JOINT LOAD TRANSFER FOR AIRPORT CONCRETE PAVEMENTS SERVING HEAVY AIRCRAFT

(AIRCRAFT TRAFFIC GREATER THAN 45,360 kg, FAA)

JOHN EMERY

CONSULTING ENGINEER

RETAINED PRINCIPAL ENGINEER – TECHNOLOGY

LVM – JEGEL / DESSAU

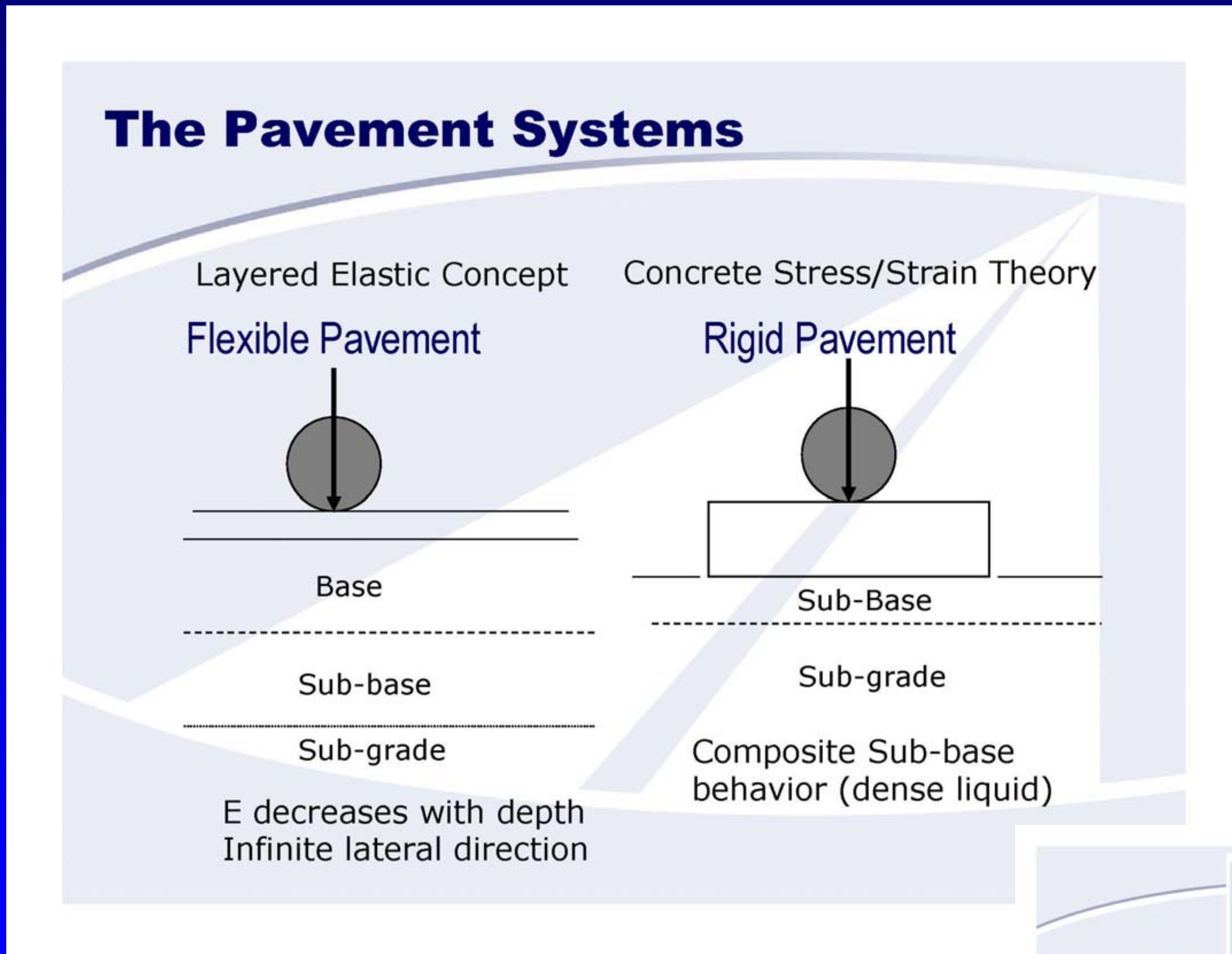
ADJUNCT PROFESSOR OF CIVIL ENGINEERING

McMASTER UNIVERSITY

john.emery@lvmjegel.com

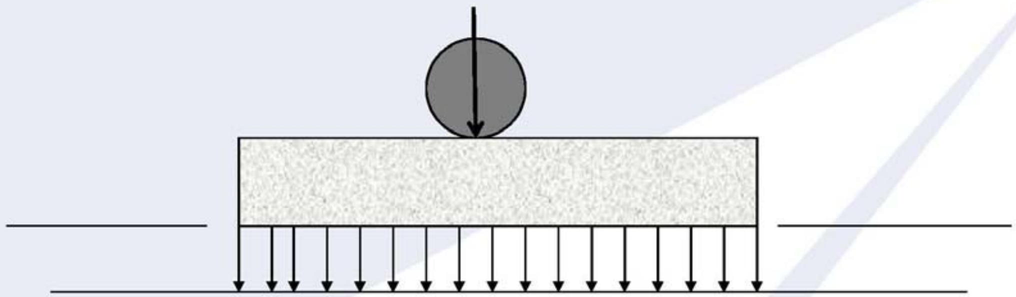
CONCRETE PAVEMENT DESIGN ASSUMPTIONS AND PROCEDURES, AND REHABILITATION TECHNIQUES, WITH EMPHASIS ON JOINT LOAD TRANSFER, RECOMMENDED BY THE AMERICAN CONCRETE PAVEMENT ASSOCIATION, ARE EMPHASIZED THROUGHOUT. THE SIGNIFICANT CONTRIBUTIONS OF JAMES L. LAFRENZ, THE ACPA DIRECTOR FOR AIRPORTS, ARE PARTICULARLY ACKNOWLEDGED.

THE TECHNICAL ASSISTANCE OF ALAIN DUCLOS, JESSICA HERNANDEZ AND DOUGLAS LIU OF LVM - JEGEL WITH THIS PRESENTATION IS GRATEFULLY ACKNOWLEDGED


The Pavement Systems
Layered Elastic Concept
Concrete Stress/Strain Theory
Flexible Pavement
Rigid Pavement
Base
Sub-base
Sub-grade
Sub-Base
Sub-grade
Composite Sub-base behavior (dense liquid)
E decreases with depth
Infinite lateral direction


Airport Pavements online
ACPA
Introduction to Airport Pavement Design
Gary L. Mitchell, P.E.
Director of Airports and Pavement Technology

Load Transfer in Rigid Pavement



Sub-Base for consistency

$E_{Concrete} >> E_{Base}$

For 20x20 panel: Pressure = 0.5 psi at base of panel

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Introduction to Airport Pavement Design

