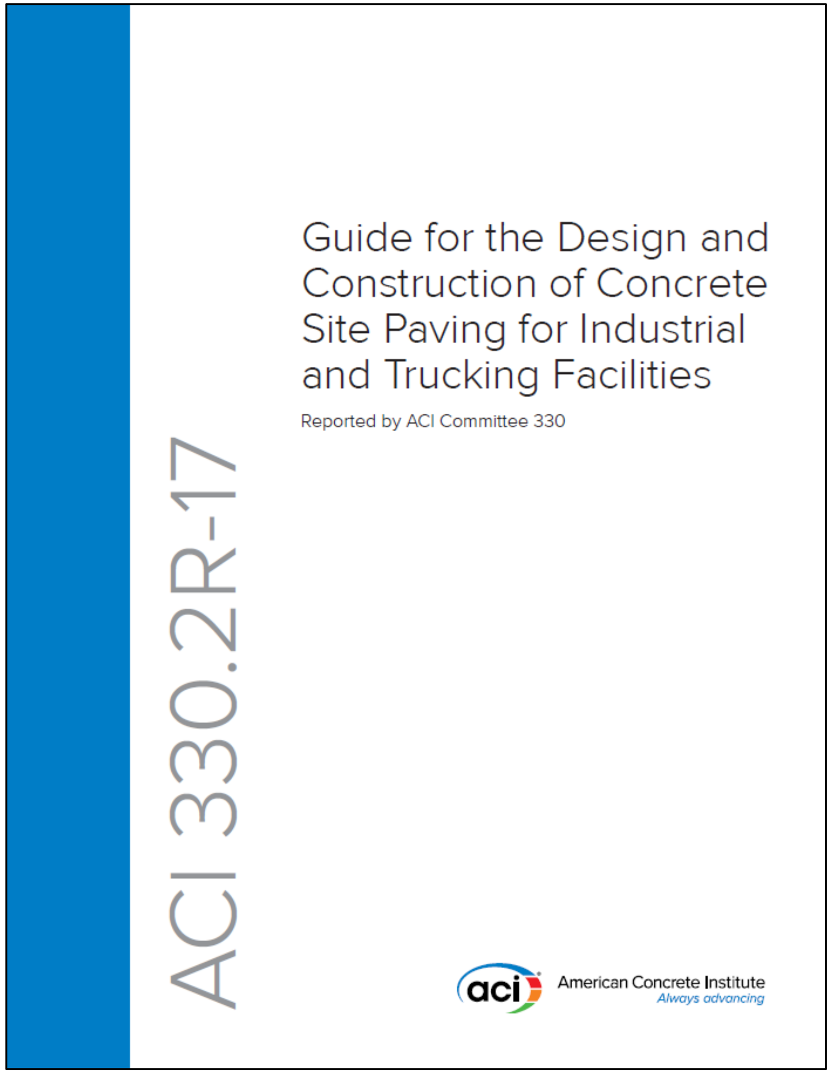
5.1—Introduction
5.2—Cementitious materials
5.3—Mixing water
5.4—Aggregates
5.5—Admixtures
5.6—Concrete mixture design

CHAPTER 6—CONSTRUCTION

6.1—Introduction
6.2—Subgrade and subbase preparation
6.3—Layout for construction
6.4—Forming and use of rigid screed guides
6.5—Concrete placement, screeding, and finishing
6.6—Installation of the different joint types
6.7—Joint sealing or filling
6.8—Curing
6.9—Special considerations for adverse weather
6.10—Striping
6.11—Opening to traffic

CHAPTER 7—INSPECTION AND TESTING

7.1—Introduction
7.2—Site preparation and grading
7.3—Subgrade and subbase
7.4—Forming
7.5—Reinforcing steel
7.6—Concrete quality
7.7—Concrete curing
7.8—Jointing
7.9—Surface texture


Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities
Reported by ACI Committee 330
ACI 330.2R-17
American Concrete Institute
Always advancing

American Concrete Pavement Association (ACPA)

CONCRETE INFORMATION

Design and Construction of Joints for Concrete Streets

To ensure that the concrete pavements we are building now will continue to serve our needs well into the future, it is essential to take into account all design and construction aspects. This includes thickness design, subgrade and subbase preparation, and jointing. This publication addresses the design and construction of jointing systems for concrete street pavements. Two other ACPA publications, *Design of Concrete Pavements for City Streets* and *Subgrades and Subbases for Concrete Pavements*, address city street thickness design and subgrade/subbase preparation.

Typically street pavement slabs range from 5 to 8 in. (125 to 200 mm) in thickness. The recommendations for jointing in this publication are for pavements within this general range and purpose. Special considerations for other concrete pavement joint systems (highways, parking areas, and airports) are covered in other ACPA publications. A proper jointing system for concrete street pavements ensures that the structural capacity and riding quality of the pavement is maintained at the highest level at the lowest annual cost. A proper jointing system will:

1. control cracking.
2. divide the pavement into practical construction increments.
3. accommodate slab movements.
4. provide load transfer.

