Implementing the 50 Percent Solution: High-Volume Pozzolan Concrete in Practice

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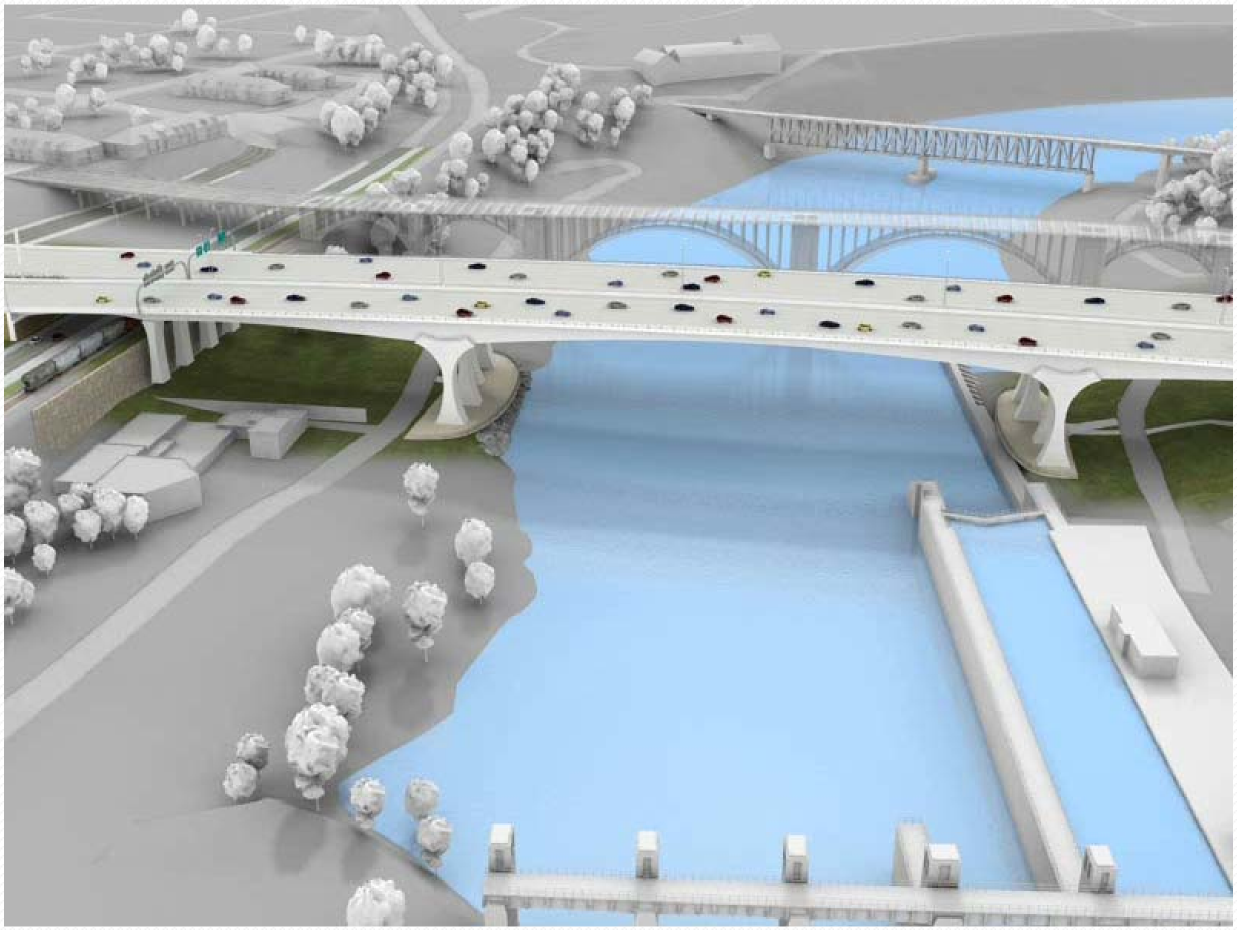
