Best Practices in Airfield Concrete Pavement Design and Construction

CAPTG Workshop

Calgary, Alberta

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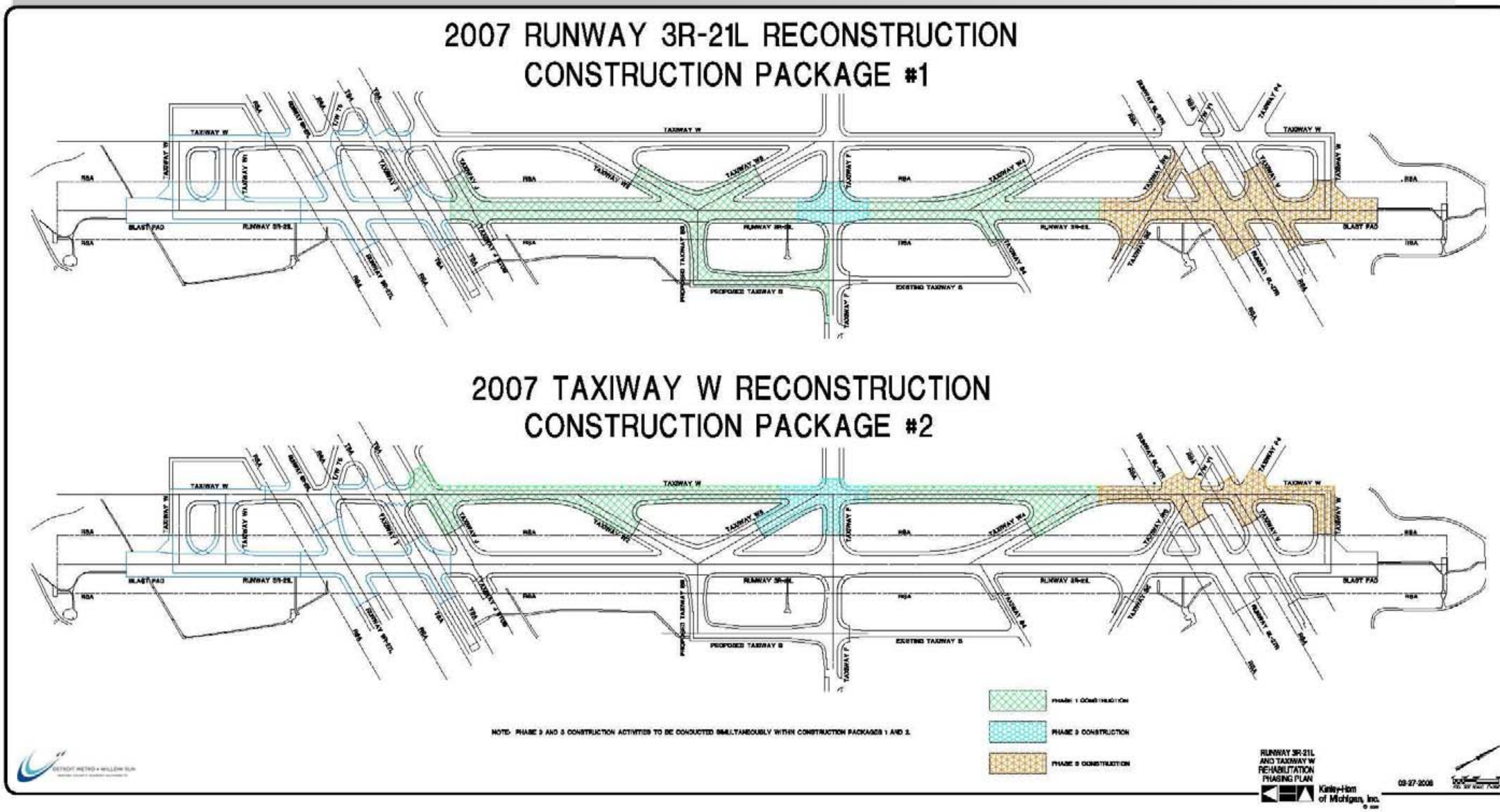
Count on Concrete

PAVEMENT

Planning for Construction

Design Phase



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An IPRF Research Report
Innovative Pavement Research Foundation
Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-02-3

Accelerated Practices for Airfield Concrete Pavement Construction—
Volume I: Planning Guide

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5420 Old Orchard Road
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Expectations

- Desired Characteristics
  - strength
  - durability
  - workability
- Which is better?
  - A well-built poorly designed pavement
  - A well-designed poorly built pavement

Planning Considerations:

- Coordination with stakeholders
- Identify Key Personnel
- Eliminate the Unknowns
  - Geotechnical

Geotechnical

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Utilities

Planning Considerations:

- Coordination with stakeholders
- Identify Key Personnel
- Eliminate the Unknowns
  - Geotechnical
  - Utilities
  - Weather

Weather

Procurement and Contracts

Deliver Options

Require Minimum Qualifications

Pre-Qualify Bidders Early

Early Procurement of Long Lead Items

Early NTP

Set Aside Funding for Contingencies

Bonus for Early or “on-time” Completion

Phasing and Scheduling

Time of Year/Week/Day

Minimize the Number of Phases

Overlap Phases

Alternate Facilities

Consider Wind Direction

Partial Use of Runway/Taxiway

Affects on Other Work

10 vs. 1

?


KOMATSU
C300LC
KOMATSU

Design Considerations

Alternative Designs (Pvmt. Section)

High-Early Strength Pavement

“What If” Contingencies

Critical Airport PCCP Design Features

- Subgrade support – uniformity & stability
- Base and subbase (uniformity, stability & drainage provisions)
- Slab thickness
- Concrete properties - (uniformity, workability, strength, & durability)
- Jointing details (layout, load transfer, & sealing)

Planning for Construction

Construction Phase

Quality Concrete

- Quality is not about Strength
- Quality is not about proper air content
- Quality is not about “slump” of plastic concrete
- Quality is not about 100% Inspection

Safe, durable, free of defects

Workability

Summary - Cost of Poor Quality

- For airport owner
  - Operational delays & loss of revenues
  - Cost of claims (litigation)
  - Reduced service life
- For contractor
  - Corrective measures
  - Partial payments
  - Cost of claims (litigation)
  - Liquidated damages

Variability

- Inherent part of any construction process.
- Sources of construction variability
  - Material
  - Process
  - Testing (precision and bias)
- Negative impact on the property being measured.

Understand the magnitude of the different sources of variability and attempt to reduce each type of variability.

GUIDELINES FOR REASONABLE LEVELS OF CONSTRUCTION VARIABILITY

(In terms of acceptable standard deviation)

- Subgrade Density (standard Proctor test): 1 to 3 lb/cu. ft (for uniform subgrade type)
- Base/Subbase Density (modified proctor test): 1 to 3 lb/cu.
- Concrete Thickness: 0.25 to 0.50 in.
- Concrete Flexural Strength (650 psi concrete): 40 to 60 psi
- Concrete fc (4,000 psi concrete): 300 to 500 psi
- Concrete Air Void (6% air void concrete): 0.5 to 1.0 %
- Pavement Smoothness ?????
- Grade/straight edge: 0.2 to 0.3 in.

Higher levels of variability may indicate that the construction process is not under control or testing procedures are marginal

.

Role of Construction Specifications

- Establish the acceptable parameters
  - Civilian: Based on FAA AC150/5370-10A
  - Military: 2003 Unified Facilities Criteria document
- May be prescriptive and/or end-result based
- Provide guidance/requirements for:
  - Materials
  - Construction methods
  - Methods of measurement for compliance with specs
  - Testing requirements
  - Basis of payment

Pre-Bid Activities

- Project overview
- Administrative/contractual details
- Construction scheduling & phasing
- Contractor's access to site & staging area
- Addendums to plans & specifications, if any
- Detailed review of project scope of work
- Bidder's questions
- Site visit

(THIS IS THE TIME TO RESOLVE ANY QUESTIONS/CONCERNS OF THE CONTRACTOR)

Partnering

- A joint meeting between QC and QA reps before construction starts
  - Review project requirements
  - Review action and suspension limits
  - Identify & clarify gaps and ambiguous items
  - Review handling of non-conforming test results
  - Review chain of command for decision making
  - Establish QA/QC data management & data review plan
- Designer, Owner, Program Manager, Contractor

Construction Logistics

- Readiness of all operations
- Concrete plant setup & readiness
- Haul roads availability
- Availability of crews, equipment, & materials
- Subcontractor readiness
- Construction and airport traffic management
- Concrete placement needs (rate of placement)
- Electrical items needs
- QA/QC requirements & backup testing equipment
- Project phasing, if any

Opening to Traffic Issues

- Typically construction related and not aircraft traffic related.
  - Develop specific criteria
    - typical construction equipment
    - different concrete pavement thickness and
    - for edge and interior loading.
  - Consider trade-offs between
    - higher strength requirement and
    - extra thickness
    - Optional base type
  - Develop alternate designs for fast track areas.

Lead Time – ASR & F-T Testing

- ASTM C 1260 (ASR) - 16 days for testing.
- ASTM C 1293 (ASR) - 1 year to test aggregate for potential reactivity; 2 years to test effectiveness of mitigation measures.
- ASTM C 666 (F-T) - 2 to 3 months.
- Modified ASTM C 1260

Notes:

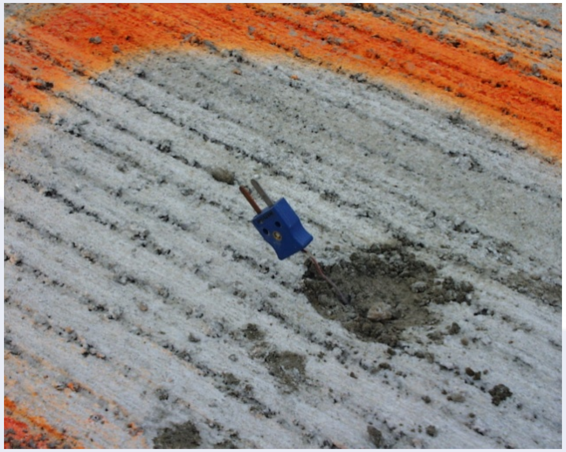
1. About 60 days is available from contract award to start of work, so aggregate acceptance needs to be done within that time or before award.
2. ASTM C 1260 can be used to test the effectiveness of mitigation measures. Several combinations of cementitious materials can be tested simultaneously.