The development of concrete pavement joint design has evolved from theoretical studies, laboratory tests, experimental pavements, and performance evaluations of in-service pavements. A careful study of the performance of pavements subject to similar traffic and environmental conditions as the proposed pavement is of great value and should be considered in the design of slab dimensions and jointing details.

Jointing Considerations

The need for a jointing system in concrete pavements results from the desire to control the location and geometry of transverse and longitudinal cracking. Cracking results from stresses caused by concrete drying shrinkage, temperature and moisture differentials, and applied traffic loadings. If these stresses are not relieved, uncontrolled cracking will occur.

In determining a proper jointing system, the designer must consider climate and environmental conditions, slab thickness, load transfer, shoulder/curb and gutter construction, and traffic. Past performance of local streets is also an excellent source for establishing joint design. Moreover, improvements to past designs using current technology can significantly improve performance.

Proper and timely construction practices, in addition to proper design, are key in obtaining a properly performing jointing system for street pavements. Late or inadequate joint formation may cause cracks to develop at locations other than those intended. In most cases, sealing is necessary to assure the proper function of street joints.

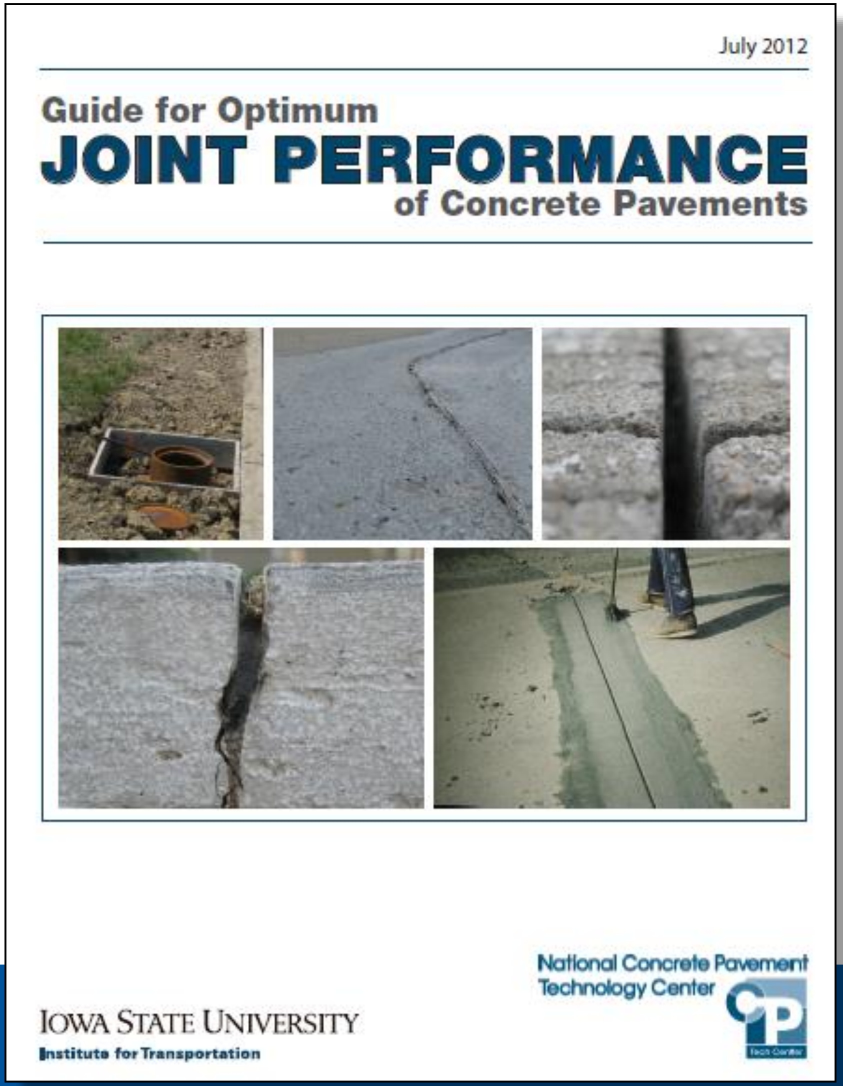
Jointing for Crack Control

Proper jointing is based on controlling cracks that occur from the natural actions of the concrete pavement. Joints are placed in the pavement to control the crack location and pattern. Observing the slab behavior of unjointed plain pavements in service for many years can illustrate how joints are used to control cracking.

To attain adequate workability for placing and finishing concrete, more mixing water is used than is needed to hydrate the cement. As the concrete consolidates and hardens, most of the excess water bleeds to the surface and evaporates. With the loss of water, the concrete contracts and occupies somewhat less volume. A second major source of early shrinkage is caused by the pavement's temperature change. The heat of hydration and temperature of the concrete normally peak a short time after final set. After peaking, the temperature of concrete declines due to reduced cement hydration and lower air temperature during the first night of pavement life. As the temperature drops, the concrete pavement contracts.