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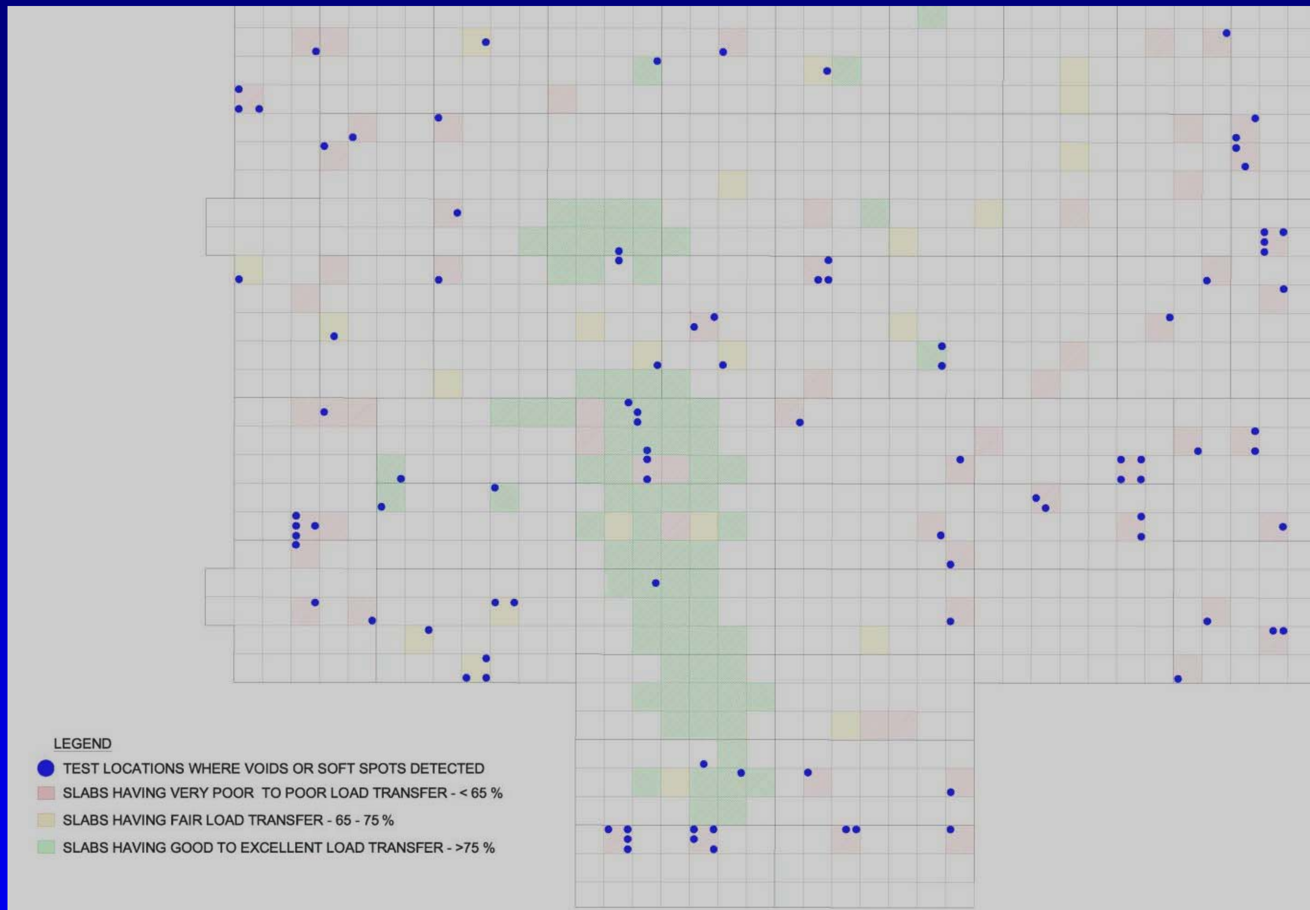
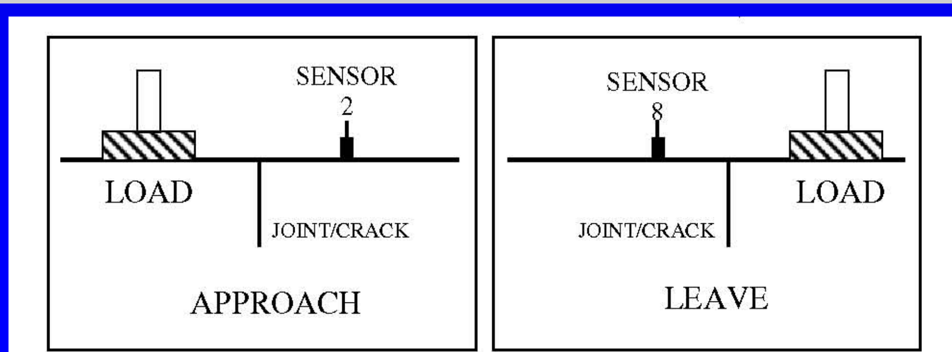
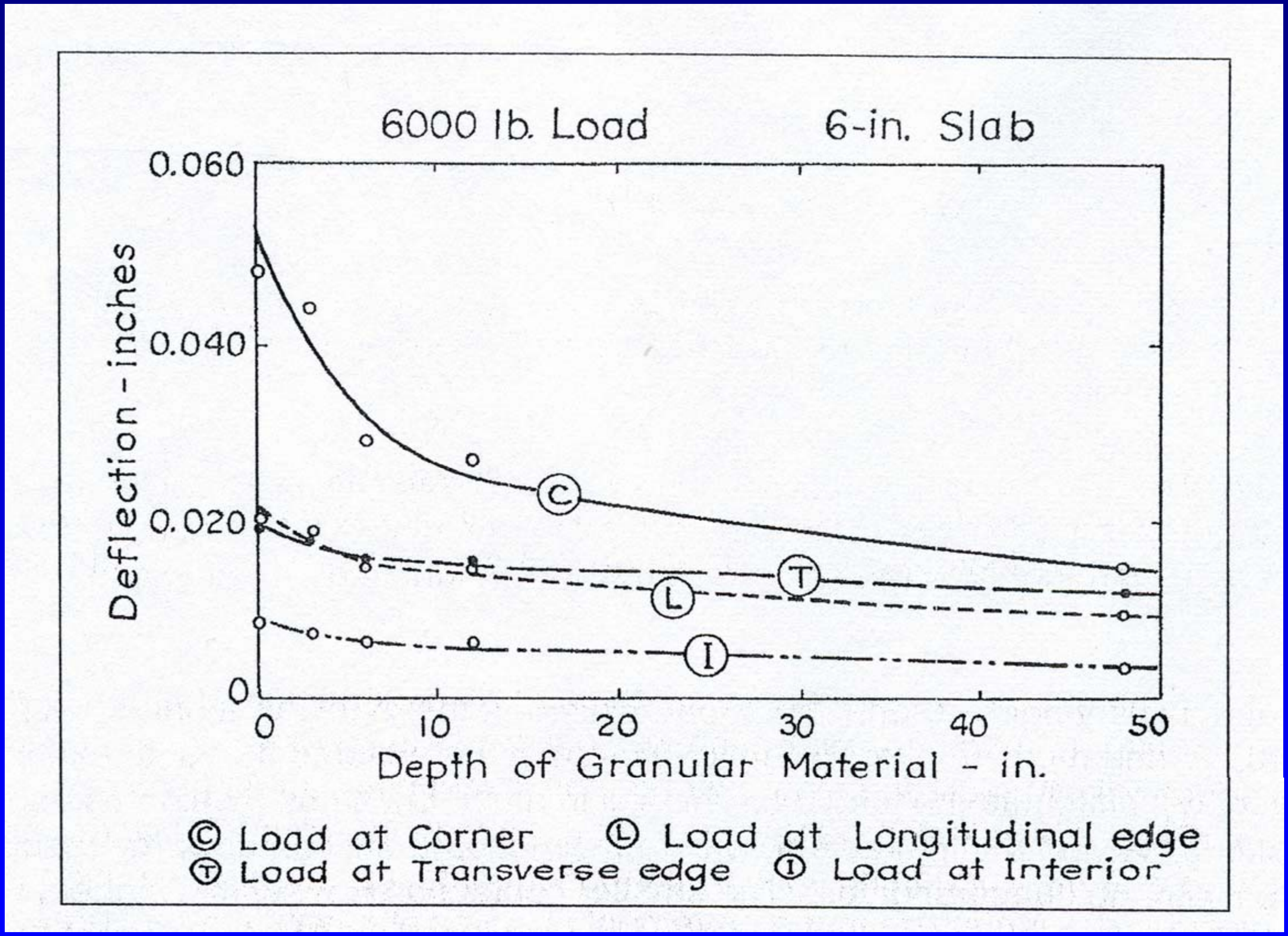
TYPICAL JOINT LOAD TRANSFER ASSESSMENT



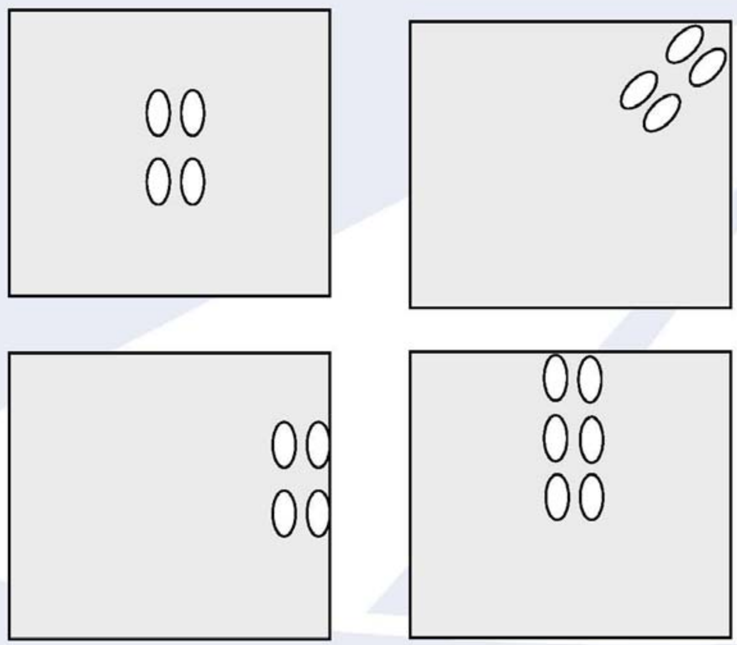


SUBGRADES AND SUBBASES
RIGIDITY AND CONSISTENCY OF SOIL SUPPORT

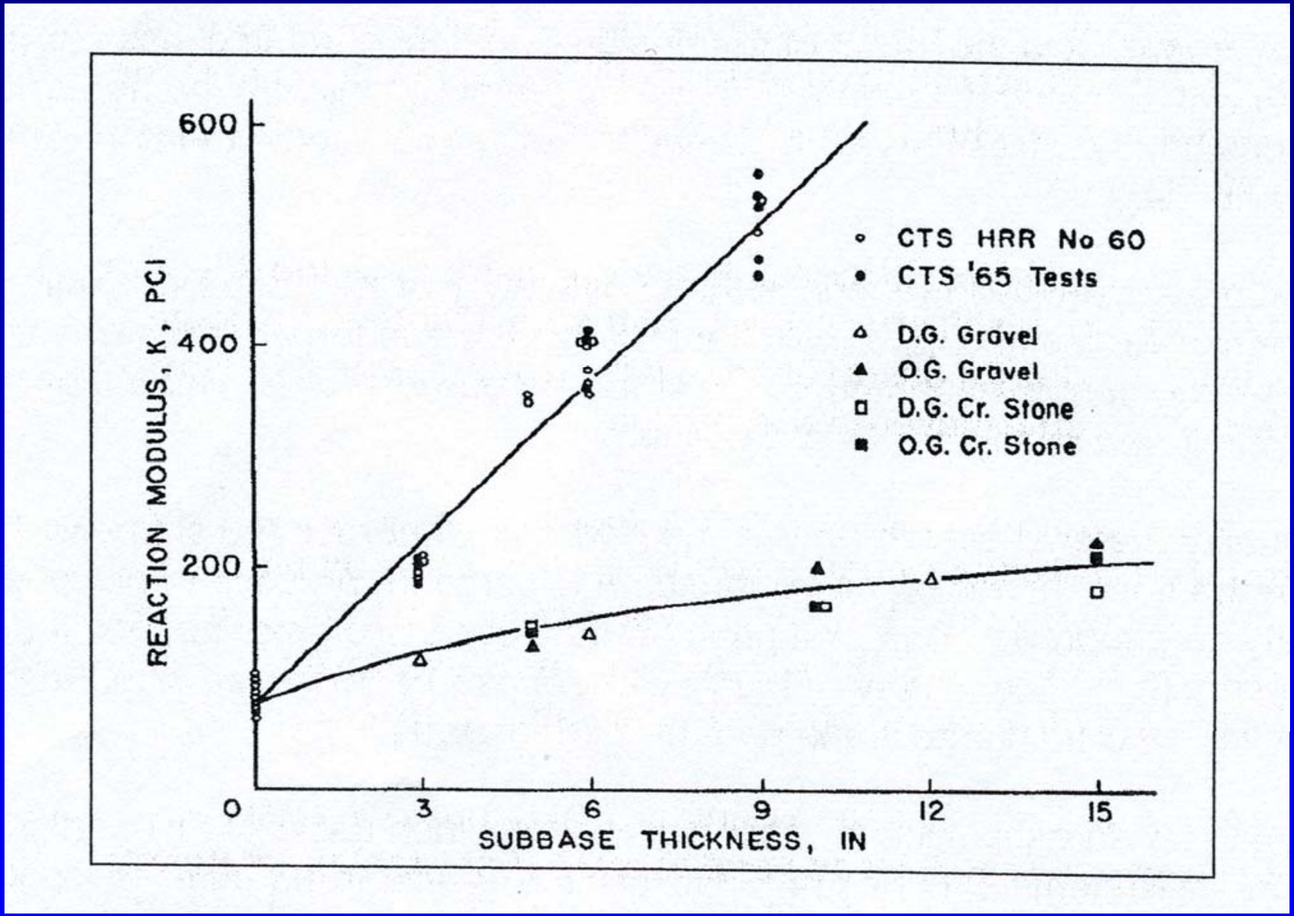


INFLUENCE OF GRANULAR SUBBASE THICKNESS ON PANEL DEFLECTION
(CHILDS, COLLEY AND KAPERNICK, ASCE, 1957)

