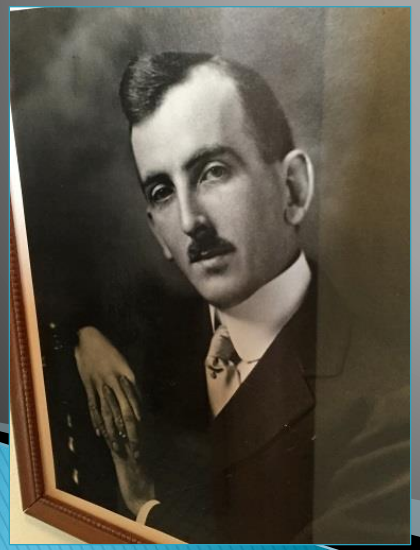
Testing High Strength Concrete – in Chicago

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



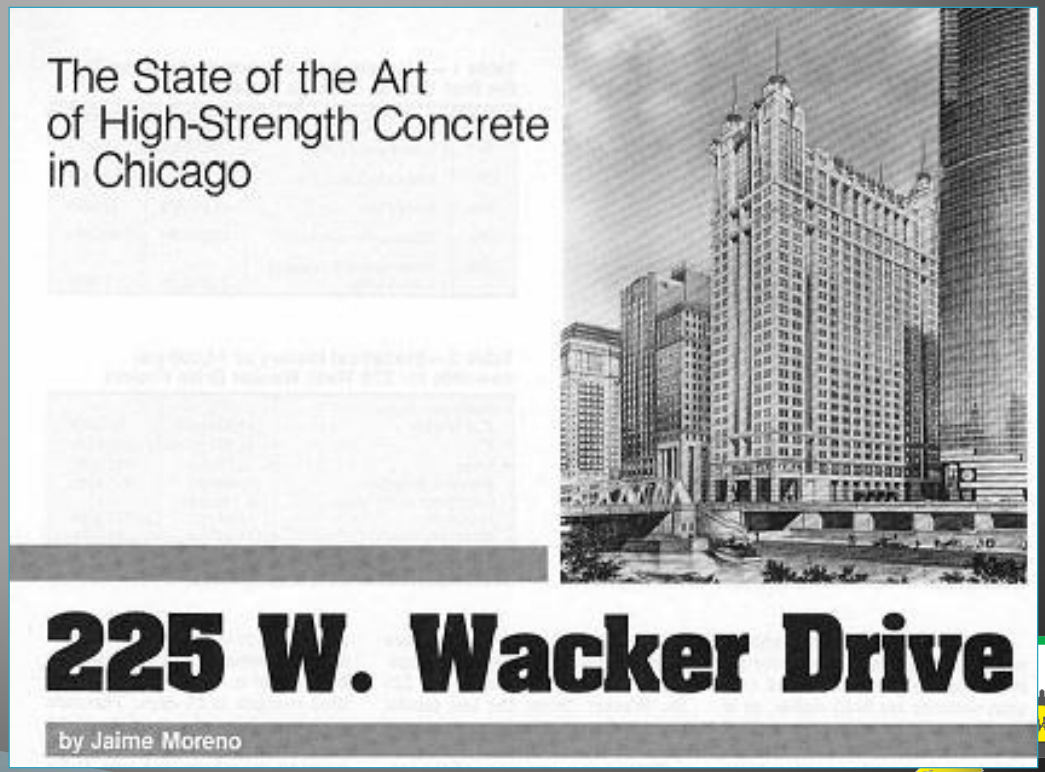
High Strength Development

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 Committies 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 Committe on High-Rise Buildings and the USA-USSR Agreement on Cooperation in the Field of Housing and Other Structures.