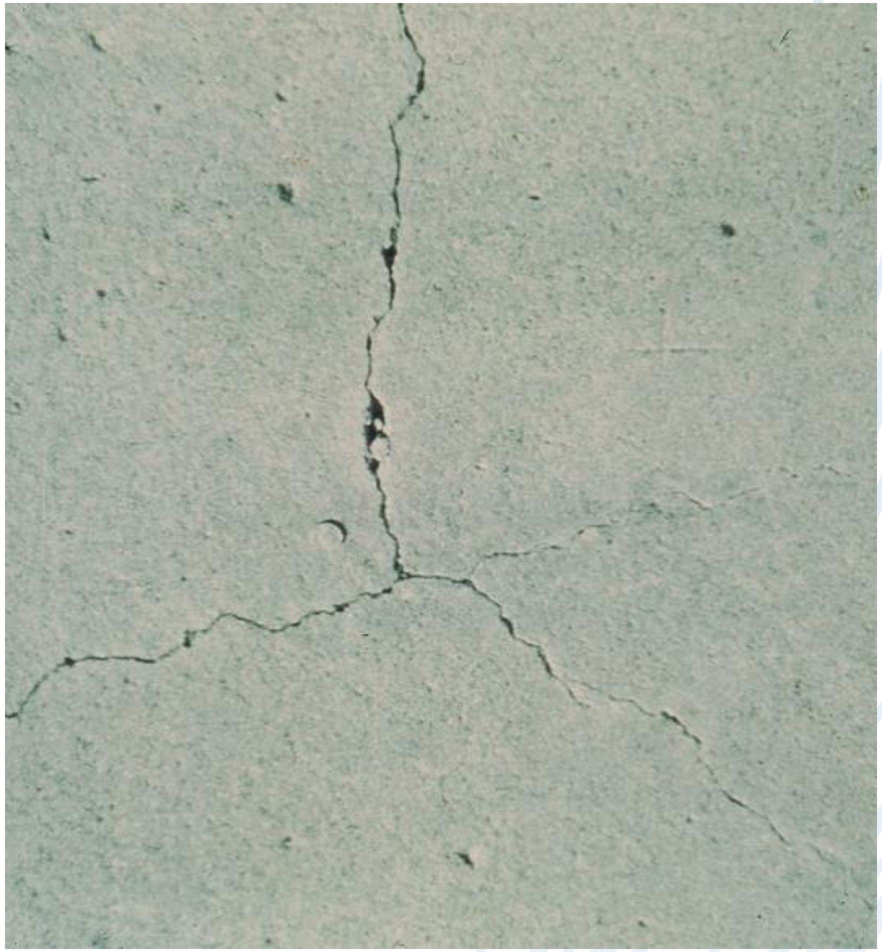
The pavement's contraction is resisted by subgrade friction, which creates tensile stresses in the concrete slab. These tensile stresses cause a transverse crack pattern like that shown in Figure 1.

CPTech Center: Joint Performance

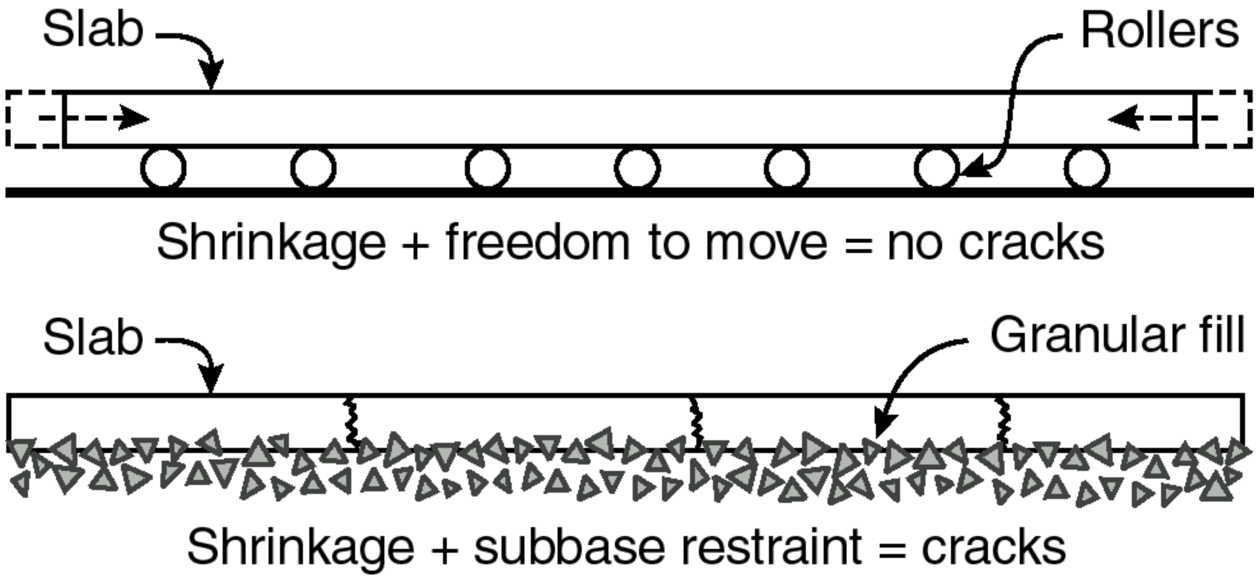


Concrete Volume Change Effects and Jointing

Concrete volume change (and cracking) behavior is the basis of many jointing and construction procedure recommendations.