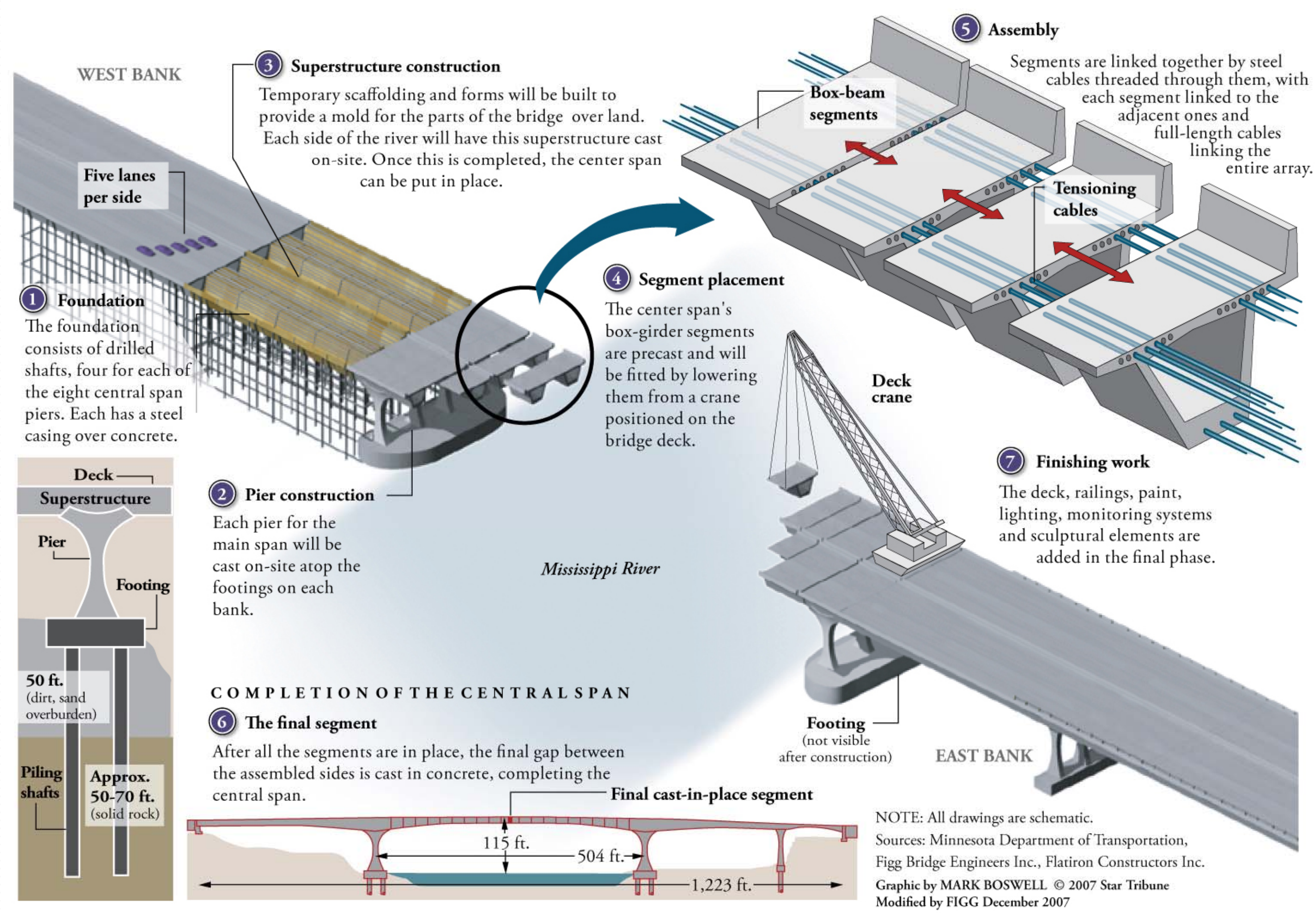
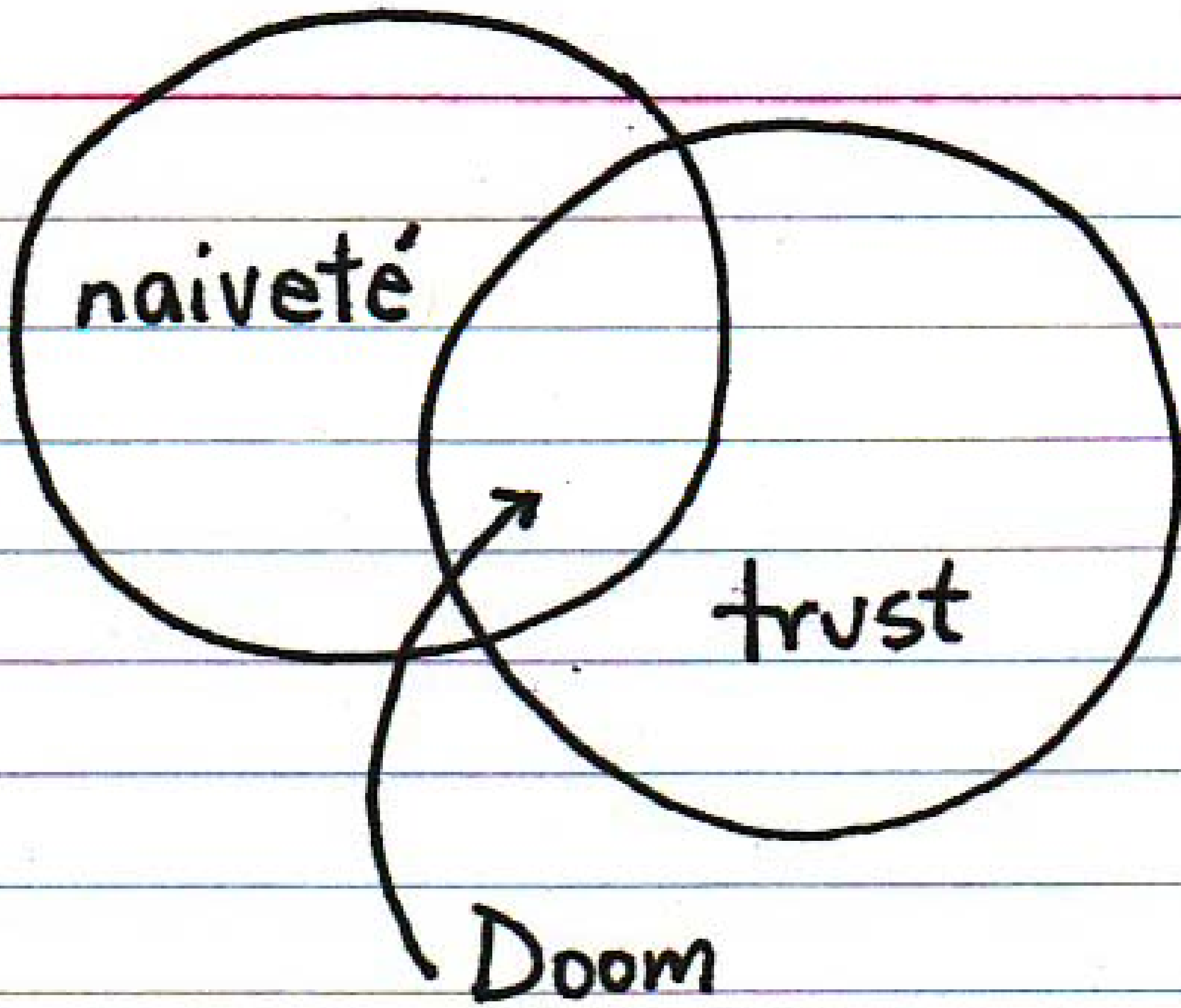