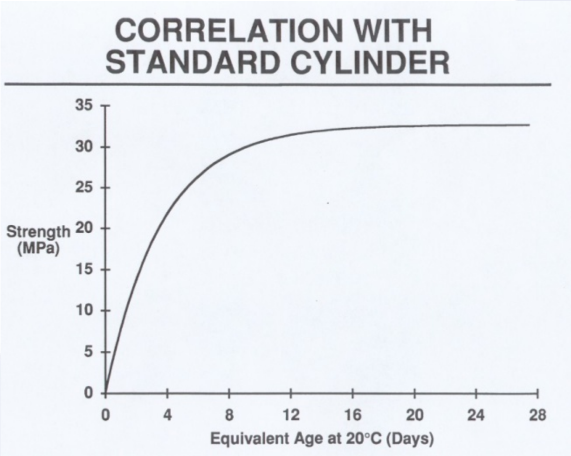
Acceptance Criteria

- (Slump and air content) **
- Flexural strength
- Thickness
- Smoothness
- Grade (lateral & vertical deviations)
- Edge slump
- Dowel bar alignment

Test Strip

- Used to evaluate concrete batching, transporting, placement, finishing, curing & QA/QC
  - Photos of acceptable and unacceptable sawcuts
  - Establish/validate maturity data or NDT for sawcutting





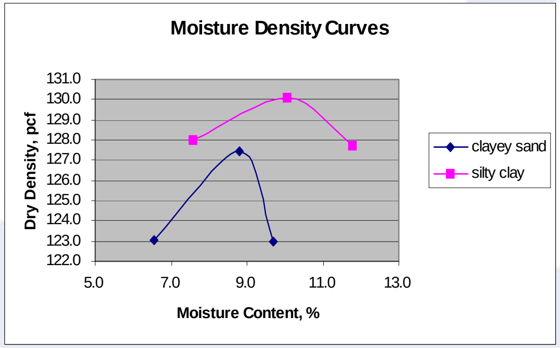
Subgrade Issues

- A critical construction item
  - For long-term pavement performance
  - For construction platform
- For difficult soil conditions, consult geotechnical engineer experienced in local soils
- Areas of concern
  - Variability of soils
  - Soils exhibiting construction-time problems – may affect fast track timetable
  - Swelling & frost susceptible soils
  - Drainage requirements

(If subgrade is not compacted well, then base/subbase cannot be compacted well)

Subgrade Issues

- Proper Compaction
  - Assess moisture sensitivity of subgrade material
- For difficult soils, consider
  - Replacement with better fill material
  - Subgrade modification with lime or cement
- Grade tolerances – ensure correct grade



Subgrade Stabilization

- Stabilize subgrade to
  - Improve low strength soil (CBR<5)
  - Reduce swelling potential
  - Improve construction conditions
- Methods
  - Lime stabilization
  - Cement stabilization

Proof-Rolling – good practice

(For Stabilized ?)

Subbase Issues

- To protect subgrade from frost and to provide drainage above the subgrade
- Subbase – granular (CBR = 20 to 100)
  - Limit passing #200 to 3 to 5 % (frost areas)
  - Develop moisture-density relationships
  - Moisture control is key to compaction
  - Grade tolerance important – use auto-trimmers for larger projects

Stabilized Bases

- Stabilized bases – CTB, LCB (econocrete), ATB, PATB
  - Strength issue for CTB/LCB – specify min/max values
  - Base stiffness affects pavement performance
  - Potential for random cracking increases

Stabilized Bases - CTB

- CTB
  - Mixed in a central mixing plant
  - 7-day fc = 750 psi
  - Pass F-T durability test for freezing environments
  - Compact mix within 60 minutes of mixing
  - Achieve a density of 97 to 98% of maximum
  - Minimize no. of construction joints
  - CTM must be cured – usually with an asphalt emulsion
  - Protect seal during curing period

DO NOT PLACE CTB IF IT CANNOT BE COVERED WITH THE PAVEMENT IN A FREEZING ENVIRONMENT. IF BASE MUST BE LEFT EXPOSED, IT SHOULD BE COVERED WITH SOIL TO PROTECT THE LAYER.

Base Tolerances

- Enhance pavement performance
- Minimize loss of concrete
- Minimize/eliminate pavement thickness PWL penalties
- Enhance pavement smoothness

Base – Drainage Layers

- To use or not to use?
- Military designs typically require use of a drainage layer – typically 4 to 6 in. thick
- Unstabilized layers should be avoided
- PATB most commonly specified
  - Use stabilized base under PATB
- Understand effect on "window of joint sawing opportunity" if permeable base is used

(Note: stability is more important than porosity – very high drainability is not necessary)

Concrete Plant Checklist

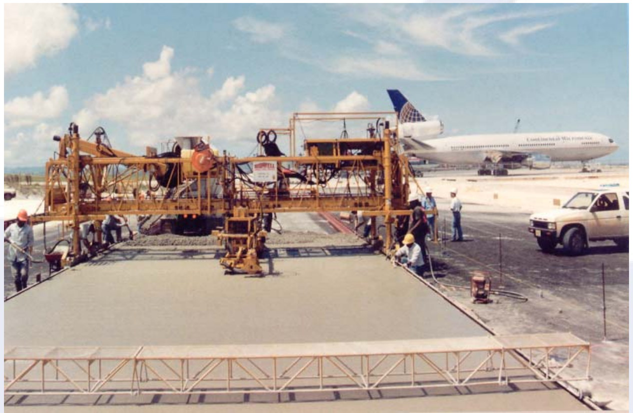
- Foundation of stockpiles - stable/well drained
- Stockpiles – minimize segregation, contamination
- Aggregate moisture content control
- Bins – minimize intermingling of particles

Slipform Pavers

- Self propelled with two or four tracks
- Weight > 2,000 lb/ft width
- Variable speed hydraulically controlled internal vibrators
- Can carry a head of concrete in front of screed
- Continuous auger/plow pan to distribute concrete
- Finishing attachments

Bridge Deck Pavers

- Truss system with suspended screw auger to spread concrete, oscillating vibrator & a roller
- Ride on forms or self propelled wheels
- One or two vibrators that move transversely
- Do not carry a head of concrete
- Weigh < 1,000 lb/ft width



Light Weight Finishing Machines

- Truss screed or roller screed
- Typically used for thin pavements or non-critical small areas
- Requires manual strike-off, manual vibration, and considerable bull-floating behind screed
- Excessive mortar at surface = poor air void system

Manual Paving

- Labor intensive
- Used for small areas only

Critical Factors for Concrete Paving

- A good concrete mixture
- A good grade & trackline for paving
- Stringline management
- Continuous supply of concrete to paver
- Consistent concrete workability
- Well maintained paving equipment
- Proper operation of paving equipment
- Controlled density of concrete – just the right vibration & finishing
- A skilled and dedicated crew

String-line Management

- Important for final surface smoothness
- Provides accurate reference for elevation and alignment control of all grade operations
- Stakes $\leq$ 25 ft
- Stringless Pavers?

STRINGLINE AIDS
- Use rigid stakes
- Use quality line
- No perceptible sagging
- Eyeball for staking errors
- Re-survey staking errors
- Monitor & maintain line

Concrete Placement

- Deposit concrete as close to paver as possible
- Avoid stop & go operation
- Maintain uniform speed
- Maintain uniform head
- Manage/monitor vibration
  - Check for vibrator trails
- Maintain steady concrete delivery
  - Number of trucks
- Proper distribution

Concrete Placement Issues

- Proper vibration effort
  - Consolidation Control
  - Provide surface fines for a tight finish
- Concrete dumping
  - In front of paver – better – can control control concrete head better, but dowel basket caution
  - Side loading belt placer or spreader
- No water addition
- Voids along slipformed sides

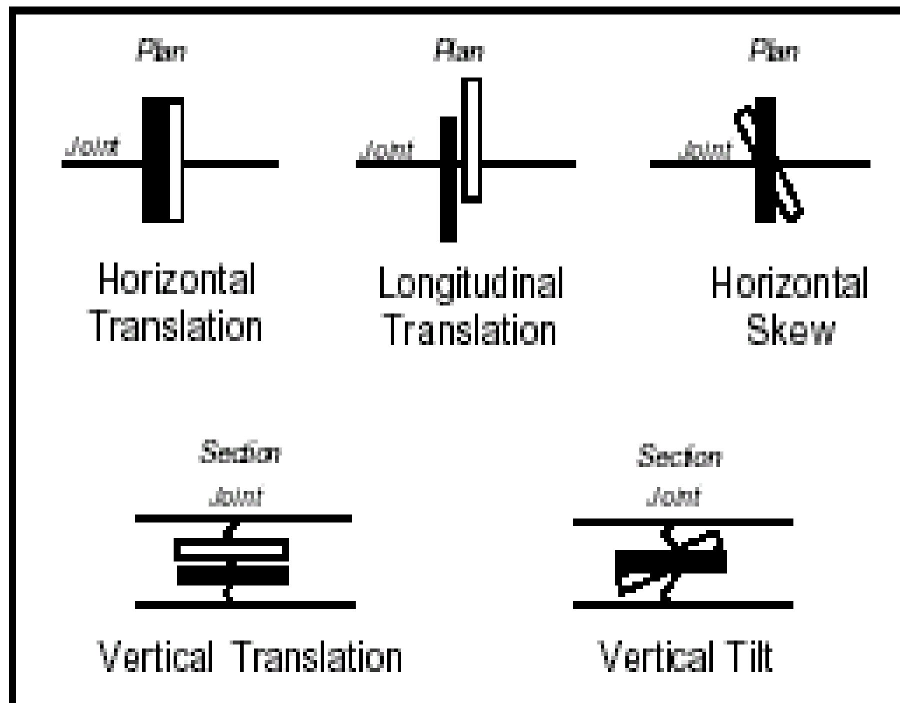
Dowel Bar Installation

- Transverse joints
  - Pre-positioned using baskets
  - Placed using DBIs
- Longitudinal joints
  - Drilled & grouted in hardened concrete
  - DO NOT USE INJECTORS
- Plastic Inserts