Drying Shrinkage and Cracking



Shrinkage + Restraint = Cracking

Cracking results from combined effects of restraint and shrinkage (drying and/or thermal)…
…whenever resulting tensile stresses exceed tensile strength.

How to determine…

JOINT SPACING

Joint Design & Layout Affect Performance

Spacing Issue

Rules of Thumb for Jointing & Slab Dimensions

- Spacing:
  - Recommendation of 2.0 to 2.5 times the depth in feet
  - For example: 4” thick = 10’ maximum (4 x 2.5)
- Panel shall be kept as square as possible
  - L:W of 1½:1 (Maximum length to width ratio)

Slab Length & Related Design Factors

$$\ell = \sqrt[4]{\frac{Eh^3}{12(1-\nu^2)k}} \quad \text{in.-lb units}$$

$$\ell = \sqrt[4]{\frac{1000 \cdot Eh^3}{12(1-\nu^2)k}} \quad \text{SI units}$$

where

ℓ = radius of relative stiffness, in (mm);

E = concrete modulus of elasticity, psi (MPa);

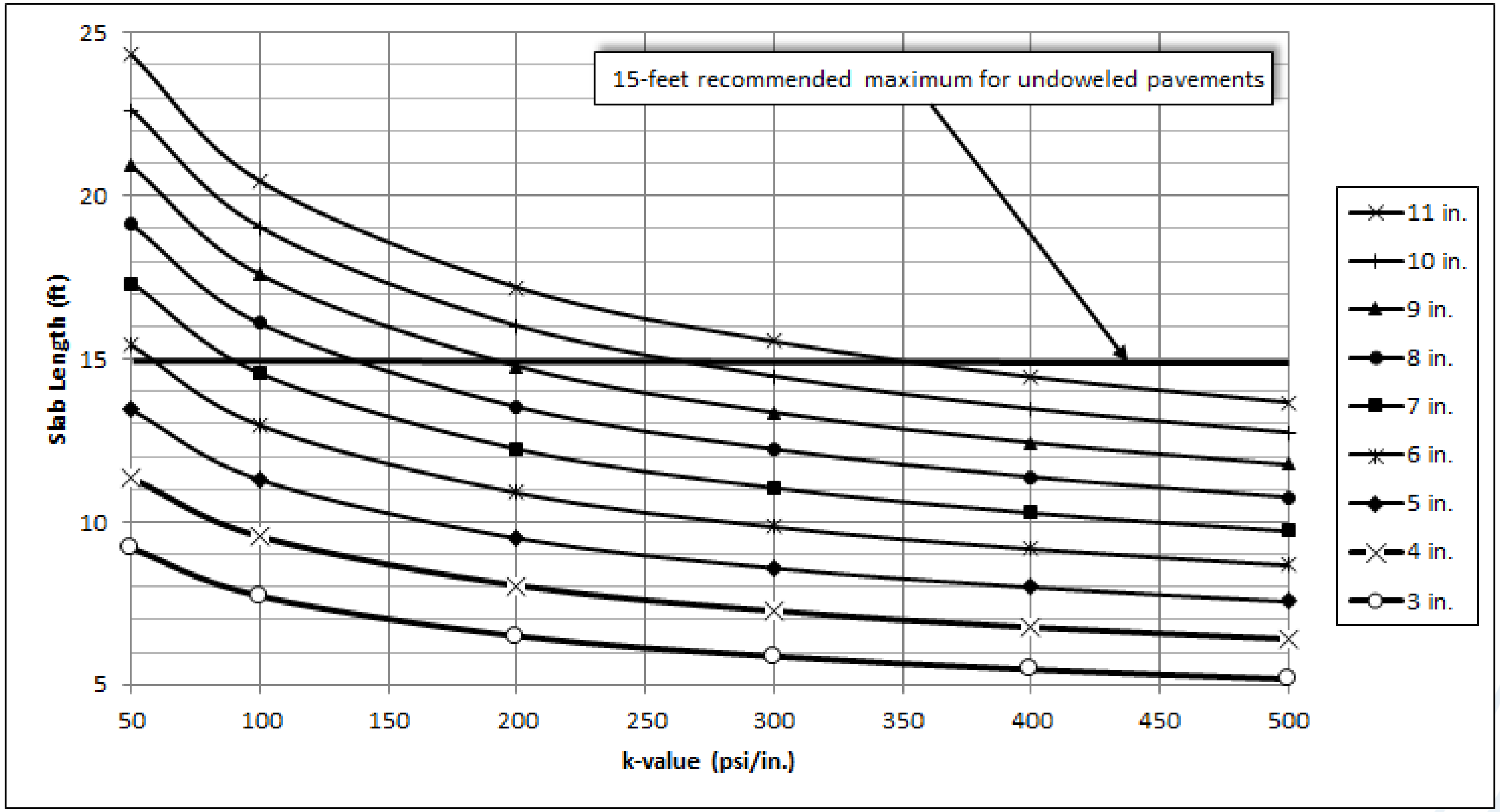
h = pavement thickness, in. (mm);