Maximum Stress Gear Positions



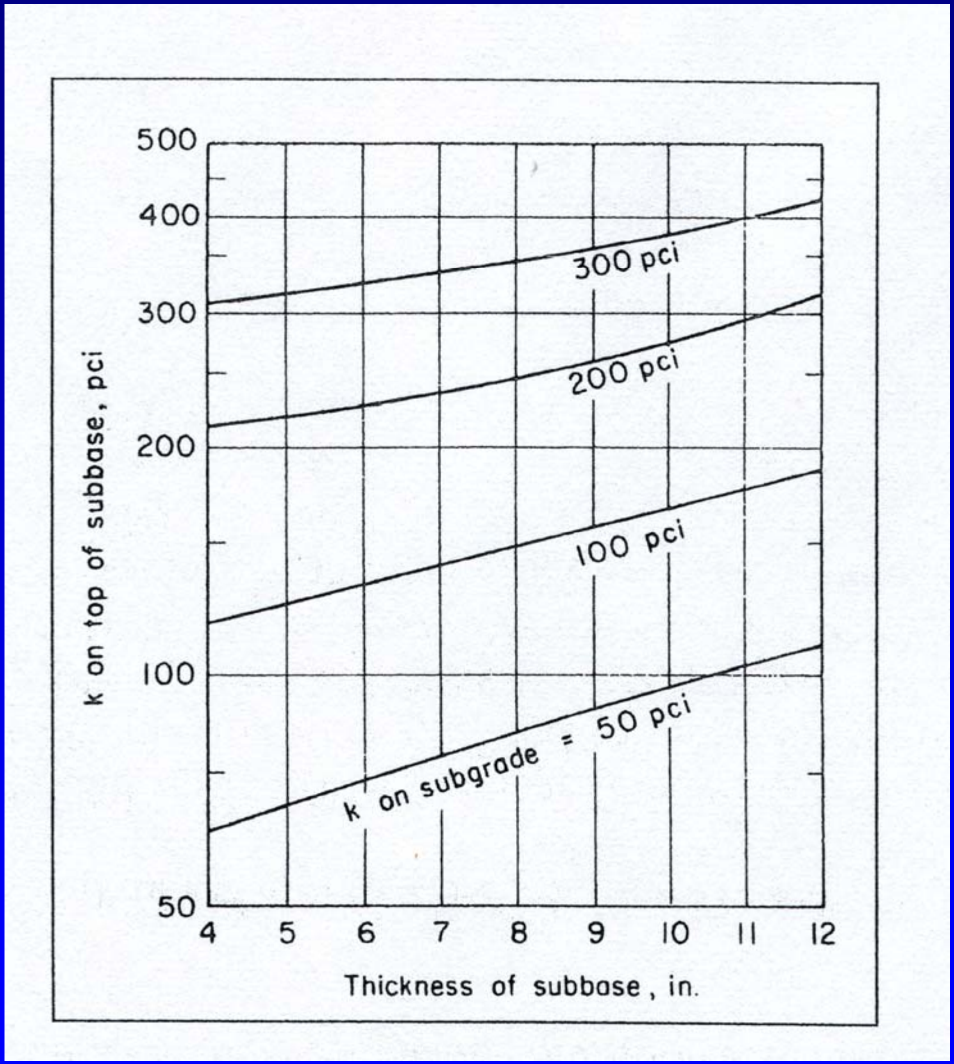
SUBGRADES AND SUBBASES
RIGIDITY AND CONSISTENCY OF SOIL SUPPORT



EFFECT OF CEMENT-TREATED AND GRANULAR SUBBASE THICKNESS ON k-VALUE (CHILDS, HRB, 1967)

THE SUPPORT PROVIDED BY A SUBGRADE WAS QUANTIFIED BY WESTERGAARD AS THE MODULUS OF SUBGRADE REACTION ‘k’ IN PCI (WESTERGAARD, HRB, 1927).

SUBGRADES AND SUBBASES
RIGIDITY AND CONSISTENCY OF SOIL SUPPORT



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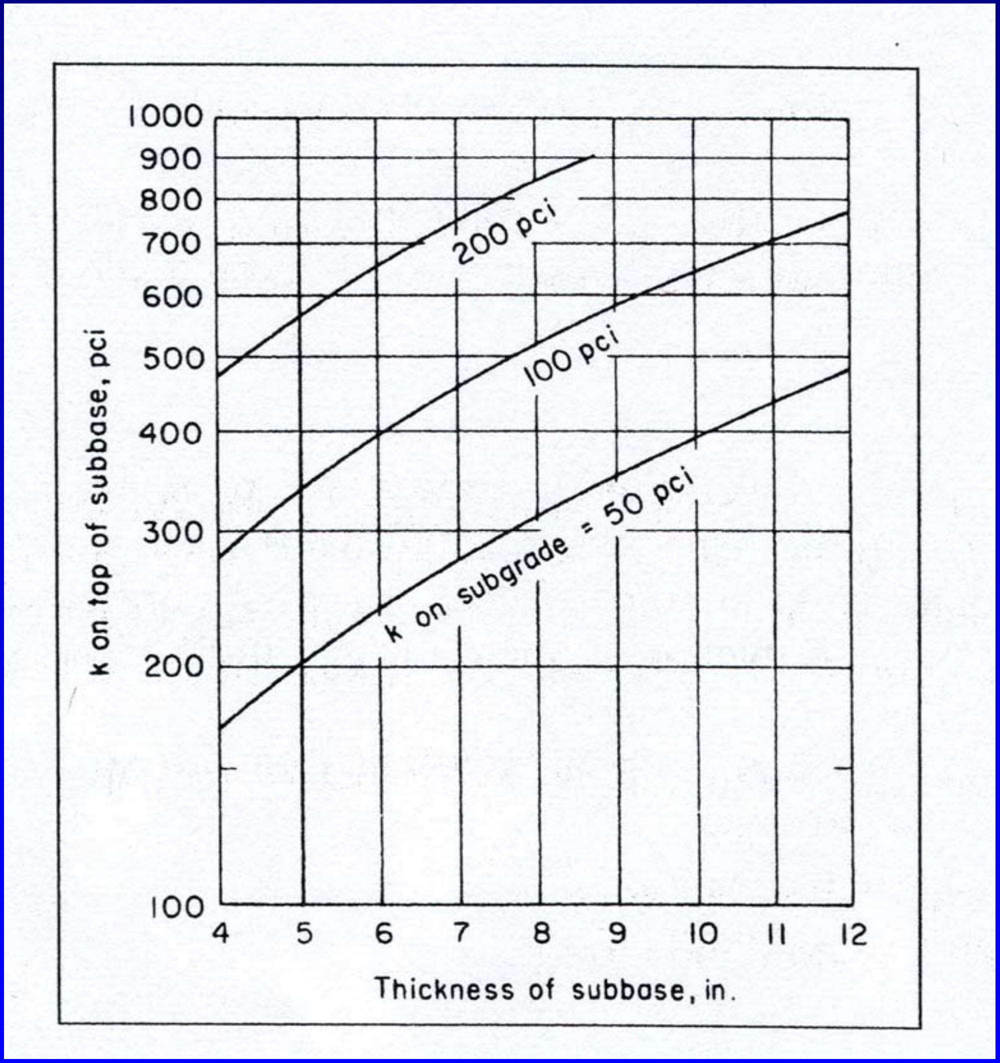
SUBGRADES AND SUBBASES
RIGIDITY AND CONSISTENCY OF SOIL SUPPORT



EFFECT OF CEMENT-TREATED SUBBASE THICKNESS ON k-VALUE
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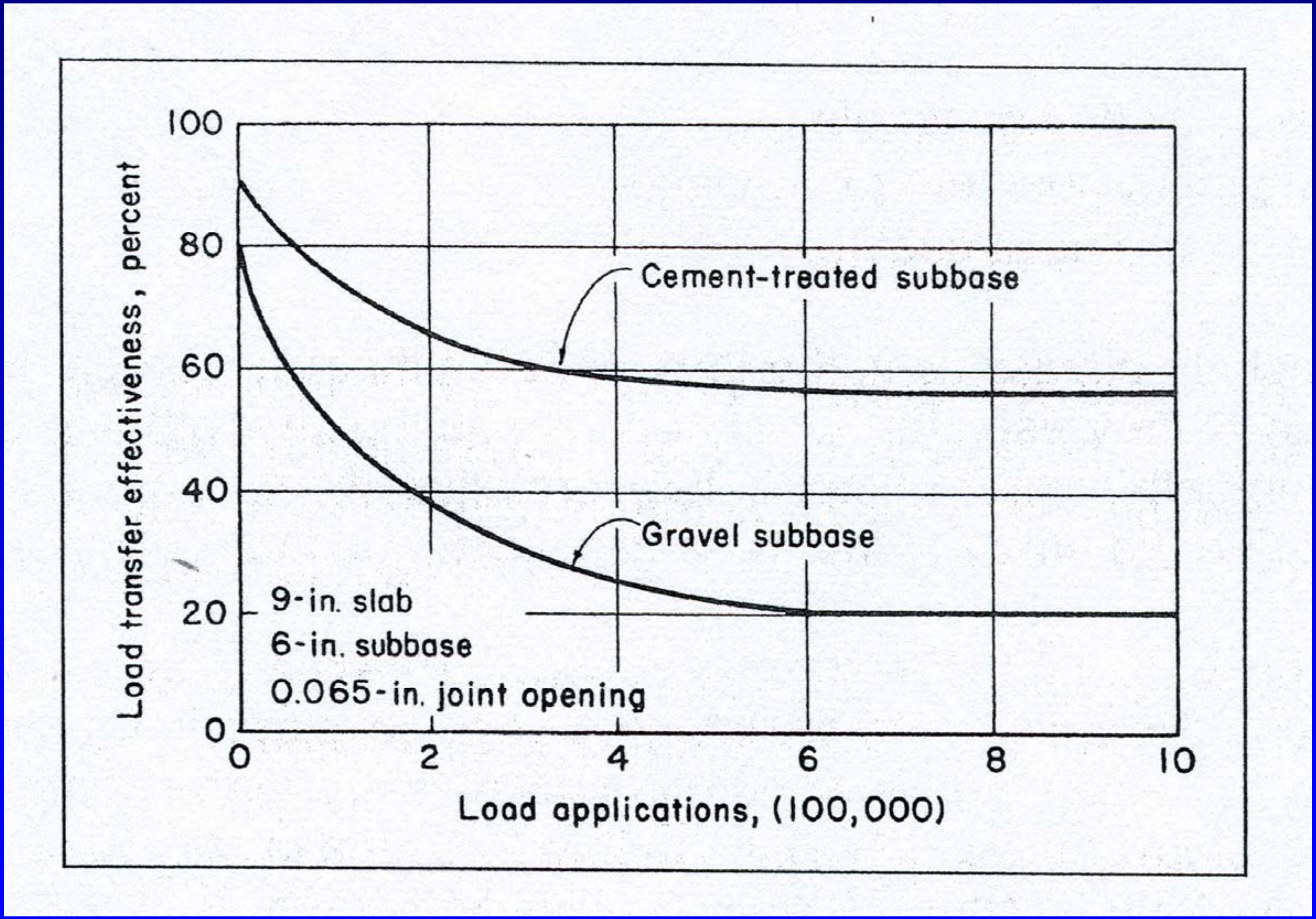
SUBGRADES AND SUBBASES
RIGIDITY AND CONSISTENCY OF SOIL SUPPORT