Dowel Bar Misalignment

Type of Misalignment	Effect on Spalling	Cracking	Load Transfer
Horizontal Translation	—	—	yes
Longitudinal Translation	—	—	yes
Vertical Translation	yes	—	yes
Horizontal Skew	yes	yes	yes
Vertical Tilt	yes	yes	yes

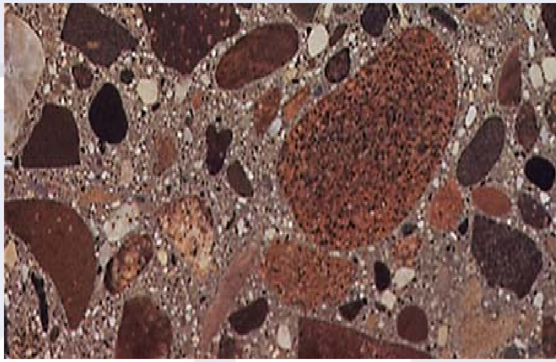
Categories of dowel misalignment are illustrated below.

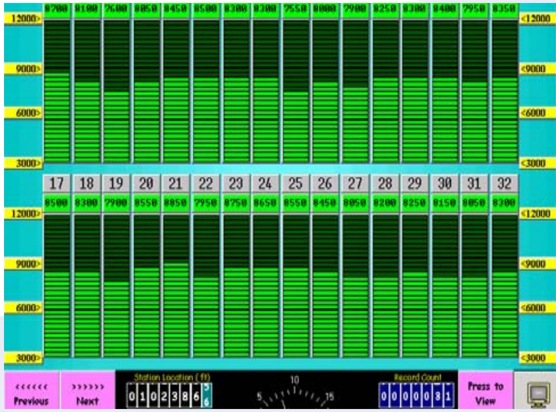


Misalignment categories.

Concrete Consolidation

- Inadequate consolidation
  - Lower in-place concrete strength
  - Honey-combing
- Over-consolidation
  - Poor air void system
  - Less durable concrete
- Monitor vibration effort regularly
  - vibrator smart system recommended – continuous monitoring





Poor Consolidation

Finishing Operations

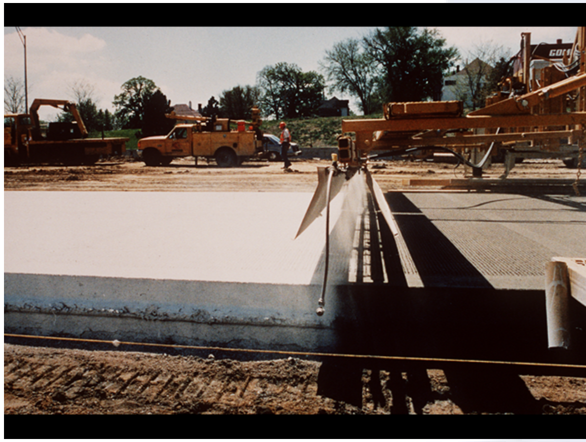
- Minimal hand finishing – do not over-finish
- Longer straight edges = smoother surface
- Little if any water added to facilitate finishing – if used, it should be fogged, not sprayed
- PCCP smoothness & surface durability depends on skill of finishers

Finishing Operations

- Finishing needs are minimized by
  - A workable mixture
  - Proper paving equipment operation
- Excessive hand finishing will work water to the surface

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



Paving Around In-Pavement Structures

- Lights, hydrant pits, utility manholes & drainage structures (trenches)
- Properly planned for and executed – consider during design phase
- For light cans, methods include
  - Blockouts
  - Split can & coring

Paving Around In-Pavement Structures

- Design layout - minimize interference with joints
- Account for expansion
  - Use isolation joints at/around in-place structures
  - Stiffen trench drain walls to resist expansion forces

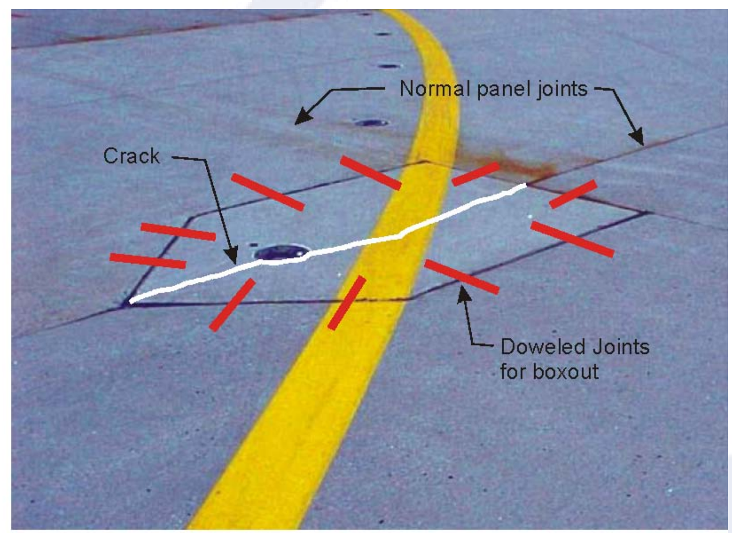


Figure 3.2 – Defective Boxout - Doweled Joints All Sides.

Hot-Weather Concreting

- Applicable when air temp. > 77 F for 3 days
- Potential problems
  - Rapid slump loss; Reduced air content
  - Premature stiffening; Plastic shrinkage cracking
  - Thermal cracking
- Use of less cement & more supplementary cementing materials (slag, Class F FA, etc)
  - Reduce heat of hydration
  - Class C FA not recommended
- Adjust admixture dosage

Cold-Weather Concreting

- When daily temp. < 40 F for 3 days
- Potential problems
  - Delayed set time
  - Slower rate of strength gain
  - Delay in saw-cutting – potential for cracking
- Maintain concrete temp. > 50 F for > 72 hours
- Use more cement & less slow-reacting supplementary cementing materials
- Joint sawing & opening to traffic may be delayed
- Verify in-place strength gain using maturity meter, cores or NDT before opening to traffic

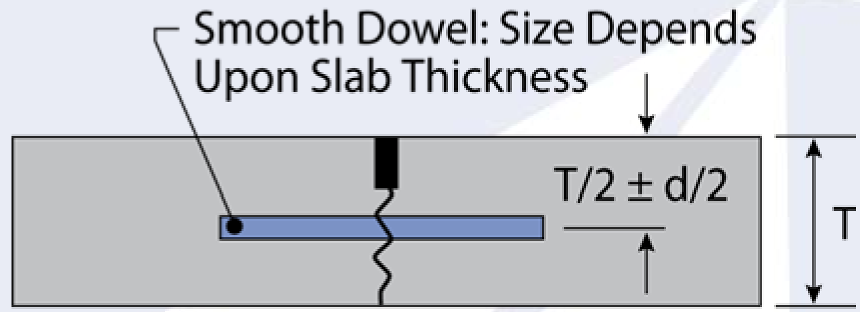
Protection of Concrete Against Rain

- Establish procedures to follow in case of impending rain
  - Stop paving operation ASAP
  - Cover freshly placed concrete
  - Do not remove excess water before covering
- Damage due to rain
  - Surface damage – wash away of paste
  - Rapid cooling - potential for cracking & greater slab curling
- Evaluate rain damage by examining & testing core samples – effect on durability

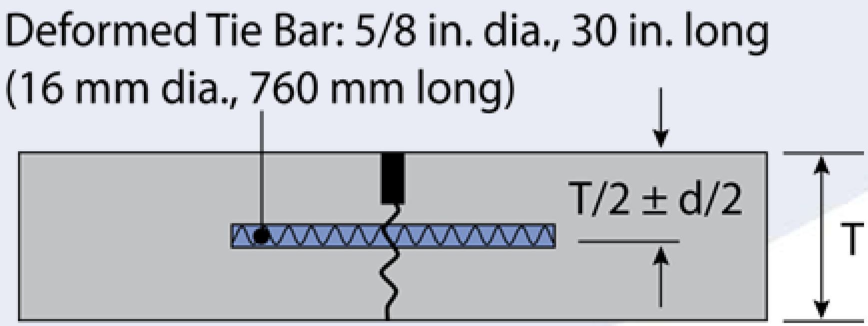
Joint Sawing & Sealing

- Joint sawing & sealing is an art & not an exact science
- Requires experienced crew
- Sawing and sealing operation effectiveness
  - Understand window of opportunity
  - Understand sawing process
    - Blade type & speed of sawing vs. aggregate type
  - Maintaining a clean reservoir
  - Correctly installing sealant material

Contraction Joints

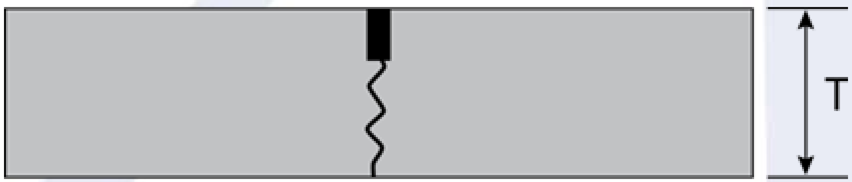


Type C – Doweled



Use only on pavement ≤ 9 in. (225 mm)