ν = Poisson's ratio of the pavement (≈ 0.15); and

k = modulus of subgrade reaction, psi/in. (MPa/m).

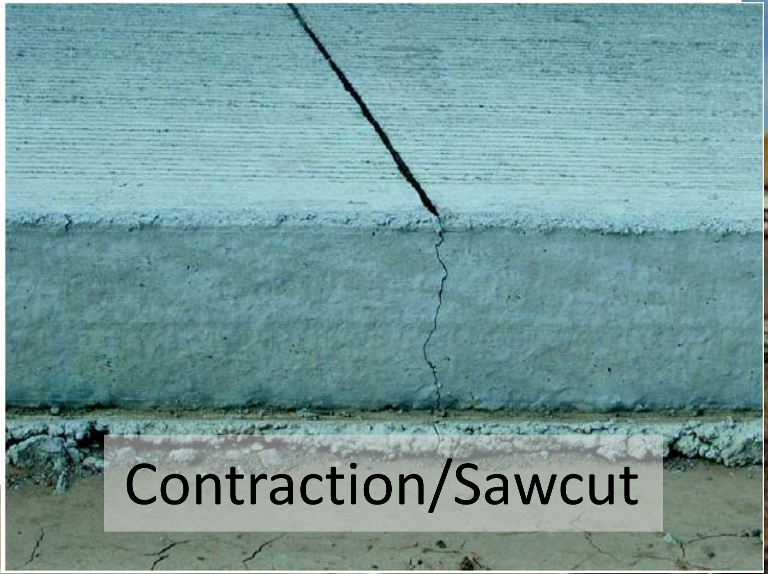
Experience indicates that there is an increase in transverse cracking when the ratio L/ℓ exceeds 5.25 (L=slab length).

Slab Length vs. Pavement Thickness Relationships



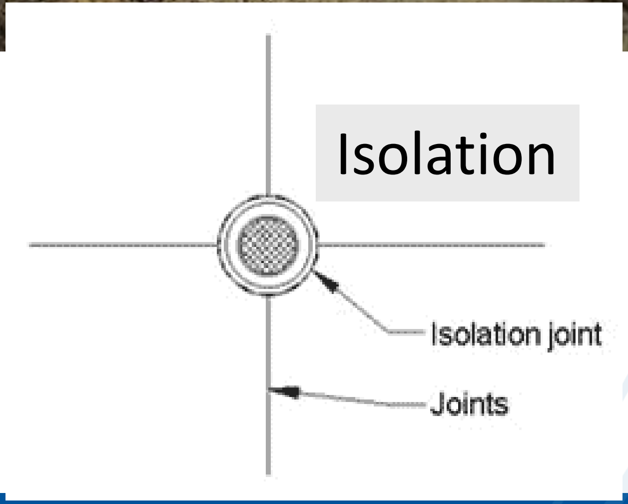
Using the criterion of a maximum L/ℓ ratio of 5.25, the allowable joint spacing would increase with increased slab thickness but decrease with increased (stiffer) foundation support conditions.