Concrete Construction - 1990


The State of the Art of High-Strength Concrete in Chicago

225 W. Wacker Drive

by Jaime Moreno

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

Field Testing and Casting

Air, temperature test like normal

- look for air spikes

Typically exceeding 8” slump, recommend using slump flow (ASTM C1611)

Youtube.com user arkotwal

Field Testing and Casting

Casting Specimens
-Use 4x8s exclusively

<10,000 psi cast and cure as normal

- Extend initial cure from 24 hr to 48-72hr
- 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 10ksi (or less) is hitting 12 ksi

Project:
Contractor:

Mix Number: **Specified Strength:** 8000 Lbs/Sq. In. @ 56 Days

Set Number: 1500366
Date Sampled: 13-Feb-2015
Slump: 8.00 in.
Air Content:
Location: Calsson cap @ E.9/8 to the bottom of slab on grade..

Time Batched: 12:31 PM
Time Sampled: 1:35 PM
Conc. Temp: 52 °F
Air Temp: 17 °F

Ticket No.: 03211373125
Truck No.: 8185
Days in Field: 3
Sampled By: MH
Weather Cond.: cloudy

Spec. No.	Date Tested	Age, Days	Dia., In.	Area, In.^{2}	Max. Load, Lbs.	Compressive Strength, Psi	Frac. Type	Remarks
1500366A	20-Feb-2015	7	4.01	12.63	116,605	9,230	2	
1500366B	13-Mar-2015	28	4.01	12.63	137,250	10,860	3	
1500366C	13-Mar-2015	28	4.01	12.63	135,665	10,740	3	
1500366D	10-Apr-2015	56	4.01	12.63	149,670	11,850	2	
1500366E	10-Apr-2015	56	4.01	12.63	153,235	12,130		
1500366F	10-Apr-2015	56	4.01	12.63	155,100	12,280	2	
1500366G	24-May-2015	100						Reserve

Laboratory Testing

Compressive Strength Video

Laboratory Testing

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

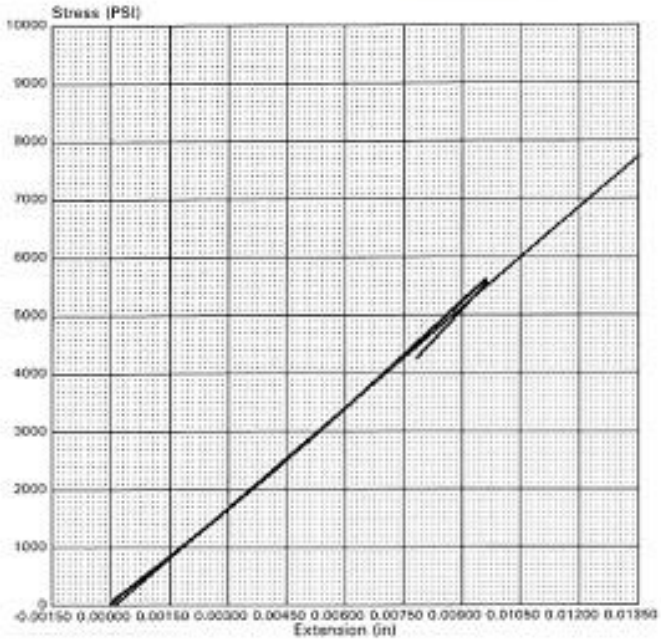
Laboratory Testing

Modulus of Elasticity

RESULTS

Date:	04-08-15
Time:	07:50:51
Data Buffer(% full):	47.9
Specimen ID#:	6523
Specimen Type:	CYLINDER
Length (in):	8.0000
Gage Length (in):	10.5420
Area (sqin):	12.629
Peak (LB):	70806
Peak (PSI):	5607
Modulus of Elasticity (PSI):	6070436
Strength @ 1.0% Strain (LB):	0
C469 Modulus (PSI):	6035769