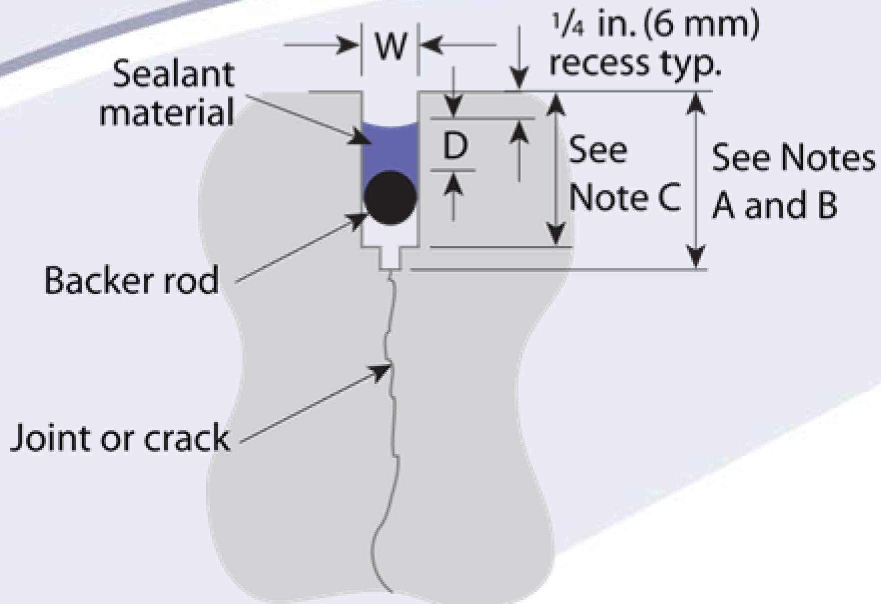
Type B – Tied or Hinged

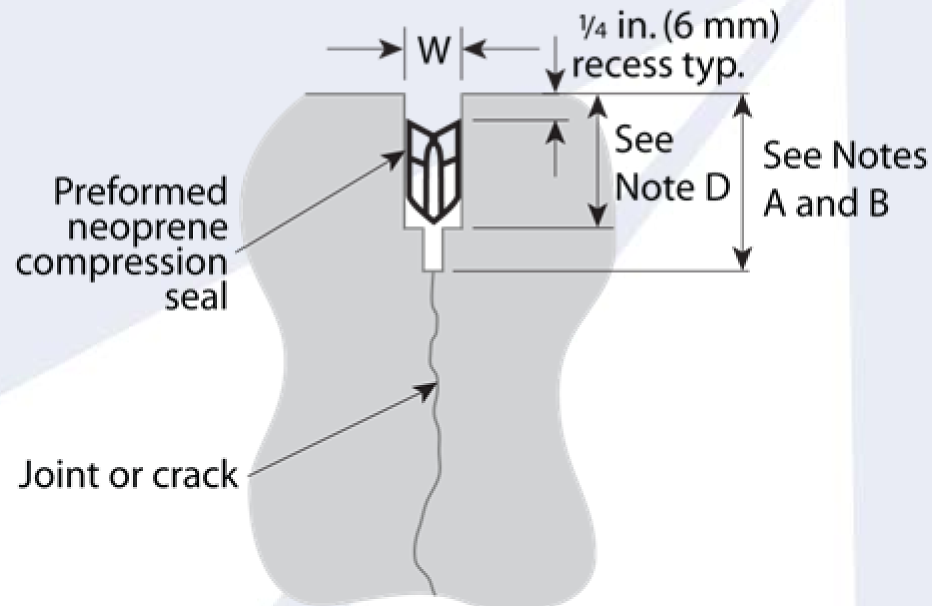


Type D – Undoweled or Dummy

- Note: Use an initial sawcut depth of T/4 on unstabilized (granular) subbases and T/3 on stabilized subbases.

Contraction Joints



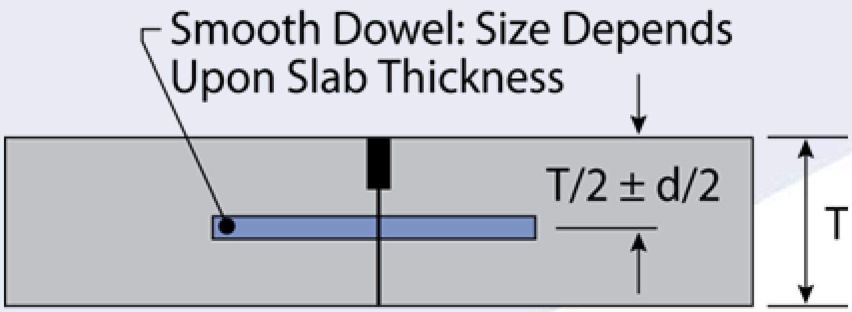


- Notes:
  - A - Initial cut to a depth of T/4 or T/3 as required for conventional sawing.
  - B - Initial cut to a depth of 1.25 in. (32 mm) minimum for early-entry sawing.
  - C - As required to accommodate sealant and backer rod. (May be deeper than initial sawcut in case of early-entry sawing).
  - D - As required by the manufacturer.

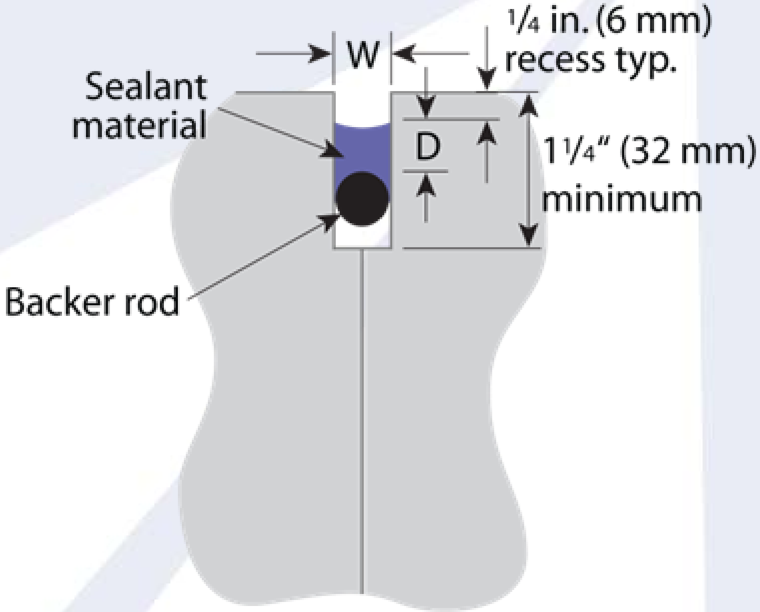
DBI Method for Dowels


PMC1511

Construction Joints



Type E – Doweled Butt



- Typical D/W ratios for poured sealants:
  - 1 for hot-poured sealant;
  - 0.5 for silicone sealant and two-component cold poured material.

Airport Dowel Dimensions

Joint Steel For Rigid Pavement

Dowels

DIMENSIONS AND SPACING OF STEEL DOWELS

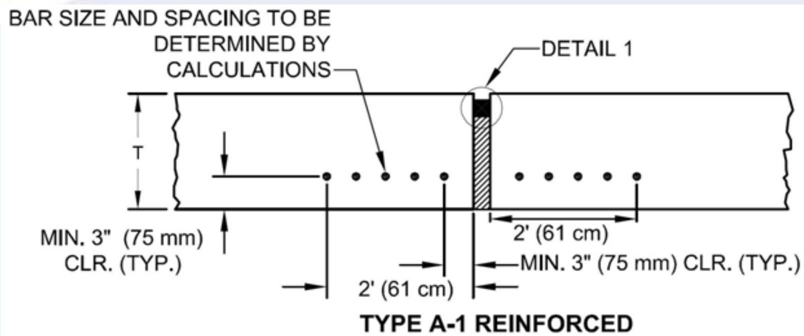
Thickness of Slab	Diameter	Length	Spacing
6-7 in (152-178 mm)	¾ in[1] (20 mm)	18 in (460 mm)	12 in (305 mm)
7.5-12 in (191-305 mm)	1 in[1] (25 mm)	19 in (480 mm)	12 in (305 mm)
12.5-16 in (318-406 mm)	1 ¼ in[1] (30 mm)	20 in (510 mm)	15 in (380 mm)
16.5-20 in (419-58 mm)	1 ½ in[1] (40 mm)	20 in (510 mm)	18 in (460 m)
20.5-24 in (521-610 mm)	2 in[1] (50 mm)	24 in (610 mm)	18 in (460 mm)

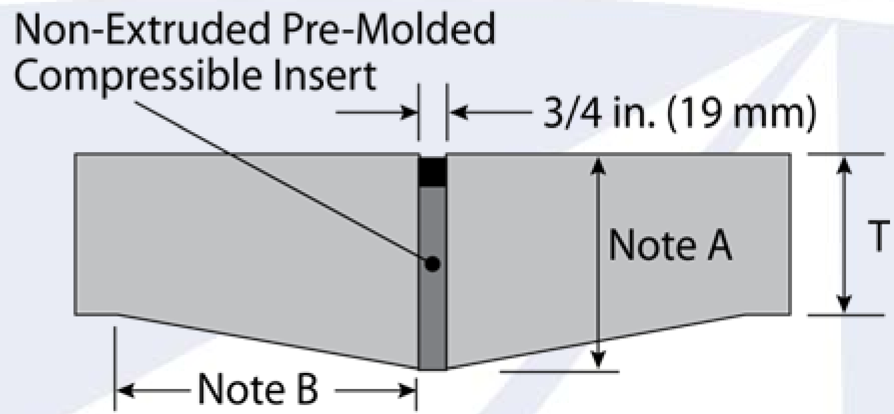
[1]Dowels noted may be solid bar or high-strength pipe. High-strength pipe dowels must be plugged on each end with a tight-fitting plastic cap or mortar mix.