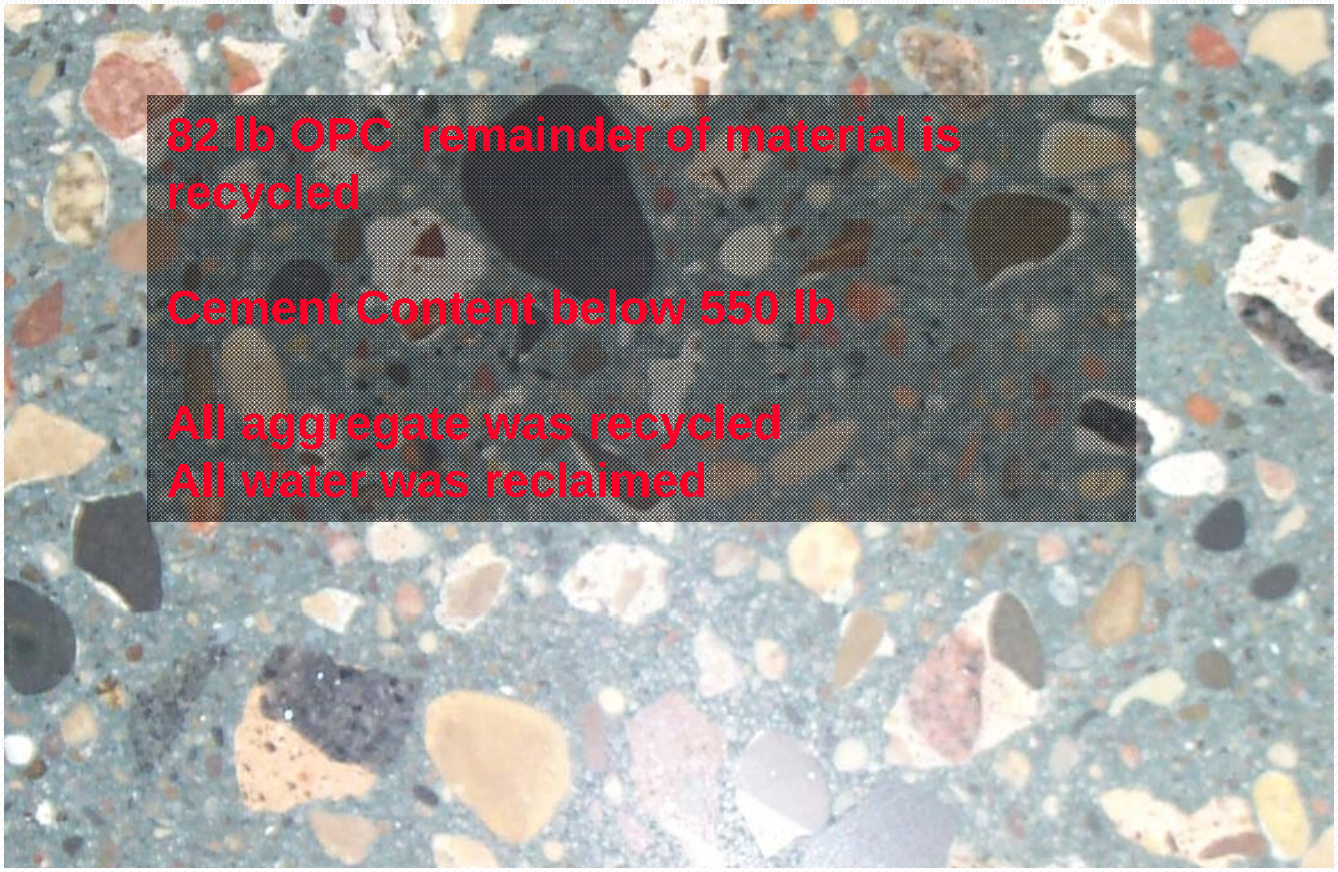

WEST BANK
3 Superstructure construction
Temporary scaffolding and forms will be built to provide a mold for the parts of the bridge over land. Each side of the river will have this superstructure cast on-site. Once this is completed, the center span can be put in place.
Five lanes per side
1 Foundation
The foundation consists of drilled shafts, four for each of the eight central span piers. Each has a steel casing over concrete.
Deck
Superstructure
Pier
Footing
50 ft.
(dirt, sand overburden)
Piling shafts
Approx. 50-70 ft.
(solid rock)
2 Pier construction
Each pier for the main span will be cast on-site atop the footings on each bank.
4 Segment placement
The center span's box-girder segments are precast and will be fitted by lowering them from a crane positioned on the bridge deck.
5 Assembly
Segments are linked together by steel cables threaded through them, with each segment linked to the adjacent ones and full-length cables linking the entire array.
Box-beam segments
Tensioning cables
Deck crane
7 Finishing work
The deck, railings, paint, lighting, monitoring systems and sculptural elements are added in the final phase.
Mississippi River
COMPLETION OF THE CENTRAL SPAN
6 The final segment
After all the segments are in place, the final gap between the assembled sides is cast in concrete, completing the central span.
Final cast-in-place segment
115 ft.
504 ft.
1,223 ft.
Footing
(not visible after construction)
EAST BANK
NOTE: All drawings are schematic.
Sources: Minnesota Department of Transportation, Figg Bridge Engineers Inc., Flatiron Constructors Inc.
Graphic by MARK BOSWELL © 2007 Star Tribune
Modified by FIGG December 2007

Why HPC with high replacement levels?

