Concrete Mixtures for Pavements

Dr. Peter Taylor PE

With thanks to
Dr. Xuhao Wang
Dr. Ezgi Yurdakul
Design

• Choosing what you need
  • All concrete:
    • Workability, strength development
  • Pavements / slabs on grade
    • Durability, cracking risk
  • Airfields
    • FOD, edge slump
Proportioning
Proportioning Approaches: Past

- Structural concrete: 1:2:4
- Other concrete: 1:3:6
- Waterproof concrete: Add salt
- No chemicals
- No SCMs
- Precision was ugly
- Bulking made it worse
Proportioning Approaches Present

- **ACI 211**
  - Last revised in 1991
  - Linear
- **Developed**
  - Before water reducers
  - Before supplementary cementitious materials
- **Primarily focused on structural concrete**
  - 100 mm (4") slump
  - 30 MPa (~4000 psi)
Workability
Workability
Preconceptions

- More cement = more strength
- Strength is everything
- Slump indicates quality
- Gradations of individual fractions are critical
How do we proportion to achieve design goals?

<table>
<thead>
<tr>
<th></th>
<th>Workability</th>
<th>Transport</th>
<th>Strength</th>
<th>Cold weather</th>
<th>Shrinkage</th>
<th>Aggregate stability</th>
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<tbody>
<tr>
<td>Aggregate System</td>
<td></td>
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<tr>
<td>Type, gradation</td>
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<tr>
<td>Paste quality</td>
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<tr>
<td>Air, w/cm, SCM type</td>
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<td>✓ ✓</td>
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<tr>
<td>and dose</td>
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<tr>
<td>Paste quantity</td>
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<tr>
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</tbody>
</table>
Proportioning

Filler
Gradation

Glue
What sort
How much
Step 1 Paste Quality

- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - ~0.38-0.42
- Air void system
  - <0.2 SAM
  - <0.008 in. spacing factor
  - >5% in place
  - Stable
Step 2 Aggregate system

- Choices…
  - ASTM C33?
  - Or combined?:
    - Haystack
    - Shilstone Plot
    - Power 45
  - Tarantula
An Experiment

• Combined gradation matters
Step 3 Paste Content
Step 3 Paste Content
Step 3 Paste Content
Step 3 Paste Content

- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
- “Optimum” depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically $V_v \sim 150-200\%$
Workability

![Graph showing the relationship between Stump, in., and Paste/Voids, % by volume for different materials (400, 500, 600, 700).]
Strength

![Strength Graph](chart)

- **w/c - 0.35**

- **Compressive Strength, psi**
  - 1 day
  - 3 day
  - 28 day

- **Cement Content, pcy**
  - 300 to 800
Air Permeability

![Graph showing air permeability index with cement content and w/c 0.35.](image)
Rapid Chloride Penetration

![Graph showing the relationship between Adjusted Charged Passed (coulombs) and Cement Content (pcy) for different w/c ratios. The graph includes data points for w/c ratios of 0.25, 0.40, 0.45, and 0.50. The data shows a positive correlation between adjusted charged passed and cement content, with higher w/c ratios leading to increased adjusted charged passed.]
Doing the Sums

• The wonders of a spreadsheet and a solver function…
Doing the Sums

• The wonders of a spreadsheet…
Doing the Sums

• The wonders of a spreadsheet…

<table>
<thead>
<tr>
<th>Mixture Proportions</th>
<th>Targets</th>
<th>Actual</th>
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<tr>
<td></td>
<td>Pounds</td>
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Cementitious: 428 pcu
Volume of paste: 24.0 %
Volume of aggregate: 76.0 %
Volume of voids: 19.2 %

w/cm: 0.42

% SCM 1: 20 %
% SCM 2: 0 %
Mass of aggregate: 3411 pcu
Excess paste, %: 4.8 %
Trial Batches

- Workability / Admixture dosages / Void ratio
- Air void system
- Setting
- Strength gain
- Permeability
What about uniformity?
Does it Work?

• Before and after reworking the proportions