Concrete Mixture Proportions

Outline

Introduction
Proportioning:
  Paste quality
  Aggregate system
  Paste quantity
In reality…

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 - 1991
- Developed
  - Before water reducers
  - Before supplementary cementitious materials
- Primarily focused on structural concrete
  - 100 mm (4") slump
  - 30 MPa (~4000 psi)
- Modified 2022 – not much change
Workability

What do we need?

- Transport properties (permeability)
- Aggregate stability
- Cold weather resistance
- Strength
- Shrinkage
- Workability

Proportioning
Proportioning

How do we proportion to achieve design goals?

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

Step 1 Paste Quality

- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - Choose for durability (~0.42)
- Air void system
  - <0.008 in. spacing factor
  - Stable

Step 2 Aggregate system

- Choices...
  - ASTM C33
  - Or combined:
    - Haystack
    - Shilstone Plot
    - Power 45
  - Tarantula
Step 2 Aggregate system

• Choose an aggregate system…

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
  - Negative effect on sustainability
- “Optimum” depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically Vv ~150-175%

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…

Doing the Sums

The wonders of a spreadsheet…
Trial Batches

- Workability / Admixture dosages / Void ratio
- Air void system
- Setting
- Strength gain
- Permeability
- ...

Does it Work?

<table>
<thead>
<tr>
<th>MNDOT</th>
<th>Optimized</th>
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<tr>
<td>Cement</td>
<td>460</td>
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<tr>
<td>SCM 1</td>
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<td>SCM 2</td>
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<td>Coarse Agg</td>
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<tr>
<td>Fine Agg</td>
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<tr>
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<td>Water</td>
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<tr>
<td>Air</td>
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<td>Total</td>
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</tr>
</tbody>
</table>

Cementitious: 570 / 501
w/c: 0.40 / 0.40
% SCM 1: 30 / 30

Ongoing Work

- What void ratios are needed for:
  - Varying aggregate mineralogy
  - Varying aggregate form
  - Varying gradation

MNDOT

- Slump
- HRWR
- Air content
- Box
- Initial set
- Strength at 7

2.0 / 2.0
2.3
6.8 / 7.0
1.0 / 1.0
6.27 / 6.32
3.340 / 3.650