EFFECT OF CEMENT-TREATED SUBBASE THICKNESS ON k-VALUE
(CHILDS, HRB, 1967)

SUBGRADES AND SUBBASES
SUBGRADE PREPARATION

- COMPACTION OF SOIL AT MOISTURE CONTENTS CONSISTENT WITH ACHIEVING MAXIMUM DENSITY
- MAXIMIZING THE ELEVATION BETWEEN THE PAVEMENT STRUCTURE AND THE NORMAL HIGH WATER TABLE
- CROSS-HAULING AND MIXING OF SOILS TO ACHIEVE UNIFORM CONDITIONS
- IMPROVING SOILS OF LOW SUBGRADE SUPPORT VALUE BY STABILIZATION
- PROOFROLLING

(LAFRENZ)

SUBGRADES AND SUBBASES

DYNAMIC CONE PENETROMETER (DCP)

MONITORING COMPACTION ACHIEVED NEAR A CULVERT ABUTMENT WHERE CONTROLLING SETTLEMENTS IS VERY IMPORTANT

SUBGRADES AND SUBBASES

LIGHT-WEIGHT DEFLECTOMETER (LWD)

MONITORING COMPACTION ACHIEVED IN TERMS OF M_r AT AN AIRPORT

A PORTABLE FWD CAN BE USED TO DETERMINE THE M_r DIRECTLY ON THE SURFACE OF THE GRANULAR BASE, GRANULAR SUBBASE OR SUBGRADE

SUBGRADES AND SUBBASES
SUBBASE MATERIALS

- OPEN GRADED GRAVELS AND CRUSHED STONE
- DENSE GRADED GRAVELS AND CRUSHED STONE
- SANDS AND SANDY CLAYS
- SOIL CEMENT
- CEMENT-STABILIZED SANDS, GRAVELS AND CRUSHED STONE
- ASPHALT-STABILIZED SANDS, GRAVELS AND CRUSHED STONE
- LEAN CONCRETE OR ECONOCRETE
- FLOWABLE FILL
- RECYCLED, CRUSHED AND GRADED CONCRETE PAVEMENT

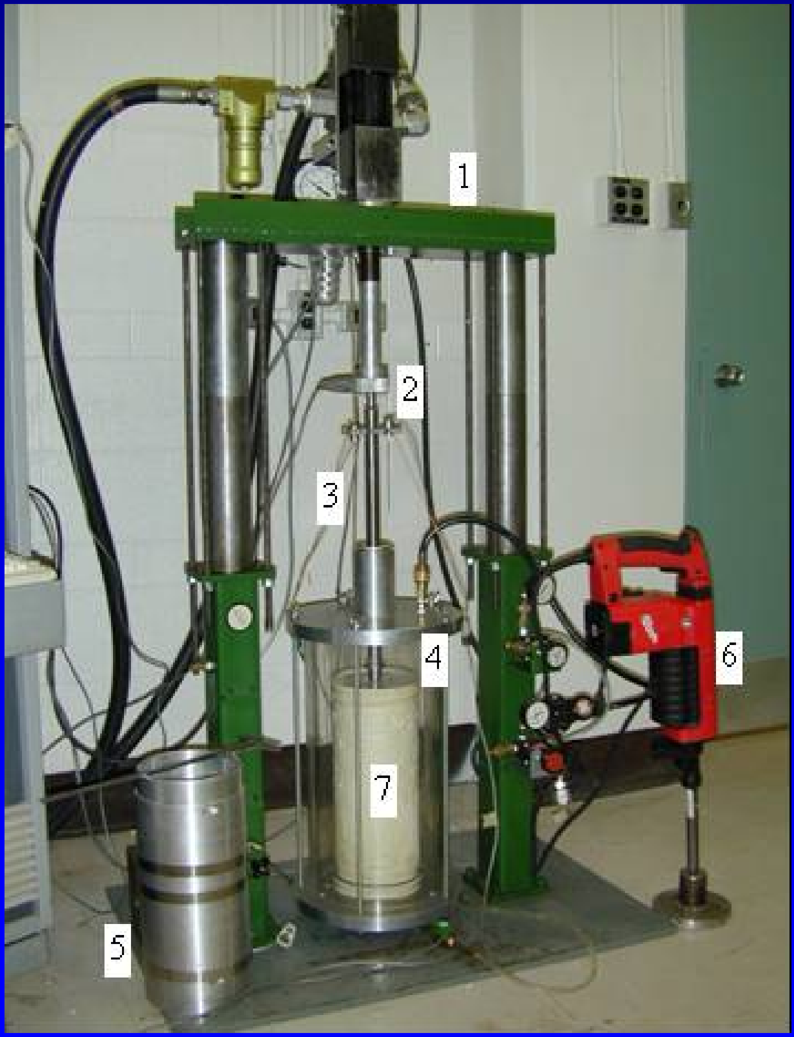
THE FAA REQUIRES A STABILIZED SUBBASE BE USED FOR THOSE PAVEMENTS THAT SUPPORT AIRCRAFT TRAFFIC GREATER THAN 45,360 kg (100,000 lbs)

(LAFRENZ)

HIGH PERFORMANCE CRUSHED ROCK

RESILIENT MODULUS, M_r

SUBGRADE, SELECT SUBGRADE MATERIAL, GRANULAR SUBBASE, GRANULAR BASE



1 – LOAD FRAME
2 – LOAD CELL
3 – LVDT
4 – TRIAXIAL CELL
5 – SPLIT MOULD
6 – COMPACTION DEVICE

TECHNOLOGY INTERACTION WITH McMASTER UNIVERSITY

HIGH PERFORMANCE CRUSHED ROCK

LLEXP IN CHINA

HIGH PERFORMANCE CRUSHED ROCK

RECOMMENDED DEFLECTION LEVELS (0.01 mm) BASED ON FWD TESTING FOR PAVEMENT CONSTRUCTION QUALITY CONTROL MONITORING EMBANKMENT CUT AND FILL SECTIONS

	Structural Layers	Upper HMA Course	Middle HMA Course	Lower HMA Course	Base	Subbase	Select Subgrade Materials
ACCEPTABLE	GOOD	≤ 20	≤ 24	≤ 28	≤ 72	≤ 83	≤ 126
ACCEPTABLE	FAIR	21-22	25-26	29-31	73-79	84-91	127-139
NOT ACCEPTABLE	POOR	≥ 23	≥ 27	≥ 32	≥ 80	≥ 92	≥ 140
	Design Deflection with Standard Loading (0.01mm)	Chinese Equation: 28.4 Asphalt Institute Figure: 28.0					
	Design Deflection with Overloading (0.01mm)	Chinese Equation: 20.5 Asphalt Institute Figure: 20.0					

1. THE FALLING WEIGHT DEFLECTOMETER (FWD) WITH 50 kN LOADING IS USED TO CHECK THE DEFLECTION ON TOP OF EACH STRUCTURAL LAYER.
2. DEFLECITON DATA OBTAINED BY BENKELMAN BEAN CAN BE CONVERTED INTO THE FWD DEFLECTION DATA USING THE FOLLOWING EQUATION:
   FWD DEFLECTION = BENKELMAN DEFLECTION/1.5
3. THESE ARE VERY STRICT ACCEPTANCE LEVELS.

