Role of Minimum Cement Contents in Concrete Specifications and Mixture Proportioning

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Introduction

- Should Minimum CM content be specified?
- Mixture proportioning with low CM content
Research Objective

Examine influence of CM content on concrete performance at specific $w/cm$

Parallel tests at Iowa State University
Experimental Variables

\( \text{w/cm}: 0.40, 0.47, 0.55 \)

CM – 417 to 720 lb/yd³

Paste: 22%, 24%, 27%, 31% at same CA/FA

Total of 20 non-air concrete mixtures

40% slag cement, 100% OPC, 25% Class F
Aggregate Voids Testing (ASTM C29)

[Images of coarse aggregate and void content graph]

[Graph showing void content percentage against coarse aggregate volume]
Concrete Tests Conducted

Slump – add Type F HRWR if slump<1 in.
Air content, density, temperature, setting time
Compressive strength
RCPT (ASTM C1202)
RMT (AASHTO TP64)
Sorptivity (C1585)
Shrinkage (C157)
Compressive Strength – 28 days

![Graph showing compressive strength versus total cementitious content]

- **Compressive Strength, psi**
- **Total Cementitious Content, lb/yd³**

- **0.55SL**
- **0.47SL**
- **0.40SL**
- **0.47FA**
- **0.47PC**
Compressive Strength – 1 day

Total Cementitious Content, lb/yd³

Compressive Strength, psi

- 0.55SL
- 0.47SL
- 0.40SL
- 0.47FA
- 0.47PC
RCPT – 28 day AC

Total Cementitious Content, lb/yd³

0.55SL
0.47SL
0.40SL
0.47FA

RCPT, coulombs
RMT – 28 day AC

Graph showing the relationship between Total Cementitious Content (lb/yd³) and RMT (mm/V-hr). The graph includes lines for different cementitious content levels:
- 0.55SL
- 0.47SL
- 0.40SL
- 0.47FA
- 0.47PC

The x-axis represents Total Cementitious Content in lb/yd³, ranging from 400 to 800. The y-axis represents RMT in mm/V-hr, ranging from 0.00 to 0.05.
Summary

Higher CM contents increase mixing water demand

For given \( w/cm \) increasing CM content:

- Same strength
- Increased chloride penetrability, sorptivity, shrinkage

Does not appear to be a technical basis for specifying minimum CM content or a maximum \( w/cm \) when not needed
Mixtures with Low CM content

How low can you go?

![Graph showing CM content vs. paste volume](image-url)
Mixtures with Low CM content

How low can you go?

Impact of air entrainment?

Impact of SCMs and WRA

Cast 12 more mixtures
Minimum CM content for acceptable performance – Effect of \( w/cm \)

For water slump of 1 in. before WR addition
**Minimum water, paste volume – Effect of w/cm**

For water slump of 1 in. before WR addition

<table>
<thead>
<tr>
<th></th>
<th>0.40</th>
<th>0.47</th>
<th>0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% SL</td>
<td>265/28%</td>
<td>260/26%</td>
<td>250/24%</td>
</tr>
<tr>
<td>PC</td>
<td>265/26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% FA</td>
<td></td>
<td>255/26%</td>
<td></td>
</tr>
<tr>
<td>40% SL A</td>
<td></td>
<td>240/24%</td>
<td></td>
</tr>
</tbody>
</table>

*But what if WRA can be added earlier?*
Minimum CM content for acceptable performance – Effect of \( w/cm \)
Minimum water, paste volume – Effect of \( w/cm \)

For no measurable water slump (use of WRA)

<table>
<thead>
<tr>
<th></th>
<th>0.40</th>
<th>0.47</th>
<th>0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% SL</td>
<td>202/22%</td>
<td>218/22%</td>
<td>230/22%</td>
</tr>
<tr>
<td>PC</td>
<td>207/22%</td>
<td>221/22%</td>
<td>235/22%</td>
</tr>
<tr>
<td>25% FA</td>
<td>199/22%</td>
<td>212/22%</td>
<td>225/22%</td>
</tr>
<tr>
<td>40% SL A</td>
<td></td>
<td>203/20%</td>
<td></td>
</tr>
</tbody>
</table>
Minimum CM content for acceptable performance

0.47 w/cm 40% slag mix

<table>
<thead>
<tr>
<th>Condition</th>
<th>Water</th>
<th>CM</th>
<th>PV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>300</td>
<td>640</td>
<td>30%</td>
</tr>
<tr>
<td>Water slump=1 in.</td>
<td>260</td>
<td>550</td>
<td>26%</td>
</tr>
<tr>
<td>No water slump (NWS)</td>
<td>218</td>
<td>460</td>
<td>22%</td>
</tr>
<tr>
<td>NWS - air entrained</td>
<td>203</td>
<td>430</td>
<td>20%</td>
</tr>
</tbody>
</table>
Benefits of not specifying minimum CM

Better concrete performance

Optimized mixtures

Sustainable construction

Incentive to lower variability, i.e. improve quality

Knowledgeable producers
How to specify to get low CM content concrete?

What if producers reduce CM contents too low?

What if we state a maximum CM content?

What if we state a maximum paste volume?

What if we state a strength range?

Reasonable performance specs – best solution!
Thank you

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