Isolation Joints

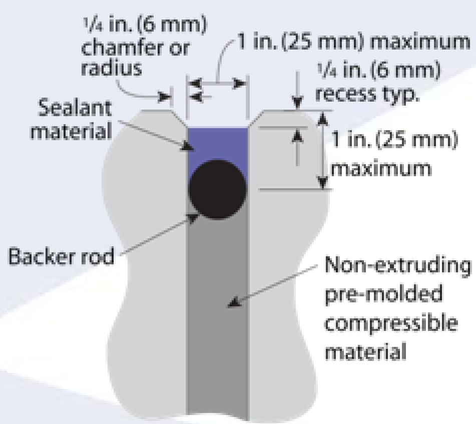
- Separate pavement segments of dissimilar movement (axis)
  - use bird’s eye view
- Where future pavement might be expected
- At Pavement Penetrations

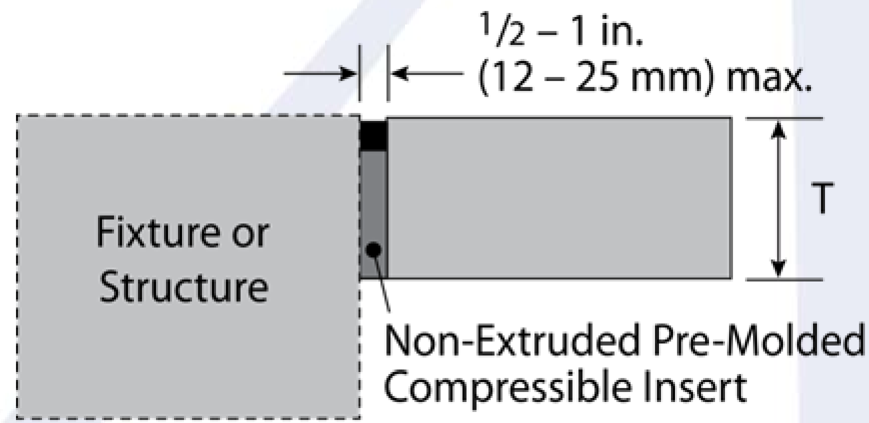
Isolation Joints





Type A – Thickened Edge





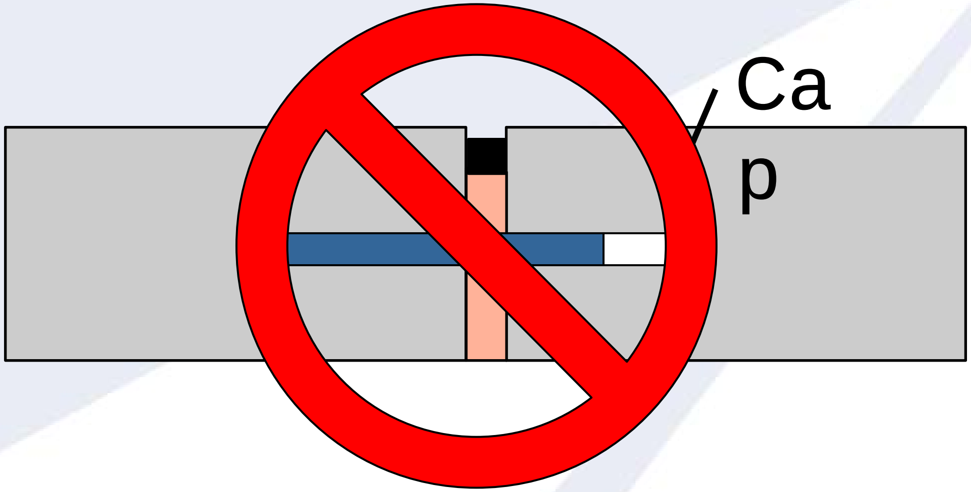
Type A – Undoweled

- Note A: 1.25 T to nearest 1 in. (25 mm) but at least T + 2 in. (50 mm).
- Note B: To nearest joint; 10 ft (3 m) minimum.

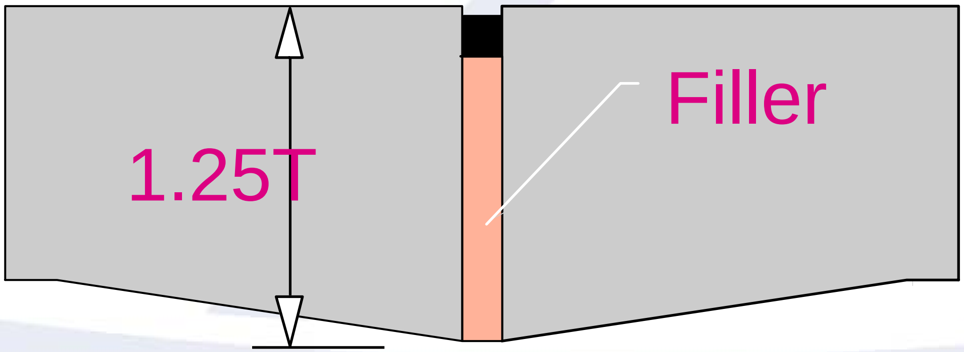
Terminology Change

Isolation/~~Expansion~~ Joints

Doweled



Thickened
Edge

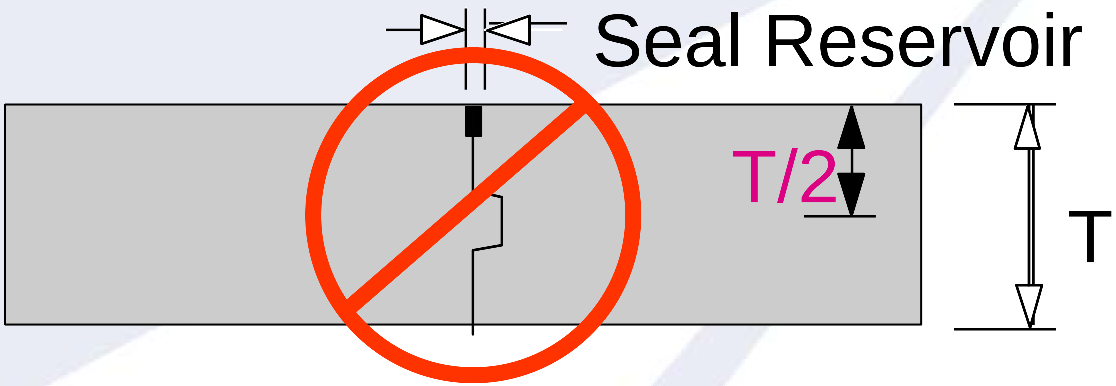


Where to Isolate...