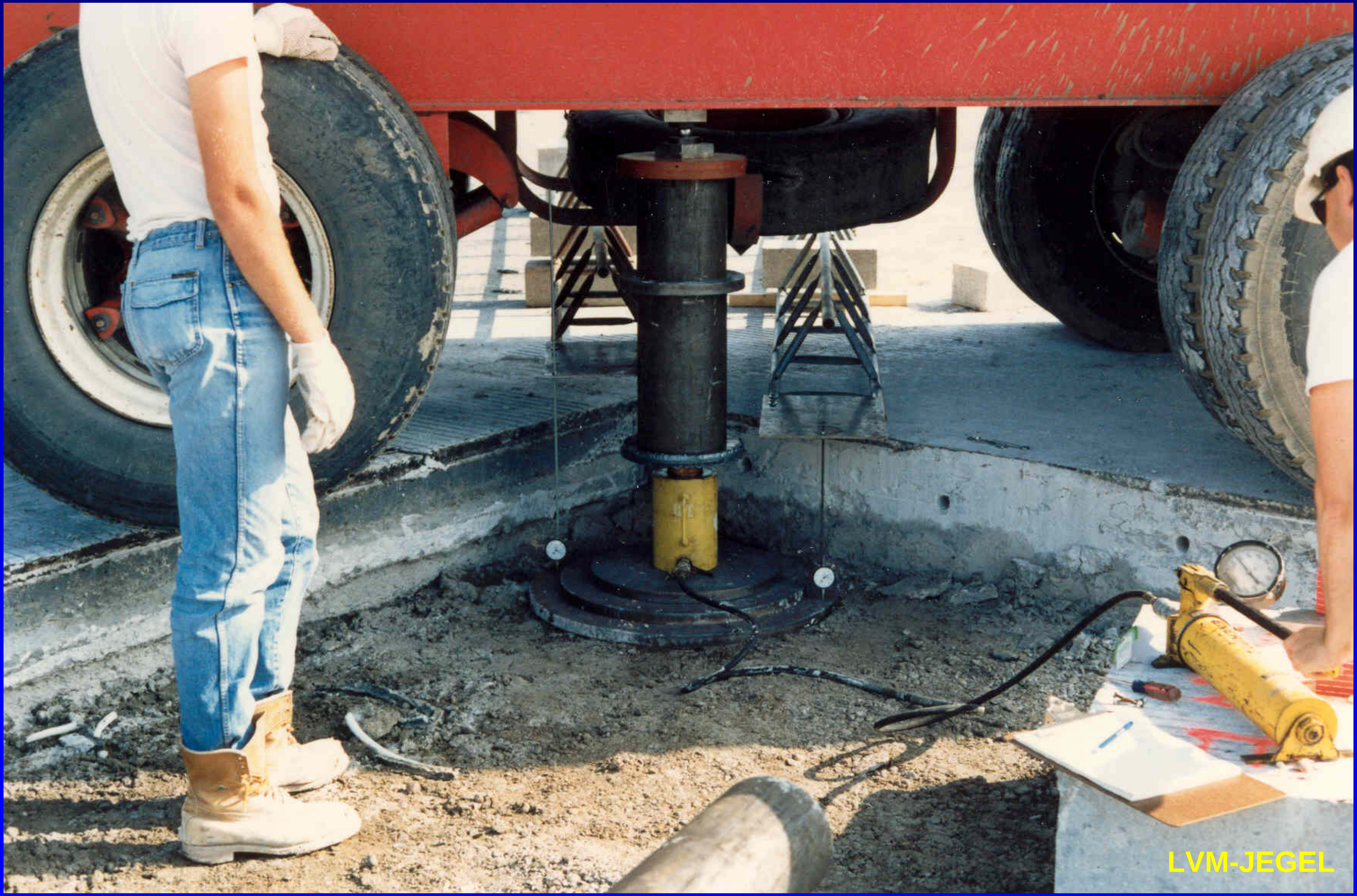
SUBGRADES AND SUBBASES
SUPPORTING STIFFNESS

THE QUANTITATIVE VALUE OF THE SUPPORT PROVIDED BY THE SUBGRADE WAS QUANTIFIED BY WESTERGAARD UNDER THE TERM "MODULUS OF SUBGRADE REACTION". THE MODULUS IS EXPRESSED IN EQUATIONS AS 'k' AND THE UNITS ARE POUNDS PER SQUARE INCH PER INCH (lbs/in^3 OR pci). THE UNITS ARE DERIVED FROM THE METHOD USED TO DETERMINE THE VALUE OF 'k'. THE STANDARD TEST FOR DETERMINING 'k' IS TO PLACE A LOAD ON A STANDARD 30-INCH DIAMETER STEEL PLATE, CALCULATE THE PRESSURE [LOAD DIVIDED BY AREA OF THE PLATE] AND MEASURE THE RATE OF DEFORMATION (ASTM D 1196).

HOWEVER THE STANDARD TEST IS VERY SELDOM UTILIZED. THE TESTING PROCEDURE IS INVASIVE, CUMBERSOME, AND LITERALLY CANNOT BE ACCOMPLISHED AT AN ACTIVE AIRPORT. THERE ARE, HOWEVER, OTHER WAYS TO DETERMINE THE SUBGRADE VALUE OF 'k'. EMPIRICAL RELATIONSHIPS ARE AVAILABLE THROUGH MANY SOURCES THAT EQUATE 'k' TO THE SOIL TYPE BASED UPON CLASSIFICATION OR CALIFORNIA BEARING RATIO (CBR) CORRELATIONS. THE MOST CONVENIENT METHOD FOR DETERMINING 'k' IS BY BACKCALCULATION FROM THE EVALUATION OF EXISTING PAVEMENTS USING THE FALLING WEIGHT DEFLECTOMETER (FWD) AND THE ASSOCIATED SOFTWARE.

(LAFRENZ)

SUBGRADES AND SUBBASES SUPPORTING STIFFNESS



TYPICAL PLATE LOAD TEST ON RUNWAY

Joint Spacing

- Temperature strain (curling stress), drying strain (warping stress), stress relaxation (creep), base restraint (friction stress), applied load (traffic), etc.

$$\ell = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$$

- Ratio of joint spacing to l between 4 and 6

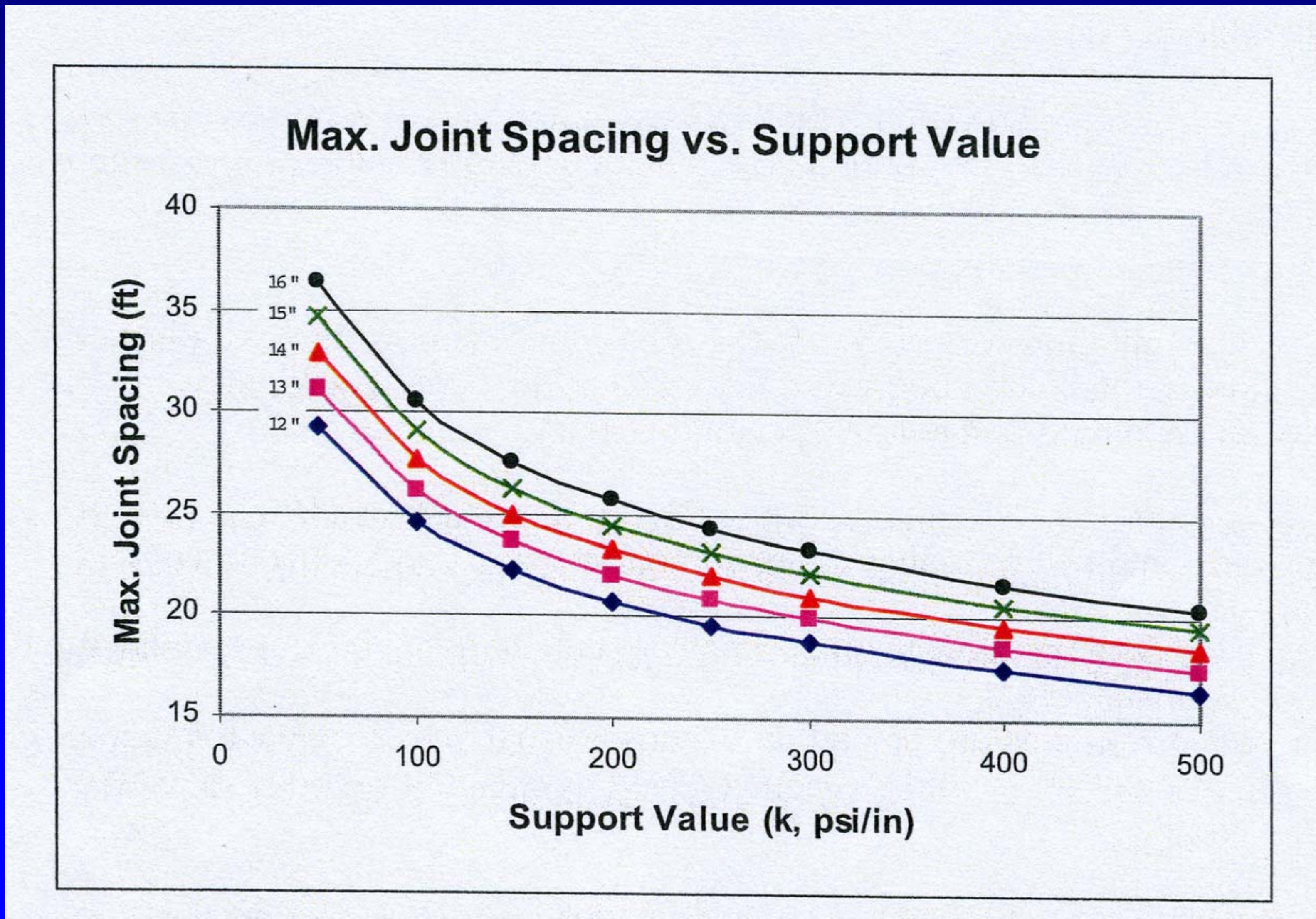
Effects of Stabilized Bases

Airport Pavement Design Seminar
August 24, 2009

ACPA

Robert Rodden
Director of Technical Services and Product Development

SUBGRADES AND SUBBASES
SUPPORTING STIFFNESS



MAXIMUM JOINT SPACING (6l) VERSUS SUPPORT VALUE (LAFRENZ)

SUBGRADES AND SUBBASES
SPECIAL SUBGRADE CONDITIONS

- EXPANSIVE SOILS
- FROST ACTION
- SOILS VULNERABLE TO PUMPING

EFFECTIVE MITIGATION OF EXPANSIVE SOIL CONDITIONS AND FROST ACTION IS ACHIEVED THROUGH SPECIAL SUBGRADE PREPARATION TECHNIQUES. THE PREVENTION OF PUMPING REQUIRES THE USE OF A SUBBASE LAYER.

(LAFRENZ)

SUBGRADES AND SUBBASES

STABILIZED SUBBASE MATERIALS

- SOIL CEMENT BASE COURSE (MIXED AT SITE)
- CEMENT-TREATED BASE (CTB) (CENTRAL PLANT MIX)
- ASPHALT-STABILIZED BASE (CENTRAL PLANT MIX)
- ECONOCRETE (READY MIX SUPPLIER)
- CEMENT-TREATED RECYCLED CONCRETE PAVEMENT (CENTRAL PLANT MIX)

KEY FACTORS TO CONSIDER IN THE SELECTION OF SUBBASE MATERIALS

- STRENGTH OF STABILIZED SUBBASE MATERIAL
- POTENTIAL BONDING OF PLASTIC CONCRETE TO SUBBASE
- JOINT SPACING (PANEL SIZE DIMENSIONS)

(LAFRENZ)

