Achieving What is Needed

• Durability through:
  ➢ Specifications
  ➢ Construction
  ➢ Quality Assurance

Summary – Achieving Durability

• Specifications
• Construction
• Quality Assurance

• Reduced paste quantity
• Improved paste quality
• Adequate entrained air
Durability

• Ability of the concrete to survive the environment to which it is exposed

Long Lasting/Durable

• Longer Lasting Facilities: can only be achieved if the materials, construction process and workmanship meet a specified/expected level of quality
  • INSPECTION
  • QA TESTING
Specifications

- Specify materials and properties that will yield durable concrete pavement
- Test and inspect to assure those materials have been used and that the concrete pavement has been constructed in accordance with the specifications

Specifications

- CP Tech Center Guide Specification for Highway Concrete Pavements: Commentary October 2012
- Statewide Urban Design and Specifications (SUDAS)
  - Promoting uniformity of urban design and construction
- Tailor specifications to the environment and locally available materials
**Construction**

- Which is better?

  - An excellent design with so-so construction practices

  Or

  - A so-so design with excellent construction practices

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**Construction**

- **Materials**
- **Equipment**
- **People**

  - Adequate testing and inspection is in everyone’s best interest
Durability

• How do we measure (test) durability?
  ➢ Slump?
  ➢ Unit weight?
  ➢ Compressive strength?
  ➢ Air content?
  ➢ Permeability?
  ➢ Water/Cementitious Material Ratio?

Defining Quality and QA

• Philip Crosby
  ➢ Quality: “Conformance to requirements”

• AASHTO & TRB Definition
  ➢ Quality Assurance: “All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service.”

• Simply: Quality Assurance is making sure the quality of a product is what it should be
Achieving What is Needed

• Durability through:
   Permeability
   Paste Quality & Quantity (W/CM)
   Curing
   Sawing
   Air Entrainment
   Optimized Gradation
   Uniformity
   Weather Management

Permeability
(truth is stranger than fiction)

• In 1855, physiologist Adolf Fick first reported his now-well-known laws governing the transport of mass through diffusive means.
• Today, Fick’s Laws form the core of our understanding of diffusion in solids (permeability).

Stranger yet,

• Friedrich Fick (1783-1861), Adolf’s father was responsible for reorganizing street construction in the city of Kassel, Germany.
Permeability

- The ease with which fluids can penetrate concrete
- **All durability damage is governed by permeability**
  - Use low w/cm
  - Use SCMs
  - Control paste volume
  - Cure
  - Minimize cracking

Permeability

- Test
  - RCPT (indirectly)
  - Wenner (indirectly)

- Quality indicator for:
  - Surrogate test for durability
  - Should we specify permeability?
Permeability

Permeability – Paste Quality

• Paste
  ➢ Cementitious materials
  ➢ Water and admixtures
  ➢ Air (entrapped and entrained)

• W/CM RULES!
Permeability – Paste Quality

• Workability
  ➢ Viscosity
  ➢ Early stiffening

Permeability – Paste Quality

• SCMs change concrete properties
• Means we have to allow for them
• Cracking risk changes
• Finishing and curing needs change
Permeability – Paste Quality

• Hydraulic cements need to conform to one of the following standards:
  ➢ ASTM C 150 or AASHTO M 85 (portland cement)
  ➢ ASTM C 595 or AASHTO M 240 (blended cement)
  ➢ ASTM C 1157 (hydraulic cement)

• Specify type also (I, II, III, IV or V)

Specifications

Permeability – Paste Quality

• Mix design stage
  ➢ Permeability
  ➢ Calorimetry/Time of Set
  ➢ Strength

• Production
  ➢ Mill certifications
  ➢ Strength

Testing
**Permeability – Paste Quantity**

- Enough paste to fill the voids and coat the aggregates
  - Workability
  - "Glue"
- And no more because of
  - Shrinkage
  - Heat

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**Permeability – Paste Quantity**

- Cementitious content:
  - 517 pounds per cubic yard is acceptable in severe exposure regions
  - Fly ash – not to exceed 25% of total cementitious content
  - Slag – not to exceed 50% of total cementitious content
  - If both fly ash and slag are used, the total supplementary cementing material shall not exceed 50% of total cementitious content
- $W/CM \approx 0.40$

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Specifications
Optimized Gradation

- Aggregates comprise the majority of the volume of a concrete mix
- Aggregate properties have a strong influence on:
  - Workability
  - Durability
  - Dimensional stability