Different Movement Axis

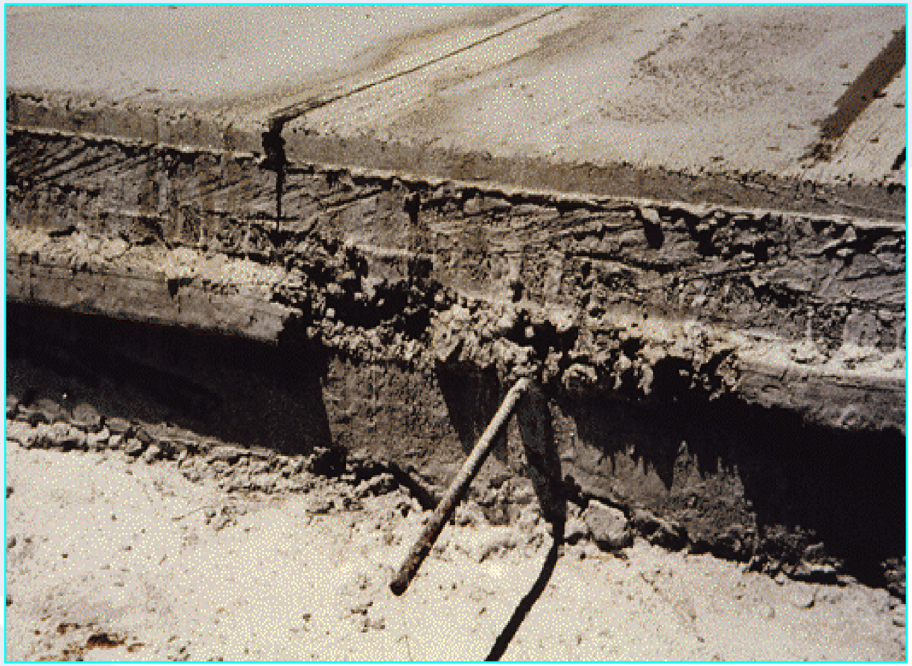
Construction Joint Details

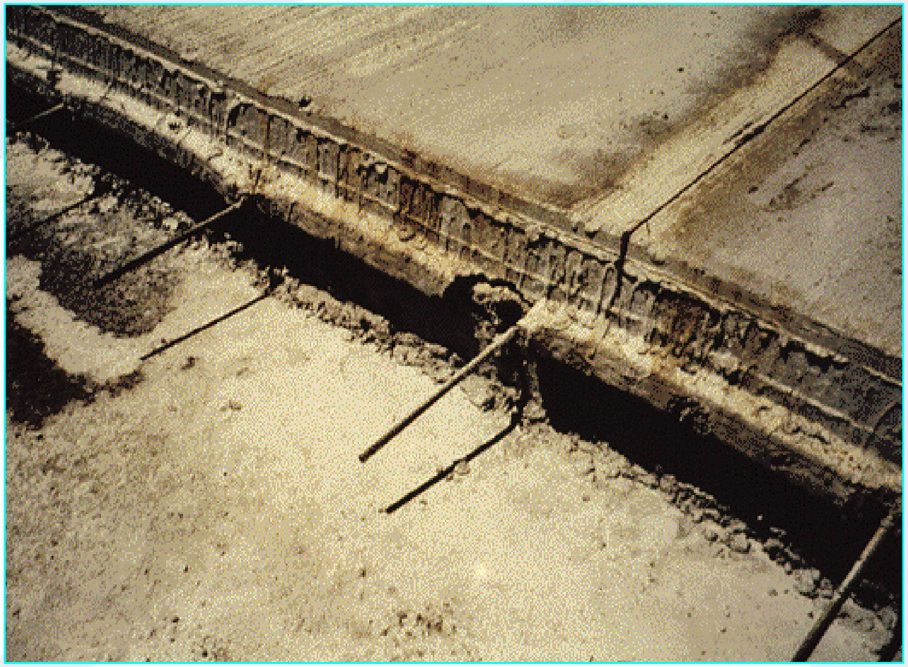
Keyed



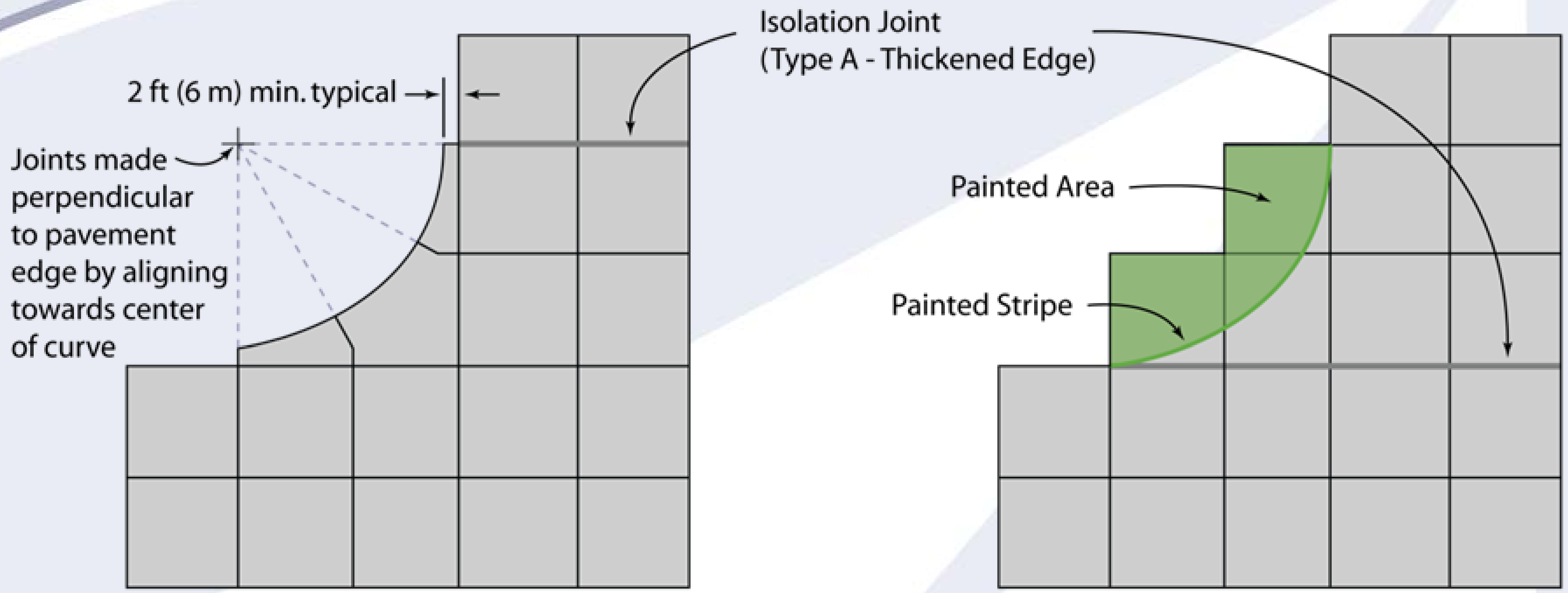
FAA AC/150-5320-6E – Detail has been removed

Bad Male Keyways





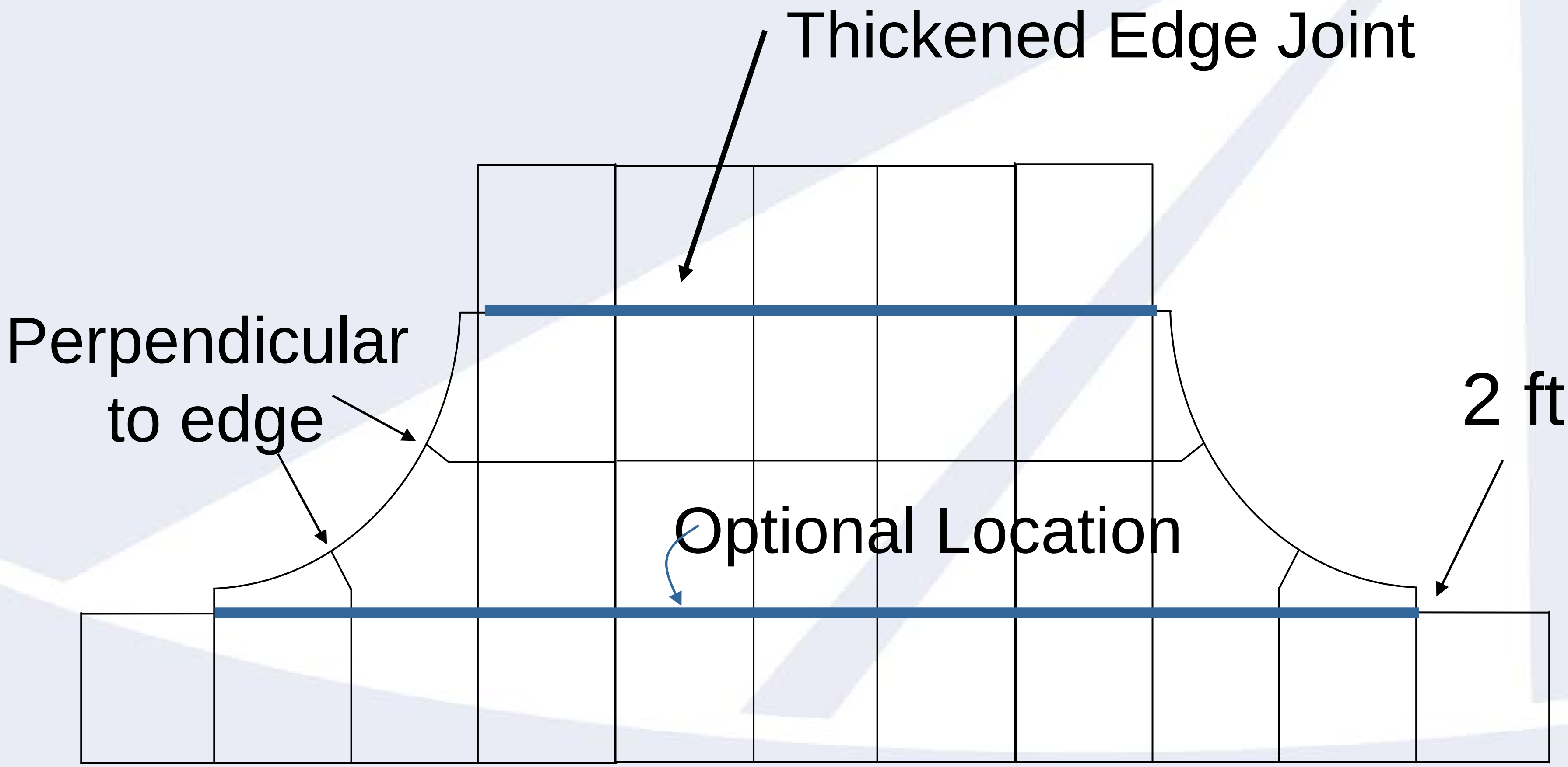
Filet Layout Options



Option 1 - Constructed Fillets (shown with optional isolation joint location)

Option 2 - Full Panels with Painted Fillet Stripe (shown with typical isolation joint location)

Filet Details



Odd-shaped Panels in Filets

- Add steel reinforcement (mesh)
- 0.05% by cross-section in both directions minimum