Load = 136795
= 10,830 psi



Laboratory Testing

Modulus of Elasticity

ACI 318: $33\ w_c^{1.5}\ f'_c{}^{0.5}$ psi

ACI 363: $(40{,}000\ f'_c{}^{0.5}+1.0\times10^6)(w_c/145)^{1.5}$

Cook/Meyer EQ: $w_c^{2.687}\ f'_c{}^{0.24}$ psi

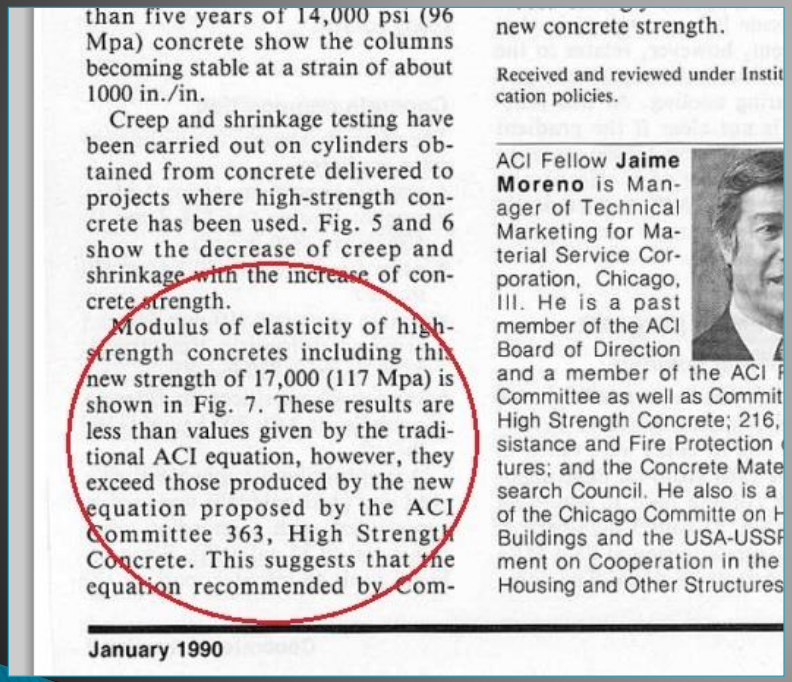
For 150pcf, 12ksi mix: 6.64, 5.66, 6.70E06

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./in.

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-

new concrete strength.

Received and reviewed under Institute publication policies.

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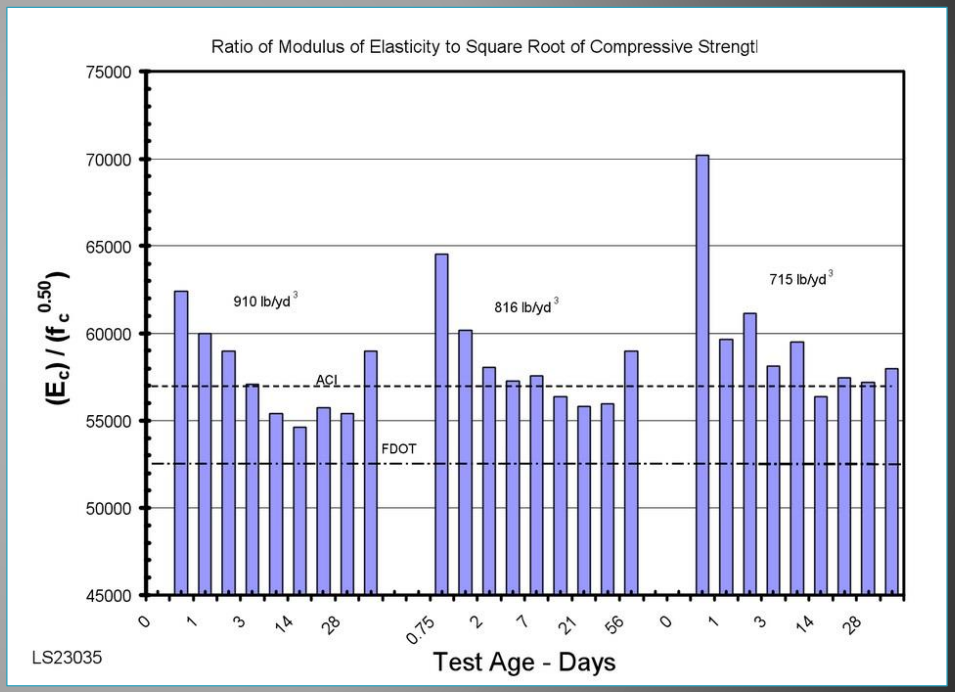
January 1990

Concrete Construction – 1990



Courtesy of Jim Cook

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