TYPES OF JOINTS


Contraction/Sawcut


Construction


Longitudinal

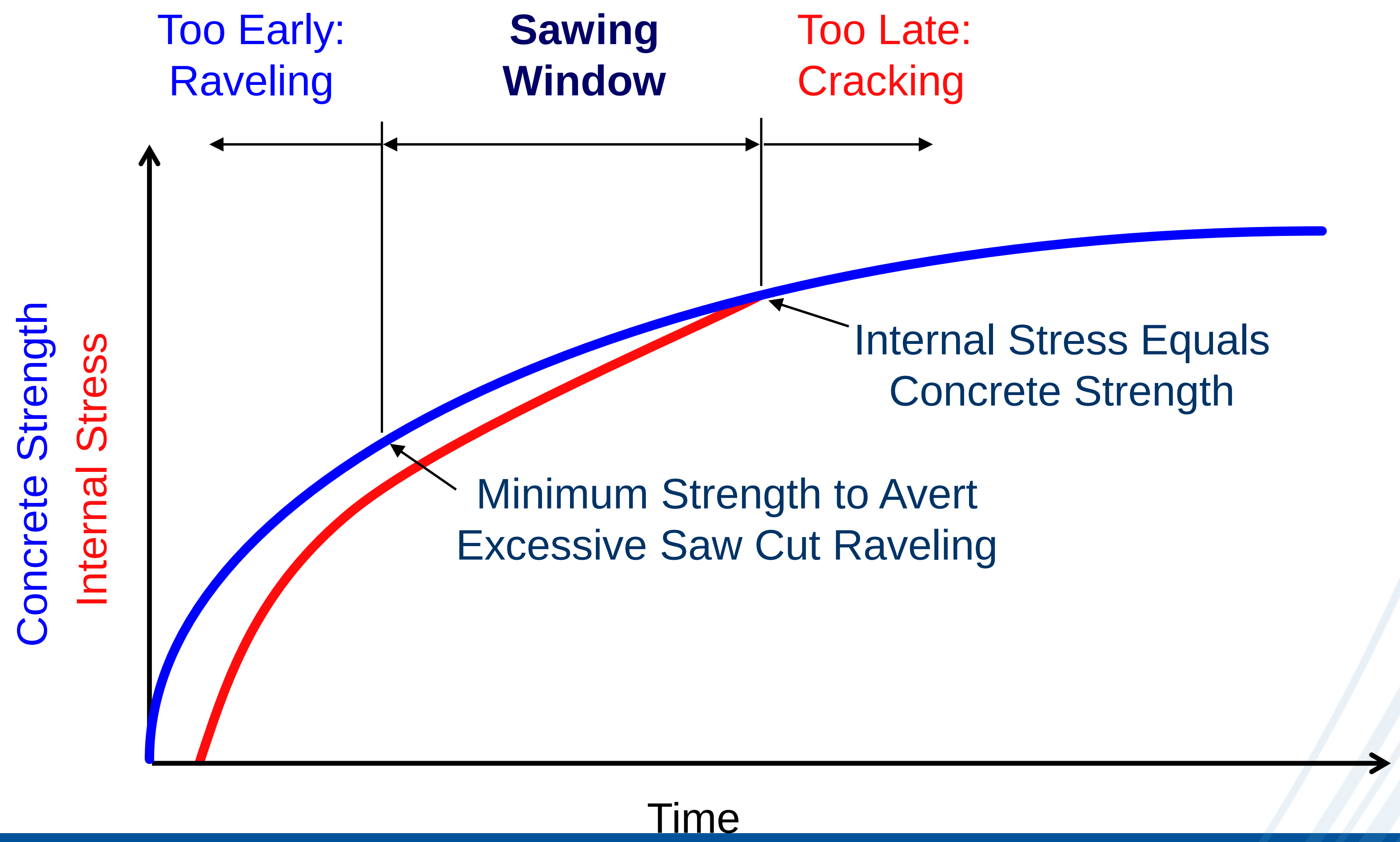

Isolation
Isolation joint
Joints

CONTRACTION (CONTROL) JOINTS

Rules of Thumb for Sawcut Joints

- Depth:
  - Conventional Sawing:
    - Minimum of ¼ of the depth: e.g. 8” thick = 2” deep
    - Recommended: $\frac{t}{3}$
  - Early Entry Sawing:
    - Typical 1” to 1.5” depth

Crack Control Window



Timing of Joint Sawing–A Critical Factor

This joint was sawed at correct time

Sawcut joints with conventional saws must be made within 4-12 hours after final finishing.

This one was sawed too late

Factors that Shorten Sawing Window

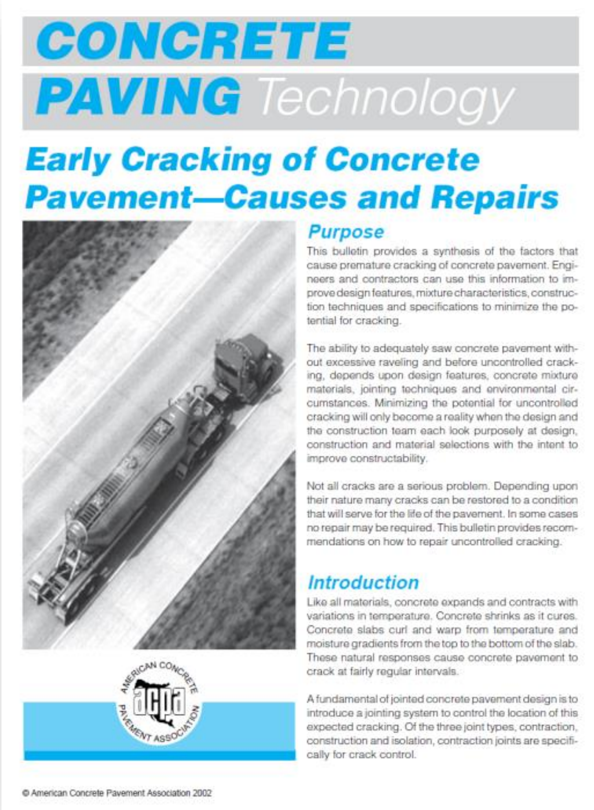
- Weather
  - Drastic Changes in weather within a short period
  - High winds and low humidity
  - Cool temperatures and clouds
  - Hot temperatures and sunny

- 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


CONCRETE PAVING Technology

Early Cracking of Concrete Pavement—Causes and Repairs

Purpose

This bulletin provides a synthesis of the factors that cause premature cracking of concrete pavement. Engineers and contractors can use this information to improve design features, mixture characteristics, construction techniques and specifications to minimize the potential for cracking.