Fillet Details

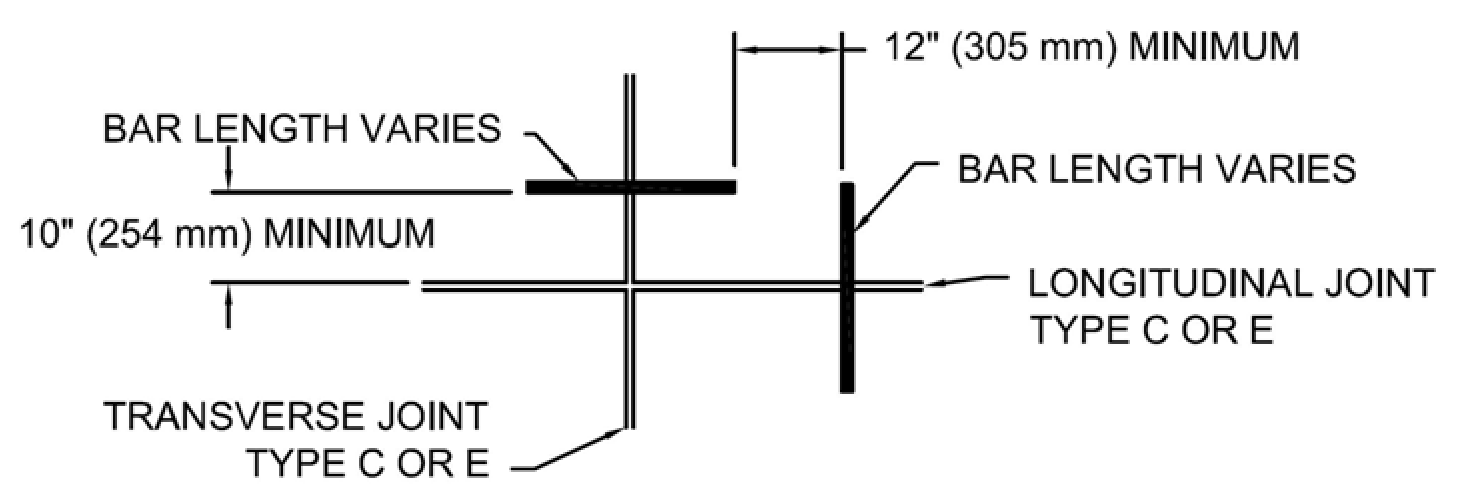
Poor Practices

Don’t bring a joint to the edge of pavement on an angle

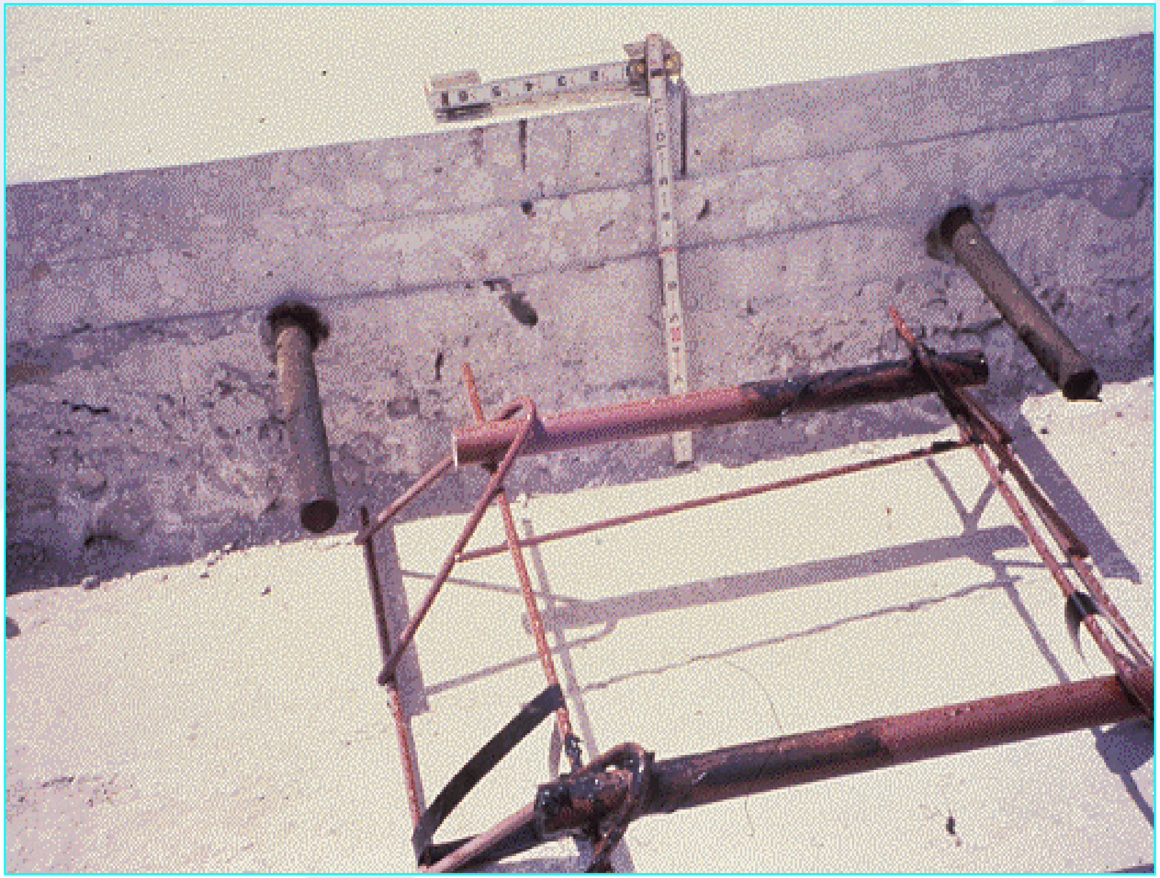
Rigid Pavement Design – Details

Rigid Pavement Joint Types and Details

- Dowel Bar Spacing at Slab Corner



Don’t place bars too close together!

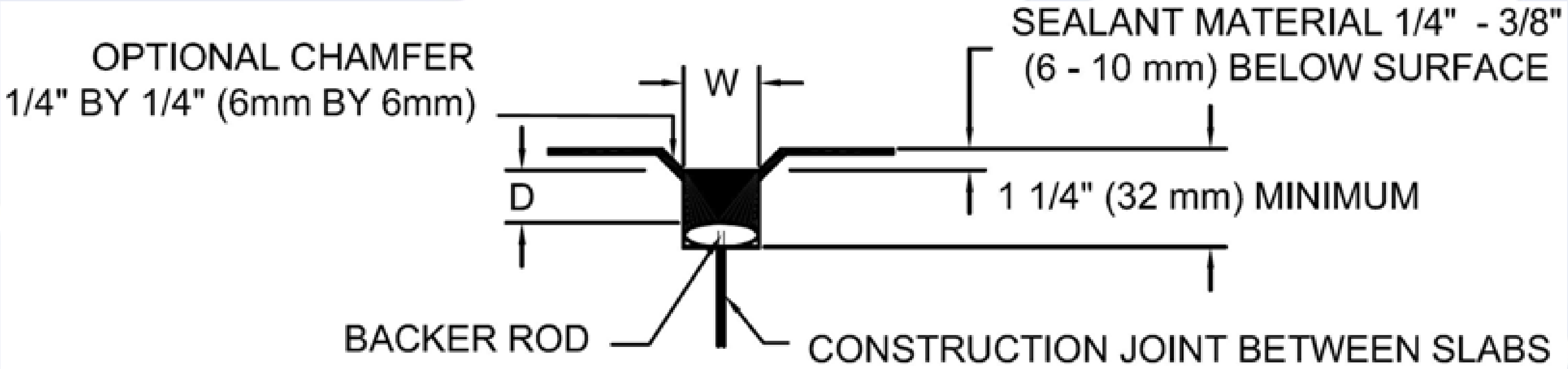


Don’t drill a dowel hole into another joint face

Rigid Pavement Design – Details

Rigid Pavement Joint Types and Details

- Beveled Joint Detail
  - Intended to reduce chipping and spalling attributed to snow plows



FAA P-501 Issues

- ASTM C 33 Contradictions (FM)
- P-501 does not directly address concrete workability (slump)
- Attempts to regulate workability by adjusting equipment
- Conflicting Directions to Contractor (e.g. finishing)
- Limits latents to 1/8 inch (no resolution)
- Others?

Concrete Mix Issues

- Concrete quality
  - aggregates quality
  - paste quality
  - bond between the two
- Paste quality => amount of water & admixtures
- Key properties of concrete
  - Workability – easily placed, consolidated, finished
  - Strength – required strength at desired time
  - Durability – long term durability under service conditions

Defining Workability

Component	Placement	Consolidation	Finish
Aggregates			
Coarse	**C**	**C**	**M**
Fine	**M**	**M**	**C**
Cement		**S**	**M**
Water	**C**	**C**	**C**
Admixtures			
Air Entraining	**M**	**M**	**S**
Mineral	**M**	**M**	**M**
Chemical	**C**	**C**	**S**

Cement

- Conform to ASTM C 150 “Standard Specification for Portland Cement”
- $C_3S < 56\%$
- Alkalies < 0.75%
- Types I II III (slag –be careful)
- 564 pcy – Portland cement only
- 517 pcy – with pozzalanic materials

Cement Factor

- **Characteristics**
  - More Cement Means Higher Strength
  - Fine Cement Means Earlier Strength
  - Low W/C Means Higher Strength
  - High Cement Factor for Higher-Early
- **Offsets**
  - Higher Water Demand
  - Needs More Water (?)
  - More Mixing Time
  - Smaller Aggregates and More Air

Mineral Admixture

- Fly Ash
  - Class F - >15% and < 25%
  - Class C – be careful (chemical analysis)

Chemical Admixture

- Air entraining
- Set-retarding
- Accelerating
- Water reducing
- Must be compatible with other components

Mineral Admixtures

- **Flyash**
  - Improves Durability
  - Increases Water Demand
  - Increases AEA
  - Sand Reduction
  - Class C contains calcium
  - Hot ↑ Cold ↓
- **GGBFS**
  - Cementitious
  - Improves Durability
  - Improves Workability
  - No Bleed Water
  - Stiff Mix
  - Sensitive to Vibration
  - Saw Cutting Critical

Combined Aggregate Grading

- Proportioned for:
  - Workability
  - Finishibility
- Percent Combined Aggregate Retain Graph