Optimized Gradation

- Include intermediate (#8 to 3/8”) particle sizes
  - Reduced paste quantity for a given workability target
  - Eliminate gap graded mixes
Optimized Gradation
• Improved workability for a given water content (W/CM)
  ➢ Portland cement = 293 lb/yd³
  ➢ Type C fly ash = 158 lb/yd³ (35% replacement)
  ➢ W/CM = 0.42 (22.7 gal/yd³)
  ➢ Mid-Range WRA
  ➢ OPTIMIZED GRADATION

Optimized Gradation
• “Shilstone” method
  ➢ Coarseness Factor
  ➢ Workability Factor
**Permeability – Paste Quantity**

- Mix design stage
  - Microwave water content
  - Combined gradation

- Production
  - Batch tickets
  - Combined gradation
  - Aggregate moisture content
  - Microwave water content

**Permeability – Paste Quality**

- Early stiffening
Permeability – Paste Quantity

- Stockpile segregation
- Out of tolerance gradation

Permeability – Paste Quality & Quantity

- Retempering - adding water to the batch
- “Blessing” the slab
- Incorrect aggregate moisture content
Permeability – Curing

• Specify the material
• Cure within 30 minutes
• Place in two coats
• Coverage rate (150 sf/gal)

Or

• The cured surface shall be uniformly white (like a sheet of paper)
Permeability – Curing

• There is no standard test for measuring curing coverage or effectiveness
Permeability - Sawing

(a) Cracks generally do not develop in concrete that is free to shrink.

(b) Slabs on the ground are restrained by the subbase, creating tensile stresses that result in cracks.

Permeability – Sawing

• Why do we saw joints?
**Permeability – Sawing**

- Specify the depth
- Require adequate number of saws and blades

- Shallow cracking (less than 2”) can be repaired by epoxy injection
- Deep cracking (greater than 2”) – full depth repair

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**Permeability – Sawing**

- Saw in the window
- Timing is critical
- Monitor depth of cut

![Sawing window diagram]

- Too early (raveling)
- Too late (cracking)
- Minimum strength to svert excessive saw cut raveling

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**Figure 8-23. Close-up of different degrees of raveling caused by joint sawing (ACPA)**

- a) No raveling—sawed later in the window
- b) Moderate raveling—sawed early in the window
- c) Unacceptable raveling—sawed too early
Permeability – Joint Filling

- Single sawcut
- Fill with hot pour

Air Entrainment
Air Entrainment
Air Entrainment

- Specify air content and tolerance
  - 6.5% ±1.5%

- Adjust acceptance target based on paired testing behind the paver (at least 1 per day)

- Acceptance testing at placement

Specifications
Air Entrainment

• Mix Design Stage
  ➢ Foam drainage

• Production
  ➢ Air content
  ➢ At discharge
  ➢ Behind the paver (quantify loss)

Air Entrainment

• Over-vibration can reduce entrained air
  ➢ Review vibrator monitor output if available
  ➢ Visually inspect cores for segregation (indicative of over-vibration)
Uniformity

Material  Process  Sampling  Testing

Composite Variability

Uniformity – QA Approach

1. Use successful practices
2. Quality control checklist items
3. Quality control measurements
4. Key inspection items
5. Appropriate actions

• REDUCED VARIABILITY THROUGH PROCESS CONTROL
**QA Approach - Successful Practices**

• Maintain a consistent speed
• Slow down or stop?

**QA Approach - Checklist Items**

• All vibrators are operational
• Paver width
• Extrusion pan – trueness and cross-slope/crown
• Curb dimensions
QA Approach - Measurements

- Thickness
- Smoothness

QA Approach - Key Inspection Items

- Stringline – constant
- Edge slump – every 50’
- Offset alignment – every 50’
- Slab width – every 50’
QA Approach - Appropriate Actions

- Adjust vibrator frequency
- Adjust speed
- Refine mixture proportions
- Stop paving if the edge keeps falling

Weather Management

- Recommended practice
- Use HIPERPAV to assess risk of cracking
Weather Considerations

- Rain
  - Be prepared to cover
  - Schedule hand pours, shoulders, etc.
  - Do not finish-in rain water
  - Grind/groove texture to remove damaged surface

Weather Management

- Hot weather
  - Reduce mix temperature
  - Sprinkle subbase
  - Night placement
  - Morning placements are most at risk
Weather Management
• Cold weather
  − Increase mix temperature
  − Do not place on frozen subgrade/subbase
  − Cover slab to protect from freezing for 48 hours
  − Replace cover after sawing to avoid thermal shock
  − Monitor concrete temperature with recording devices

Summary – Achieving Durability
• Specifications
  • Reduced paste quantity
• Construction
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• Quality Assurance
  • Adequate entrained air
Questions and Discussion