PAVEMENT JOINTS
JOINT TYPES

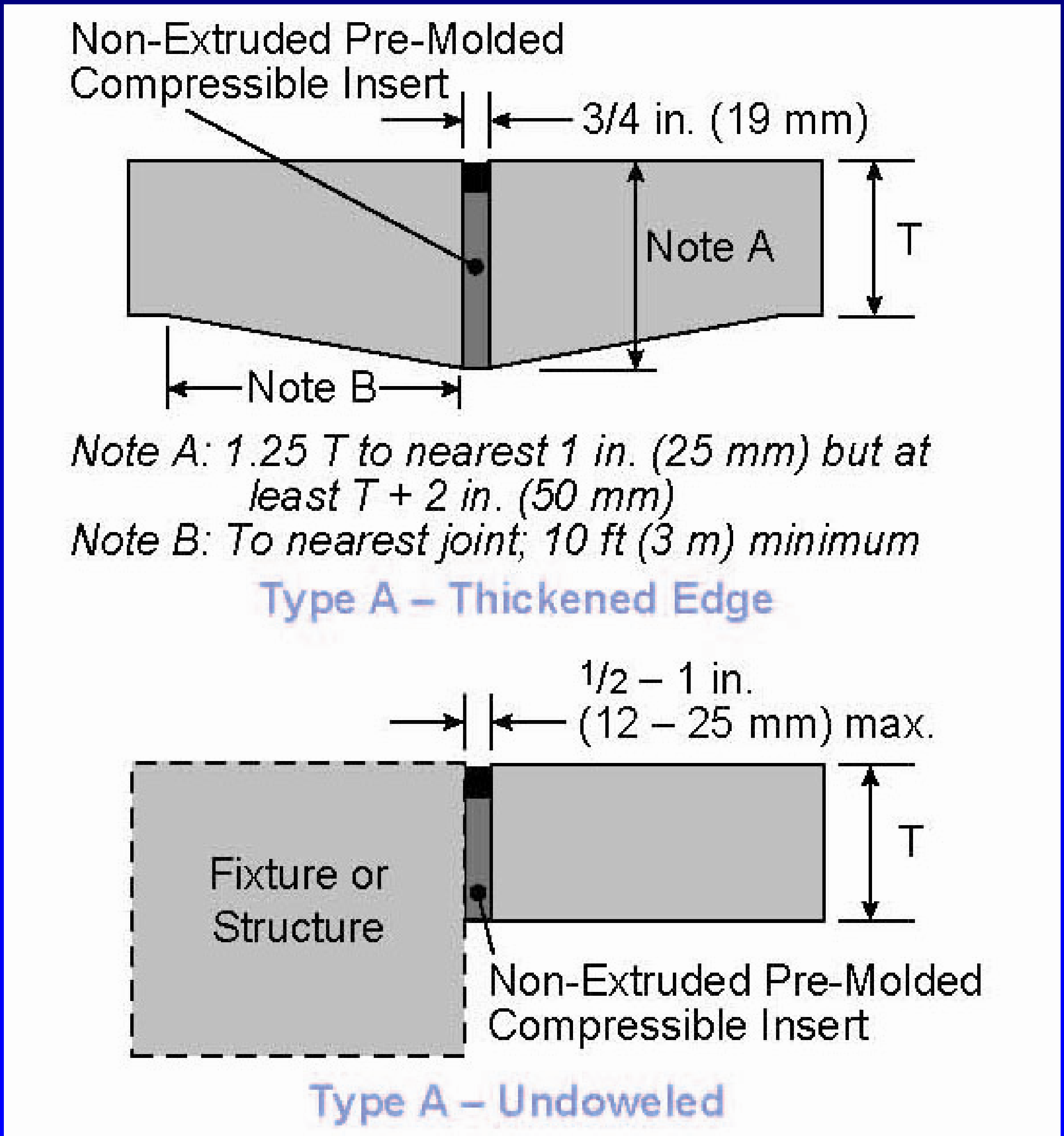
- **ISOLATION JOINTS**
- **CONTRACTION JOINTS**
- **CONSTRUCTION JOINTS**

CURRENT FAA – AIRPORT PAVEMENT DESIGN AND EVALUATION, FAA ADVISORY CIRCULAR AC 150/5320-6E, FEDERAL AVIATION ADMINISTRATION, WASHINGTON, D.C., 2008. DRAFT REVISION AVAILABLE FROM FAA.

CURRENT ACPA – AIRFIELD PAVEMENT JOINTS, JOINTING ARRANGEMENTS AND STEEL FOR AIRFIELDS SERVING AIRCRAFT LARGER THAN 100,000 lb (45,360 kg), ACPA, 2008. THERE ARE MANY EXCELLENT REFERENCES ON AIRPORT CONCRETE PAVING TECHNOLOGY AVAILABLE FROM THE ACPA, INCLUDING ONLINE COURSES.

(ACPA)

PAVEMENT JOINTS



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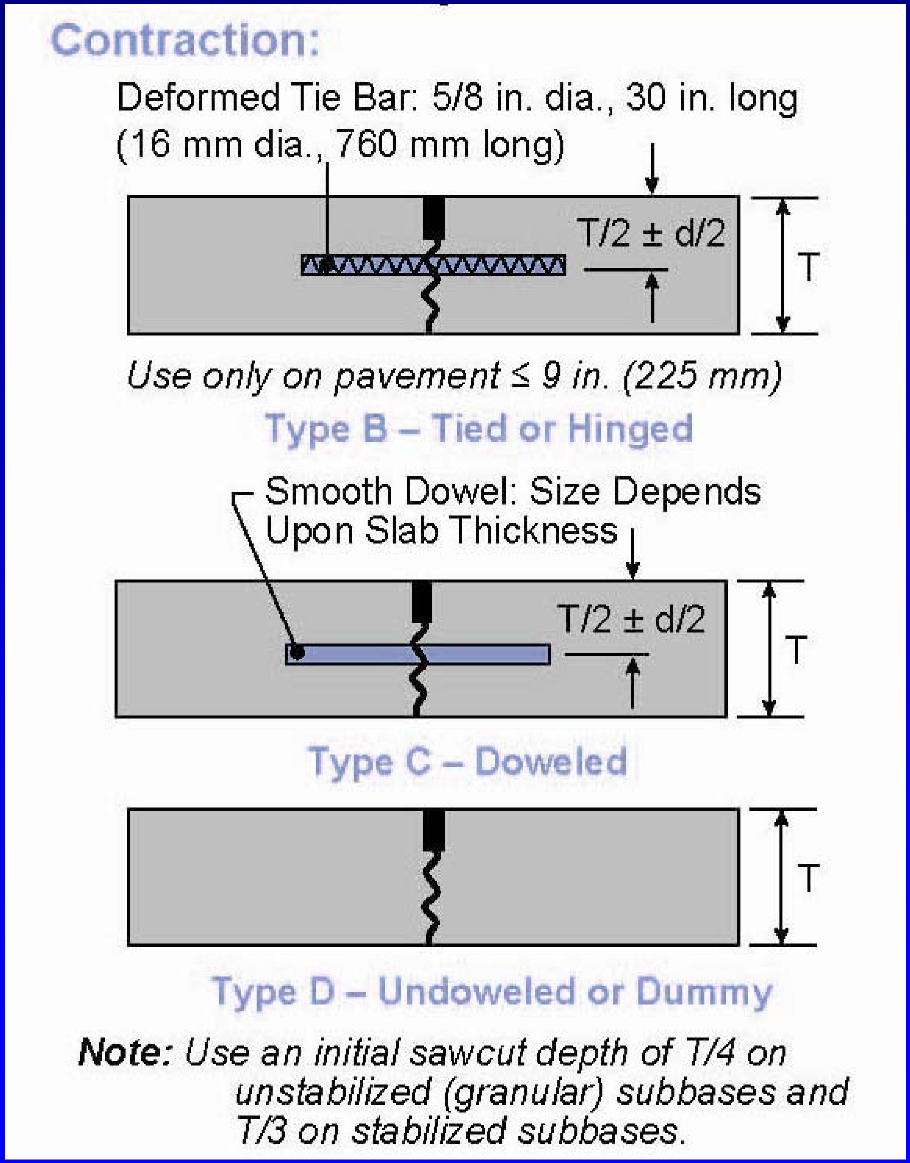
ISOLATION JOINTS

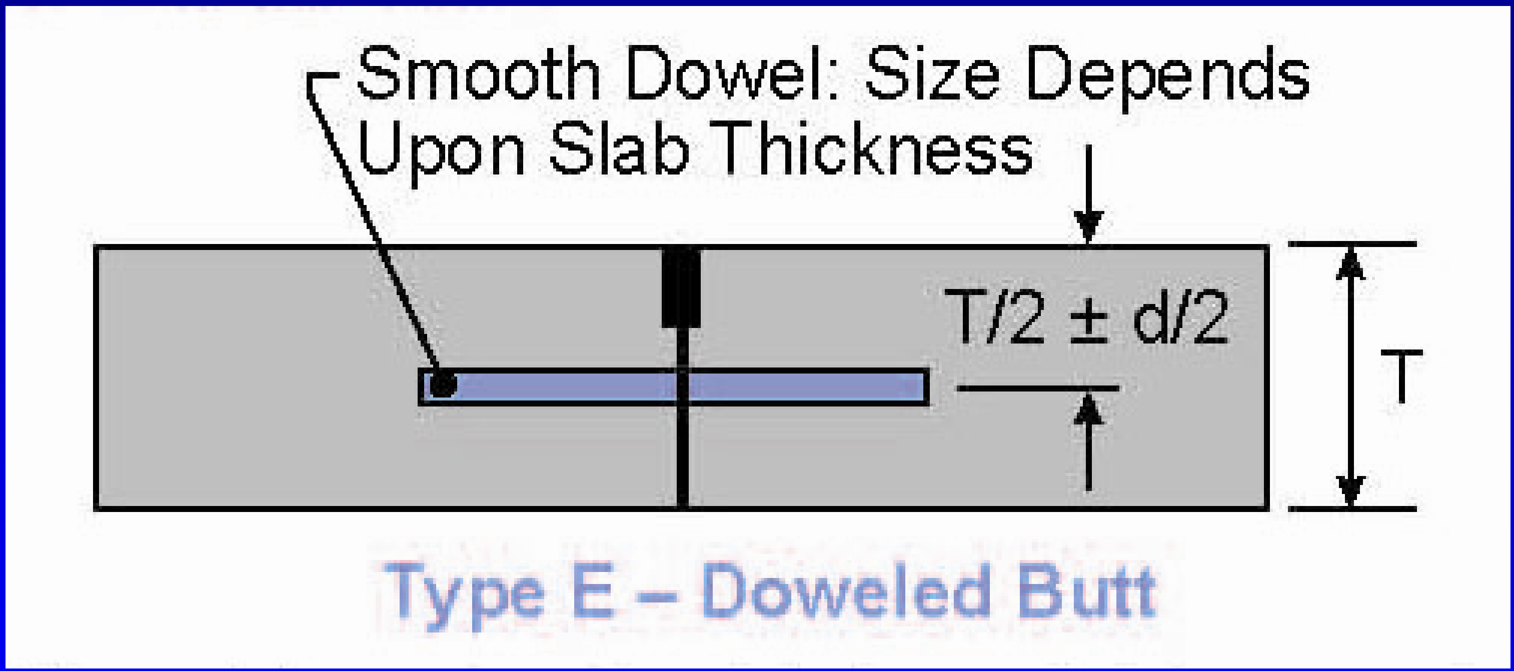
PAVEMENT JOINTS



(ACPA)

CONTRACTION JOINTS

PAVEMENT JOINTS



(ACPA)

LONGITUDINAL JOINTS
LONGITUDINAL JOINT SPACING

	Concrete Pavement on an Unstabilized (Granular) Subbase	
Slab Thickness	**Maximum Longitudinal Joint Spacing**	**Maximum Transverse Joint Spacing**
6 in. (150 mm)	12.5 ft (3.8 m)	12.5 ft (3.8 m)
7-9 in. (175-230 mm)	15 ft (4.6 m)	15 ft (4.6 m)
> 9 in. (230 mm)	20 ft (6.1 m)	20 ft (6.1 m)
	Concrete Pavement on a Stabilized Subbase	
Slab Thickness	**Maximum Longitudinal Joint Spacing**	**Maximum Transverse Joint Spacing**
8-10 in. (203-254 mm)	12.5 ft (3.8 m)	12.5 ft (3.8 m)
11-13 in. (279-330 mm)	15 ft (4.6 m)	15 ft (4.6 m)
14-16 in. (356-406 mm)	18.75 ft (5.7 m)	17.5 ft (5.3 m)
> 16 in. (406 mm)	20 ft (6.1 m)	20 ft (6.1 m)