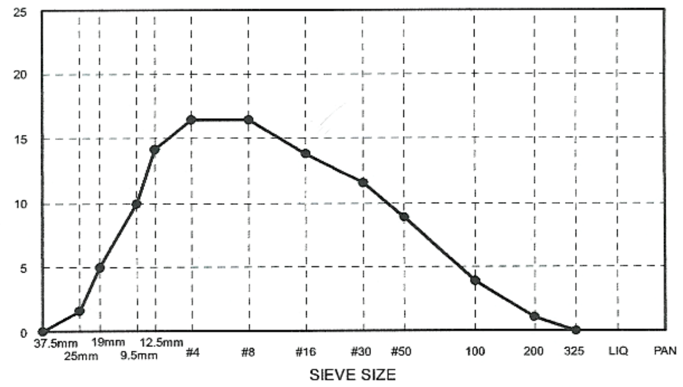


Figure 3.5 "Haystack" Particle Distribution for a Uniformly Graded Mixture

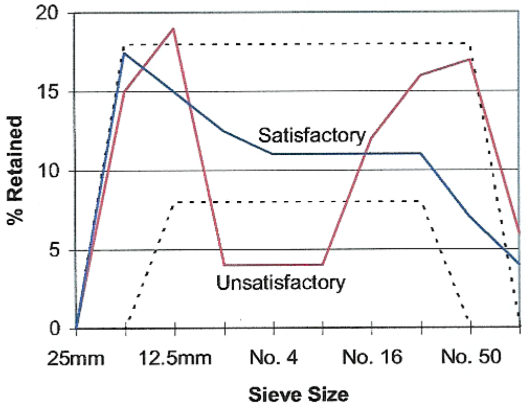
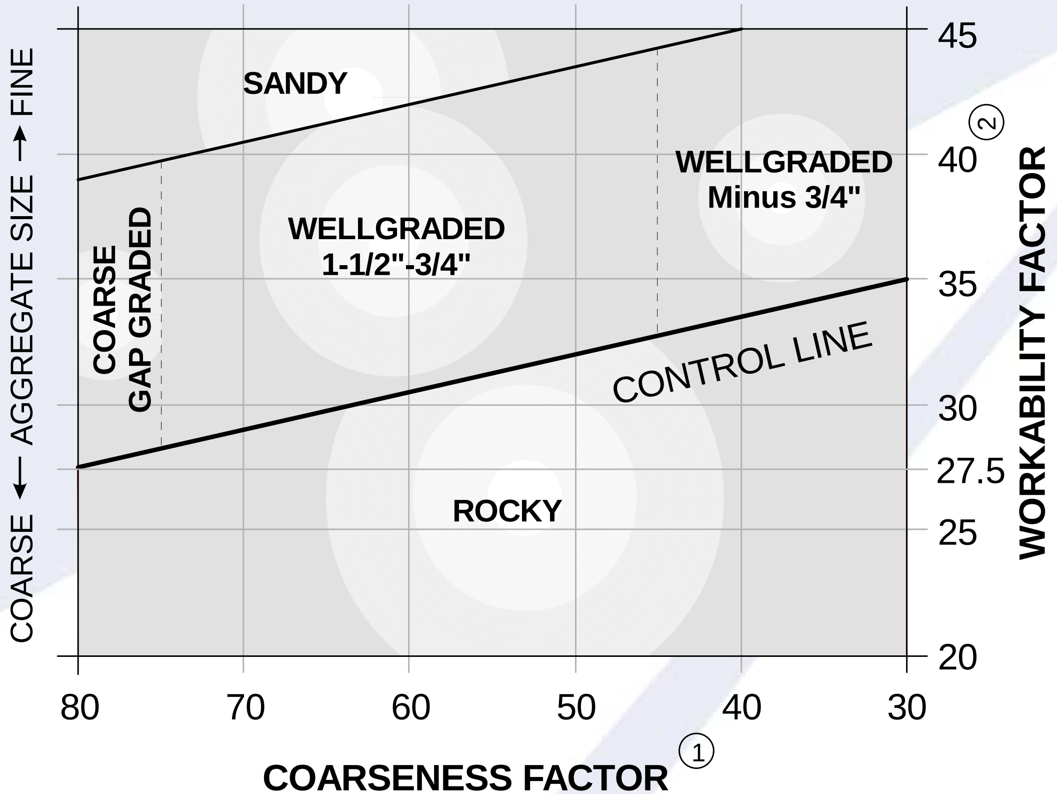


Figure 3.1 Percent Combined Aggregate Retained

USAF Constructability Chart



NOTES:

1 **COARSENESS FACTOR =** $\frac{\text{\% RETAINED ABOVE 9.5mm SIEVE}}{\text{\% RETAINED ABOVE \#8 SIEVE}}$ X 100

2 **WORKABILITY FACTOR =** % PASSING #8

Aggregate Proportioning Guide

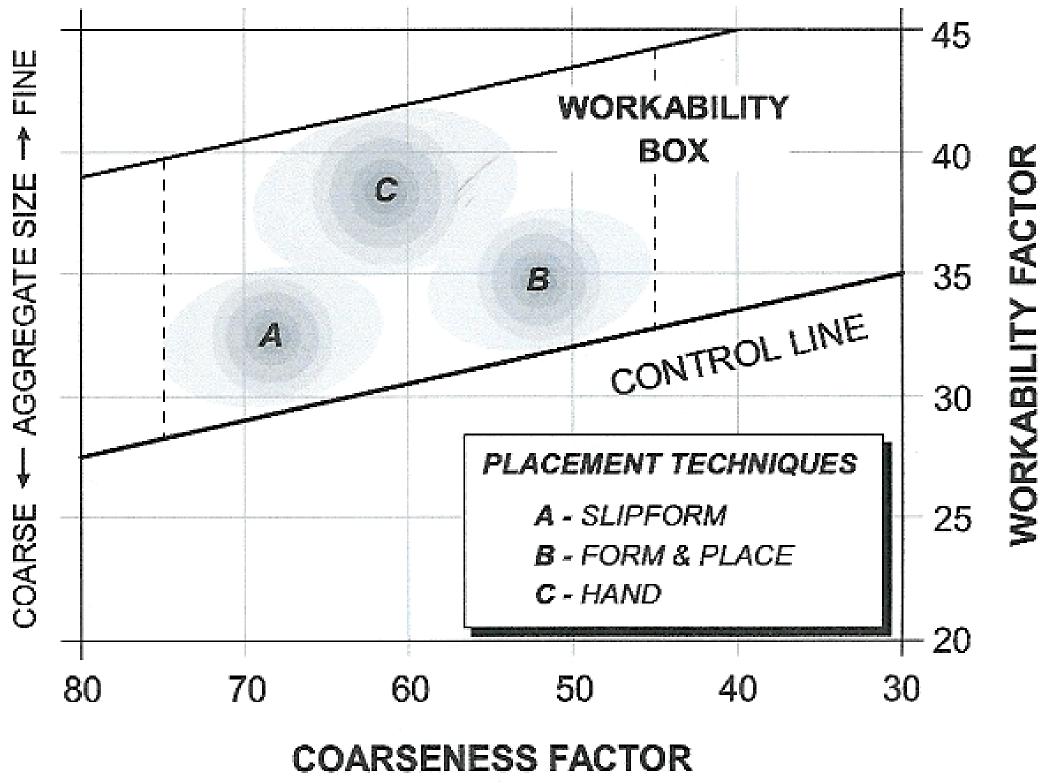
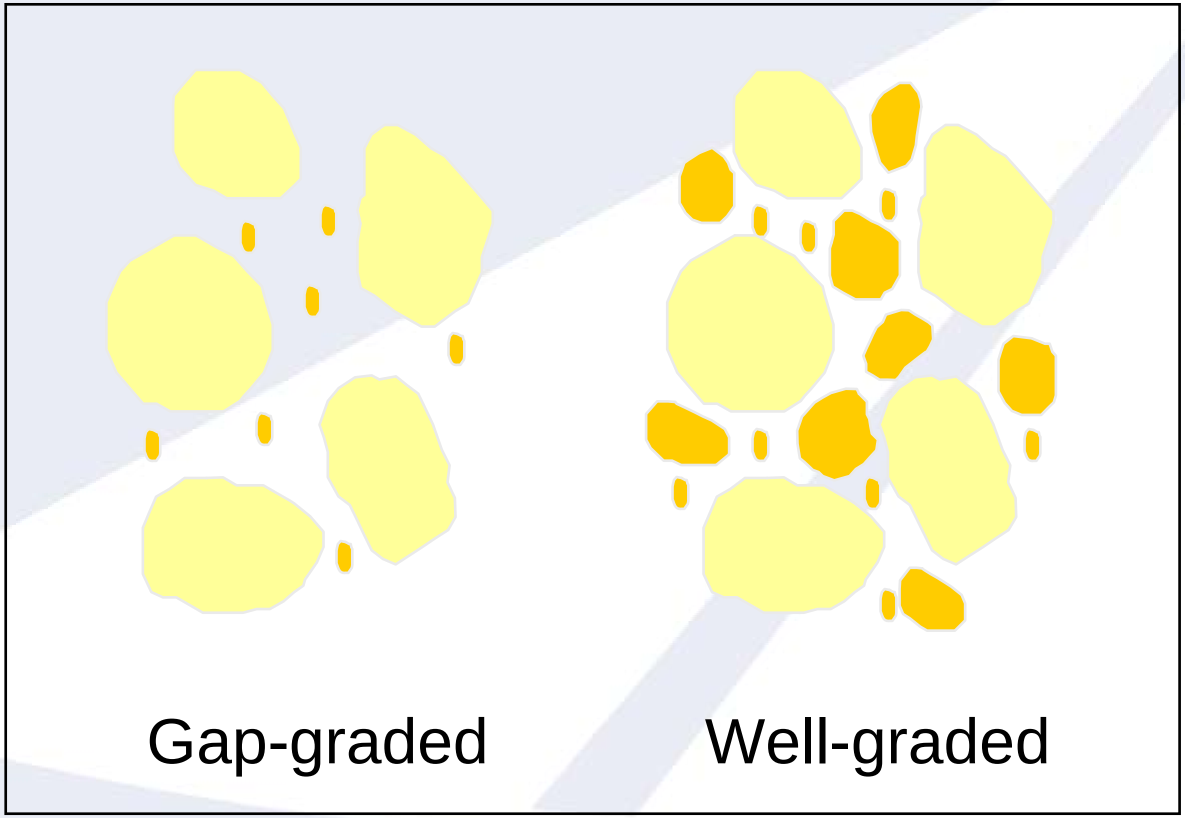


Figure 3.3 Workability Box Within Aggregate Proportioning Guide

Aggregate Grading (Optimize)

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THANK YOU!

Please contact Gary L. Mitchell with questions or comments:

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