Testing High Strength Concrete – in Chicago

ACI Spring Convention, Kansas City

Walt Flood IV, M.S., P.E.
Outline

• Brief History of High-Strength in Chicago
• Field Testing and Casting
• Laboratory Testing
• Field Monitoring
High Strength Development

Crazy ready-mix producer hires a structural engineer as an “Engineering Consultant”

Material Service Corporation

ACI Fellow **Jaime Moreno** is Manager of Technical Marketing for Material Service Corporation, Chicago, Ill. He is a past member of the ACI Board of Direction and a member of the ACI Planning Committee as well as Committees 363, High Strength Concrete; 216, Fire Resistance and Fire Protection of Structures; and the Concrete Materials Research Council. He also is a member of the Chicago Committee on High-Rise Buildings and the USA-USSR Agreement on Cooperation in the Field of Housing and Other Structures.

Concrete Construction – 1990
High Strength Development

1962 – Outer Drive East: 6ksi specified
   7.5ksi test columns
1964 – Marina City Towers: 6ksi slipform
1967 – Lake Point Tower: 7.5ksi specified
   – Westin Michigan Ave: 9ksi stair

Project Data thanks to John Albinger, Steve Fleming (Prairie Concrete), Walter Flood
High Strength Development

1972 – Mid-Continental Plaza: 7.5ksi spec 9ksi test columns
1974 – Water Tower Place: 9ksi specified
1983 – Mercantile Ex. Tower: 14ksi test col
1988 – 225 W Wacker: 14ksi specified 17ksi test columns
- 911 N Rush: 14ksi specified

Project Data thanks to John Albinger, Steve Fleming (Prairie Concrete), Walter Flood
Air, temperature test like normal
  • look for air spikes

Typically exceeding 8” slump, recommend using slump flow (ASTM C1611)
Field Testing and Casting

Casting Specimens
– Use 4x8s exclusively

<10,000 psi cast and cure as normal
• Extend initial cure from 24 hr to 48–72 hr
• Consolidate with vibrator
• Immediately into water bath
Laboratory Testing

Compressive Strength (ASTM C39)
- End preparation

- No pads or caps over 7ksi without qualification tests (ASTM C617, C1231)
- Never pads over 12 ksi
- Grind over 12 ksi
Laboratory Testing

Compressive Strength (ASTM C39)

Problem: most 10 ksi (or less) is hitting 12 ksi

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<th>Dia., In.</th>
<th>Area, In.²</th>
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Laboratory Testing

Compressive Strength Video
Modulus of Elasticity (ASTM C469)
– Specified for stiffness (very tall/ narrow)

Need at least 3 cylinders – break 1, test remaining 2 for modulus

Modulus typically controlling mix design: EG, need 12,000 psi, 6.6E06 psi; supply 14ksi to meet
Laboratory Testing

Modulus of Elasticity

![Image of laboratory equipment and stress-strain graph with results: Load = 136795 = 10,830 psi]
Modulus of Elasticity

ACI 318: \( 33 \, w_c^{1.5} \, f'_c^{0.5} \, \text{psi} \)

ACI 363: \( (40,000 \, f'_c^{0.5} + 1.0 \times 10^6)(w_c/145)^{1.5} \)

Cook/Meyer EQ: \( w_c^{2.687} \, f'_c^{0.24} \, \text{psi} \)

For 150pcf, 12ksi mix: 6.64, 5.66, 6.70E06

Provide very different results

- Variable for local materials and proportions
- Measure specific mixes
Laboratory Testing

Modulus of Elasticity

than five years of 14,000 psi (96 Mpa) concrete show the columns becoming stable at a strain of about 1000 in./ln.

Creep and shrinkage testing have been carried out on cylinders obtained from concrete delivered to projects where high-strength concrete has been used. Fig. 5 and 6 show the decrease of creep and shrinkage with the increase of concrete strength.

Modulus of elasticity of high-strength concretes including this new strength of 17,000 (117 Mpa) is shown in Fig. 7. These results are less than values given by the traditional ACI equation, however, they exceed those produced by the new equation proposed by the ACI Committee 363, High Strength Concrete. This suggests that the equation recommended by Com-

January 1990

Courtesy of Jim Cook

Concrete Construction – 1990
Field Monitoring

Maturity Method (ASTM 1074)
- Form jumping
- Post-tensioned tendon stressing

Embedded sensor
Monitor to minimize cycling times

*In-place strength not represented by cushy standard curing nor field-cured cylinders
Conclusion

Testing High Strength takes:
- more effort
- well-trained technicians
- up-front equipment verification

Real-time monitoring of strengths can provide great benefit to the project team

Coming 2016: 8,000,000 specified Modulus