The ability to adequately saw concrete pavement without excessive raveling and before uncontrolled cracking, depends upon design features, concrete mixture materials, jointing techniques and environmental circumstances. Minimizing the potential for uncontrolled cracking will only become a reality when the design and the construction team each look purposely at design, construction and material selections with the intent to improve constructability.

Not all cracks are a serious problem. Depending upon their nature many cracks can be restored to a condition that will serve for the life of the pavement. In some cases no repair may be required. This bulletin provides recommendations on how to repair uncontrolled cracking.

Introduction

Like all materials, concrete expands and contracts with variations in temperature. Concrete shrinks as it cures. Concrete slabs curl and warp from temperature and moisture gradients from the top to the bottom of the slab. These natural responses cause concrete pavement to crack at fairly regular intervals.

A fundamental of jointed concrete pavement design is to introduce a jointing system to control the location of this expected cracking. Of the three joint types, contraction, construction and isolation, contraction joints are specifically for crack control.

American Concrete Pavement Association

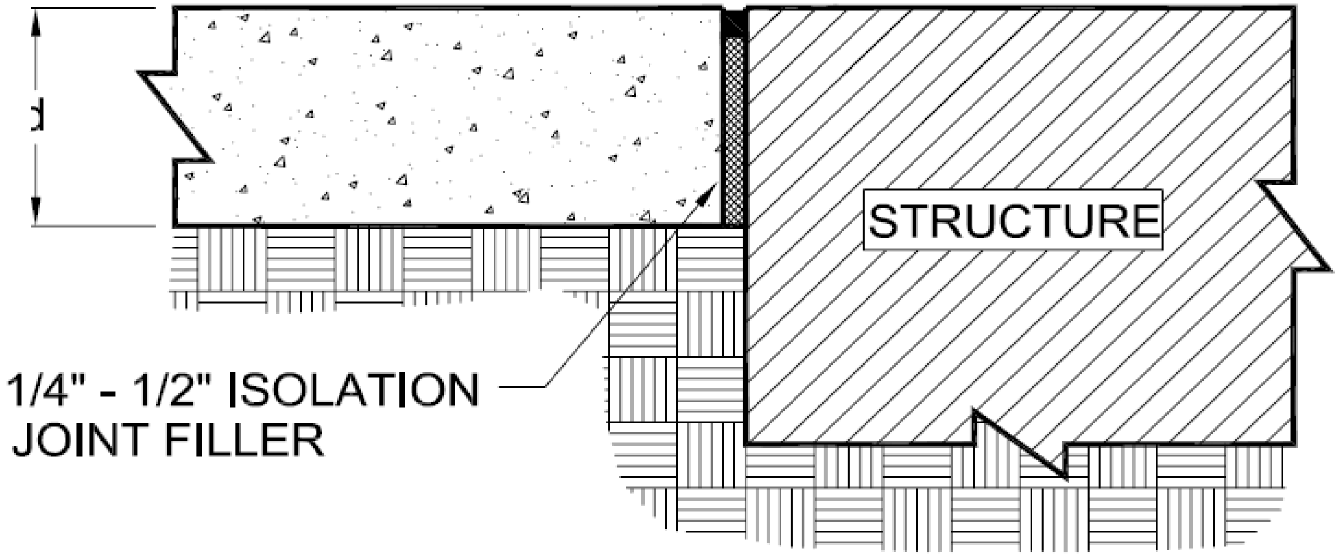
© American Concrete Pavement Association 2002

See ACPA's TB016P and
IMCP: Integrated Materials and Construction Practices for Concrete Pavement:
A State-of-the-Practice Manual

ISOLATION JOINTS

Isolation Joints

…are sometimes called expansion joints but should generally not be used to provide for expansion. They provide no load transfer and should not be used as regularly spaced joints in a joint layout. Their proper use is to isolate fixed objects, providing for slight differential settlement without damaging the pavement.



LONGITUDINAL JOINTS

Longitudinal Joints

- Spacing Criteria:
  - Spacing of 12 to 15 feet serves as both crack control and lane delineation.
  - Lanes (driveways) that are greater than 15’ require a longitudinal joint.