(ACPA)

LONGITUDINAL JOINTS

LOAD TRANSFER AT LONGITUDINAL JOINTS

- ALL LONGITUDINAL CONSTRUCTION JOINTS SHOULD BE TYPE E DOWELED JOINTS (UNLESS THEY SERVE AS AN ISOLATION JOINT)
- FOR RUNWAYS AND APRONS WHICH ARE TYPICALLY WIDE PAVEMENT AREAS, UNDOWELED JOINTS (TYPE D) ARE ACCEPTABLE FOR INTERMEDIATE LONGITUDINAL CONTRACTION JOINTS, UNLESS THE JOINT IS ONE OF THE LAST THREE JOINTS BEFORE A FREE EDGE OR ISOLATION JOINT. FOR THIS EXCEPTION DOWELED JOINT (TYPE C) IS RECOMMENDED
- FOR ALL NARROW TAXIWAY PAVEMENTS (23 m OR LESS) ON UNSTABILIZED (GRANULAR) SUBBASES, AD THINNER THAN 230 mm, TIED JOINTS (TYPE B) ARE ACCEPTABLE FOR INTERMEDIATE LONGITUDINAL CONTRACTIONS JOINTS
- FOR TAXIWAY PAVEMENT GREATER THAN 230 mm, DOWELED JOINTS (TYPE C) ARE REQUIRED IN INTERMEDIATE LONGITUDINAL CONTRACTION JOINTS ADJACENT TO A FREE EDGE

KEYWAYS – KEYED CONSTRUCTION JOINTS SHOULD NOT BE USED IN AIRFIELD PAVEMENTS WITH LARGE AIRCRAFT OPERATIONS DUE TO THE POOR PERFORMANCE GENERALLY BEING EXPERIENCED. (ACPA)

TRANSVERSE JOINTS GENERAL

TRANSVERSE CONTRACTION JOINTS (TYPE C OR D) CREATE A WEAKENED PLANE AT PLANNED LOCATIONS PERPENDICULAR TO THE DIRECTION OF PAVING IN ORDER TO CONTROL WHERE CRACKS FORM. SAWING THE PAVEMENT CREATES TRANSVERSE CONTRACTION JOINTS AND THE SAW KERF DEPTH FOR CONTRACTION JOINTS IS MOST EFFECTIVE IF IT IS AT LEAST ONE-FOURTH OF THE SLAB THICKNESS. FOR CONCRETES MADE WITH HARD AGGREGATES AND FOR PAVEMENT CONSTRUCTED ON STABILIZED SUBBASE, A SAW KERF OF ONE-THIRD THE THICKNESS OF THE PAVEMENT IS MOST EFFECTIVE. (ACPA)

FAA RECOMMENDED MAXIMUM JOINT SPACING

	Concrete Pavement on an Unstabilized (Granular) Subbase	
Slab Thickness	Maximum Longitudinal Joint Spacing	Maximum Transverse Joint Spacing
6 in. (150 mm)	12.5 ft (3.8 m)	12.5 ft (3.8 m)
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(ACPA)

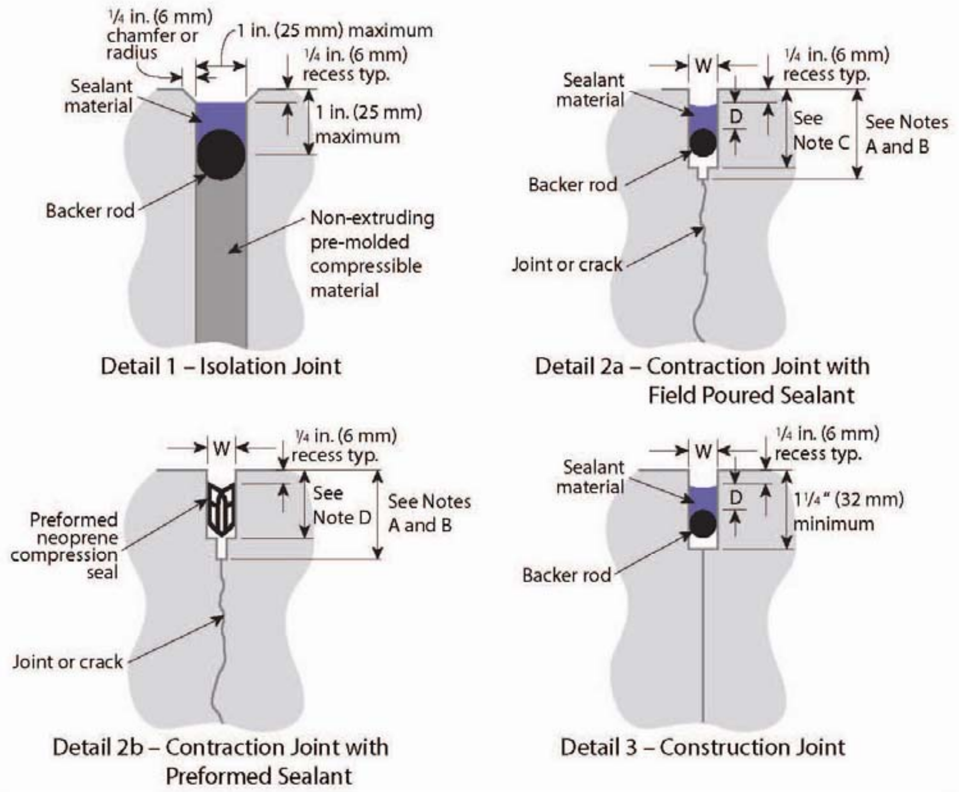
FAA RECOMMENDED DIMENSIONS AND SPACING OF SMOOTH DOWEL BARS

Slab Thickness	Dowel Diameter	Dowel Length	Spacing Between Bars
6-7 in. (150-180 mm)	3/4 in. (20 mm)	18 in. (460 mm)	12 in. (305 mm)
8-12 in. (210-305 mm)	1 in. (25 mm)	19 in. (480 mm)	12 in. (305 mm)
13-16 in. (330-405 mm)	1 1/4 in. (30 mm)	20 in. (510 mm)	15 in. (380 mm)
17-20 in. (430-510 mm)	1 1/2 in. (40 mm)	20 in. (510 mm)	18 in. (460 mm)
21-24 in. (535-610 mm)	2 in. (50 mm)	24 in. (610 mm)	18 in. (460 mm)

Note: The dowel sizes here are in the correct proportion to the load for which the pavement is designed. Because the pavement thickness is in proportion to anticipated loads, dowel size and spacing requirements also relate to pavement thickness. Condition surveys of existing pavements and extensive tests on full-scale slabs have shown no clear cases of dowel failure where the pavement slab itself is adequate for the loads carried.

(ACPA)

JOINT SEALS



Typical D/W ratios for poured sealants: 1 for hot-poured sealant; 0.5 for silicone sealant and two-component cold poured material. The lower the depth-to-width ratio or shape factor, the lower the strain on the sealant under a given joint movement. The required shape factor will depend on the properties of the sealant and the amount of joint movement. Joint movement is related to the joint spacing and to the maximum seasonal temperature change in the slab.

Preformed compression seal: Manufacturer's recommended W is sized for slab size and climate.

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 1.25 in. (32 mm) minimum for early-entry sawing.

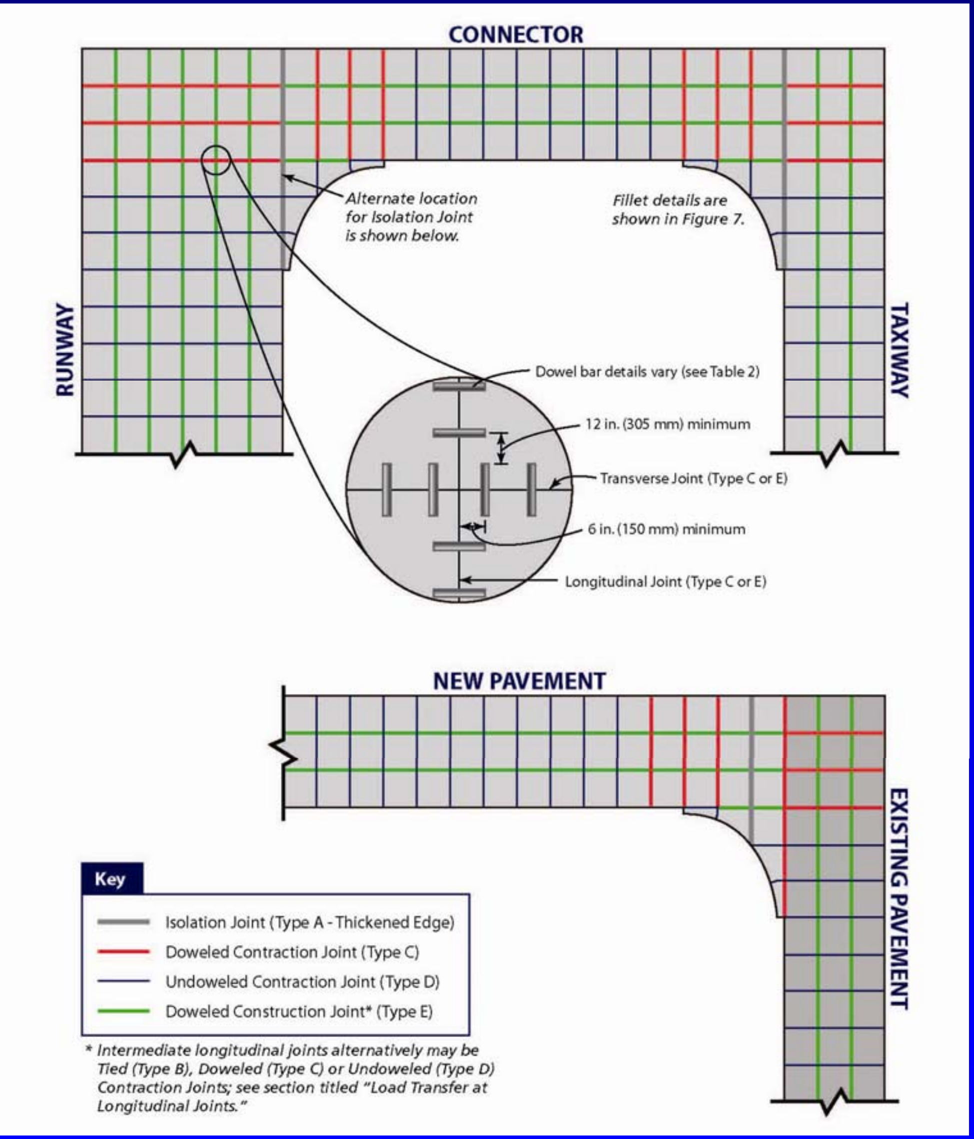
C - As required to accommodate sealant and backer rod. (May be deeper than initial sawcut in case of early-entry sawing).

D - As required by the manufacturer.

(ACPA)

JOINT SEALANT RESERVOIR DESIGN OPTIONS

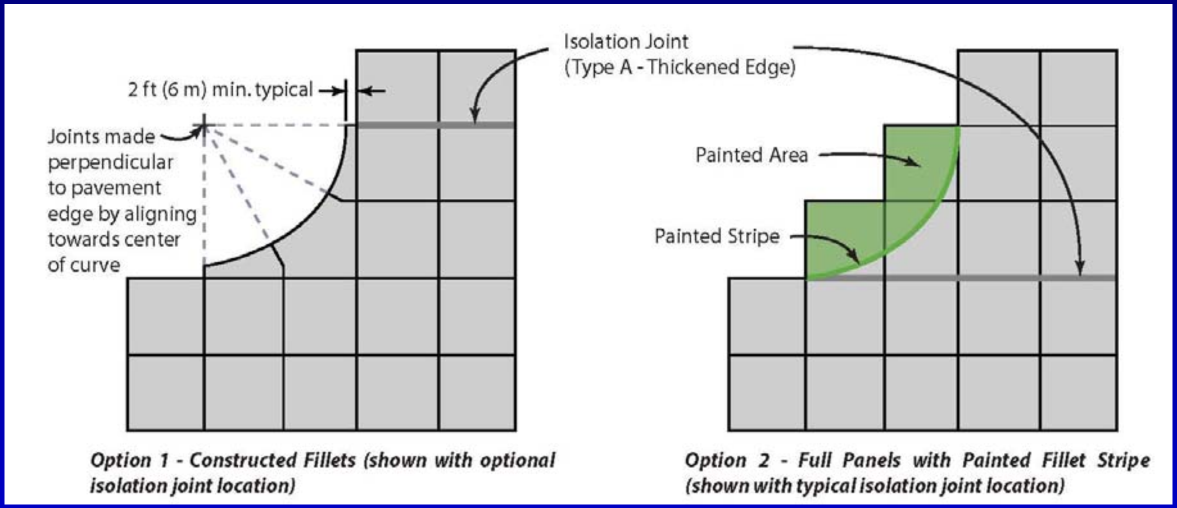
JOINT ARRANGEMENTS



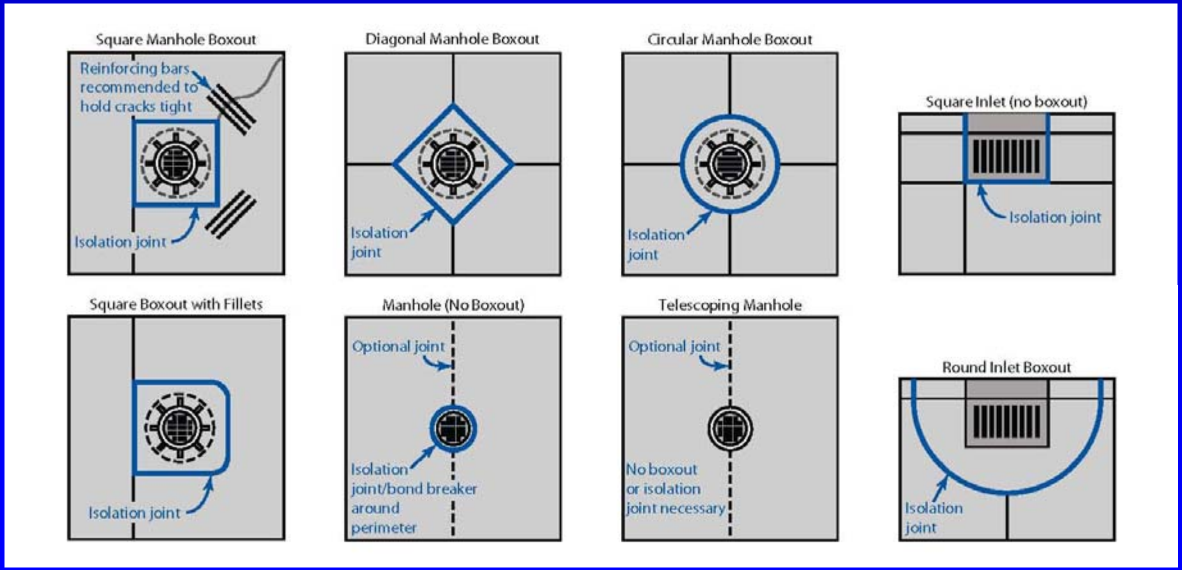
(ACPA)

TYPICAL JOINT ARRANGEMENTS FOR CONCRETE AIRFIELD PAVEMENTS

JOINT ARRANGEMENTS



OPTIONS FOR FILLET AREAS AT INTERSECTIONS



DETAILS FOR PAVEMENT BOXOUTS

(ACPA)

Layer Elastic Assumptions

- Homogeneous material
- Finite layer thickness
- Infinite subgrade thickness
- Isotropic layers
- Full friction developed between layers
- No shearing forces at the surface
- Stress properties are function of μ and E.

Methods of Thickness Design

- FAA Design Procedure – FAARFIELD
  - Layered Elastic Design for Flexible
  - Finite Element Analysis for Rigid
- U.S. Army Corp of Engineers
- For early opening to traffic…
  - Zero Fatigue stress
    - 300 psi and
    - Edge stress multiplied by 2.5 (stress ratio of 0.4)
  - ACPA Procedure (AIRpav 2000) or any other approved method

ACPA

Airport Pavements online

Introduction to Airport Pavement Design

Gary L. Mitchell, P.E.
Director of Airports and Pavement Technology

IPRF

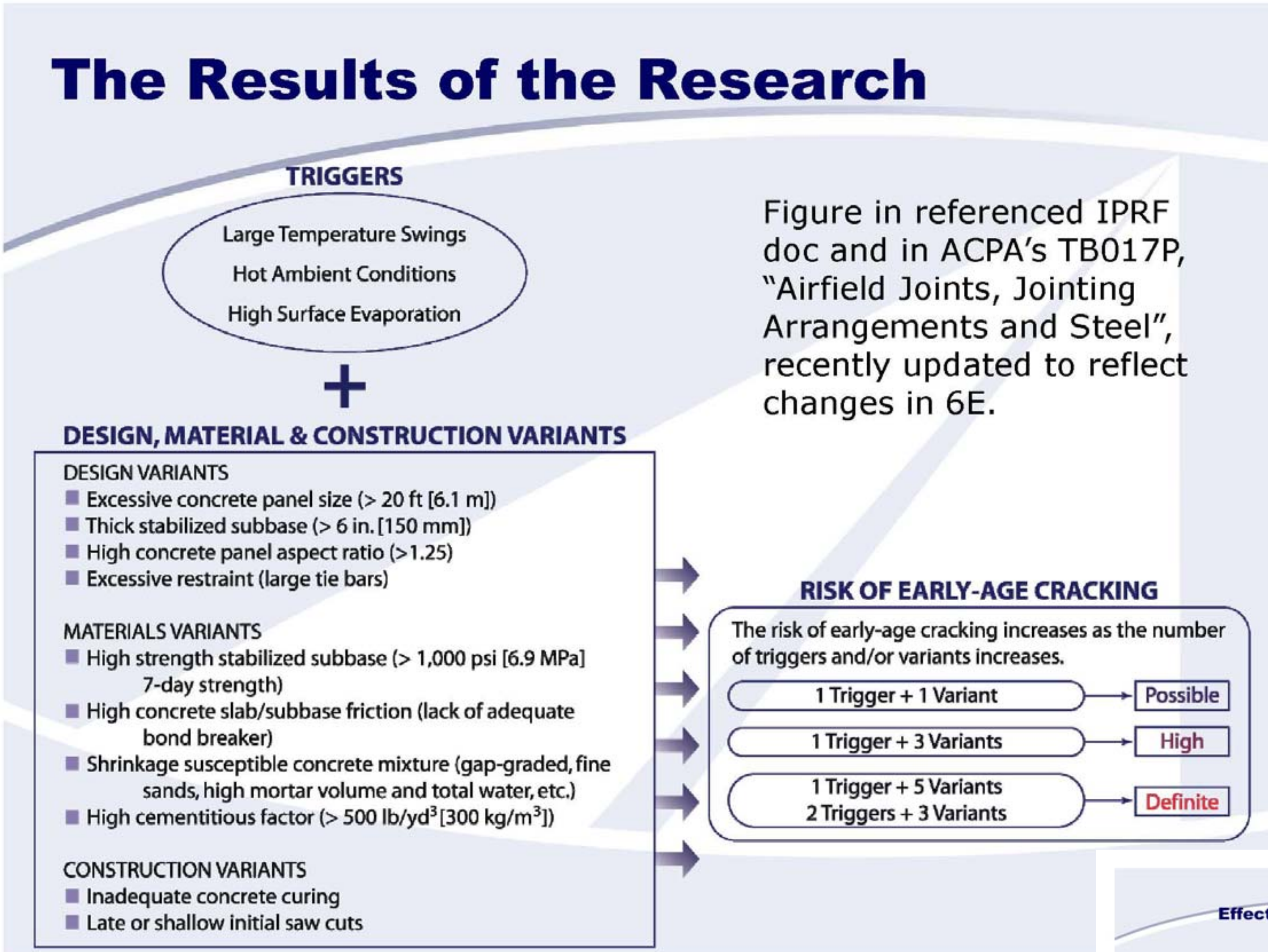


Figure in referenced IPRF doc and in ACPA's TB017P, "Airfield Joints, Jointing Arrangements and Steel", recently updated to reflect changes in 6E.

QUESTIONS ?

- PLACEMENT ADJACENT TO ASPHALT PAVEMENT?
- APRON PAVEMENT CONSIDERATIONS?
- EMBEDDED STEEL CONSIDERATIONS?
- IN-PAVEMENT LIGHTING CONSIDERATIONS?
- ETC?

FOR MORE COMPLETE DETAILS ON AIRFIELD JOINTS, JOINTING ARRANGEMENTS AND STEEL, PLEASE CONSULT THE EXCELLENT FAA AND ACPA TECHNICAL RESOURCES