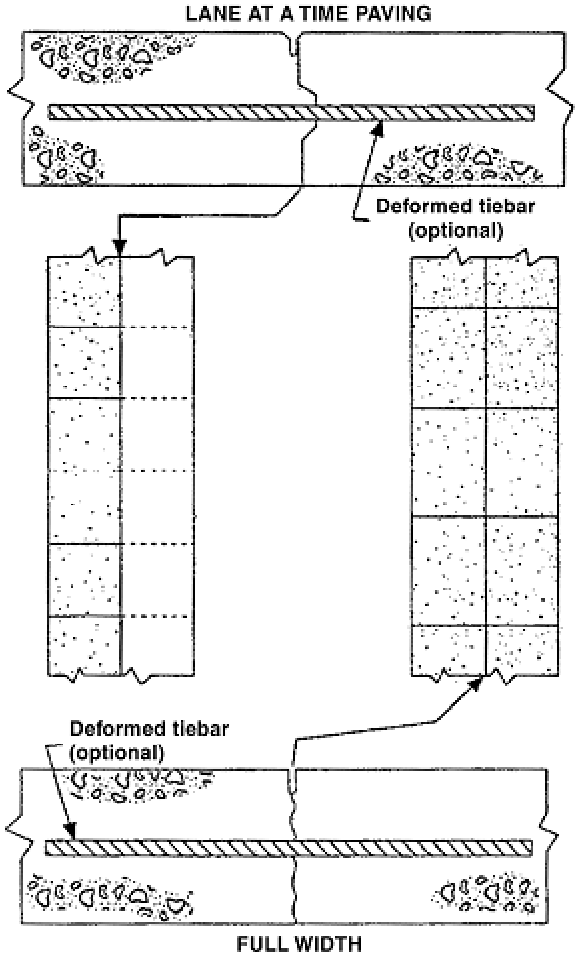


Fig. 4.5—Longitudinal joints.[33] *(Note: use butt joint with tie bar for pavements 150 mm [6 in.] thick or less.)*

Tie Bar Dimensions and Spacing (US)

Table 4.1—Tie bar dimensions and spacings (commonly Grade 60)*

Slab thickness, in. (mm)	Tie bar size × length, in. (mm)	Tie bar spacing, in. (mm)			
		Distance to nearest free edge or to nearest joint where movement can occur			
		10 ft (3.0 m)	12 ft (3.7 m)	14 ft (4.3 m)	24 ft (7.3 m)
5 (130)	#4 x 24 (13M × 600)	30 (760)	30 (760)	30 (760)	28 (700)
6 (150)	#4 x 24 (13M × 600)	30 (760)	30 (760)	30 (760)	23 (580)
7 (180)	#4 x 24 (13M × 600)	30 (760)	30 (760)	30 (760)	20 (500)
8 (200)	#4 x 24 (13M × 600)	30 (760)	30 (760)	30 (760)	17 (430)
9 (230)	#5 x 30 (16M × 760)	36 (900)	36 (900)	36 (900)	24 (600)
10 (250)	#5 x 30 (16M × 760)	36 (900)	36 (900)	36 (900)	22 (560)
11 (280)	#5 x 30 (16M × 760)	36 (900)	36 (900)	34 (860)	20 (500)
12 (310)	#5 x 30 (16M × 760)	36 (900)	36 (900)	31 (780)	18 (460)

*Corrosion protection should be used in an area where deicing salts are used on the pavement on a regular basis.

Doweled Joints

- Not needed on low volume streets and roads.
  - Especially when transverse joint spacing is less than 15 feet.
- May be justified when k values are less than 100 psi/in.
- Generally, pavement must be at least 8” thick to accommodate conventional dowels.

Do I or Don’t I…

JOINT SEALING

Joint Sealing

- Topic of some debate.
- Sealants must be maintained and drainage design must be effective.
- Some poured sealants shown not to be durable.
- Some joint types difficult to seal.
- Factors to consider in whether or not to seal joints:
  - Traffic level
  - Soil types & local performance
  - Subbase use
  - Presence of wind blown debris

Sealing? 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.

Saw Blades

- Most common are industrial diamond (require water cooling) or abrasive (carborundum).
- Must match the saw blade to the concrete which is based primarily on aggregate hardness but also depends on power output of saw.
- <u>Very thin blades (~2 to 3 mm) may be used when joint sealing is not specified.</u>

CONCRETE CURING

Concrete Curing

- Maintain adequate moisture & temperature regimes in freshly placed concrete
- Inadequate curing
  - Excessive moisture loss at surface => plastic shrinkage cracking
  - Weak surface => durability problems
  - Excessive slab warping
- Timely curing behind paver
- See DOT Website for Pre-Qualified Matls

Curing Methods

Curing

- Spray membrane curing compound - ASTM C 309, white pigmented preferred.
- Timing is critical - spray immediately after finishing.
- Suggested application rate:
  - Maximum coverage: 200 ft^2 / gal.
  - Higher rate (less coverage) for windy or dry conditions (100 -150 ft^2 / gal.)


Texture/cure machine (GOMACO T/C-600).
Follows the paver applying a white curing compound

Thank You