- While this might not be the clearest opportunity for innovation, it was a requirement of the RFP to have a structure with a design life of 100 years.


naiveté
trust
Doom

Extreme Example



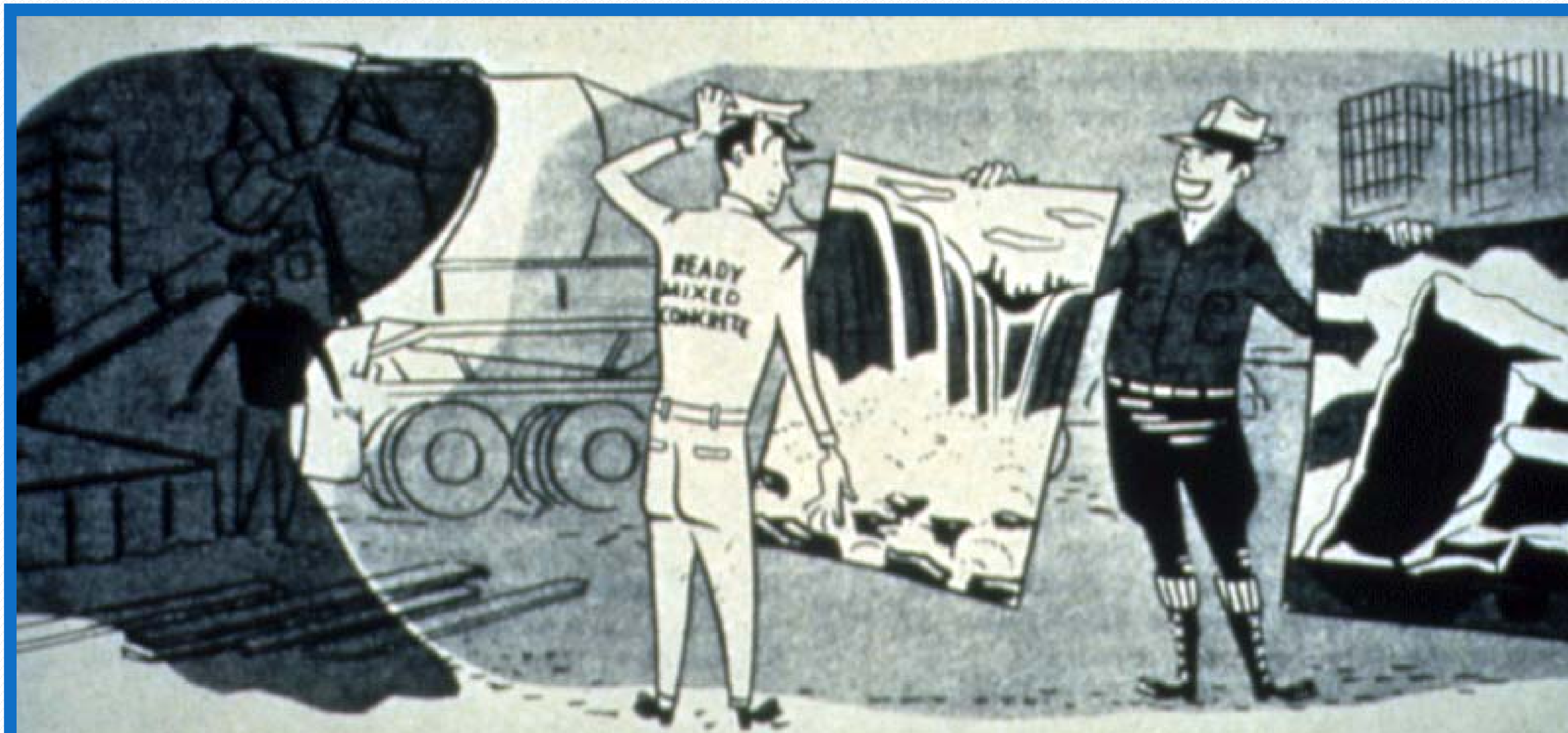

GEMSTONE
GEMSTONE
E-CON-PLACER

AET 4060

- RCP at 84 days 490 Coulombs passed
- Setting Time 4:30 Initial Set
- Air Void System
  - Air Content 5.5 percent
  - Spacing Factor   0.008 in
  - Specific Surface 600 in^2 /in^3
- Shrinkage 0.005 percent at 28 days
- Strength Gain

Planning

- As a result some very non-traditional concretes were utilized in the construction.
- Performance-based design
  - Designer Requirements
  - Owner Requirements
  - Constructor Requirements



"Here's what I want: Your concrete should pour like, Niagara and have the strength of Gibraltar."

Performance Requirements

- The concrete had many requirements, some of which were in opposition to one another:

- There were shafts drilled to a depth of over 120 feet to socket to the bedrock through to bridge superstructure concrete which has to resist the ingress of chloride ion for the next century.

- All elements below the superstructure are mass concrete, as are the soffit slabs at the maximum shear elements, and the pier tables and diaphragms in the superstructure.

- There was a requirement for high early strength in construction, as the bonus for early finishing was substantial.

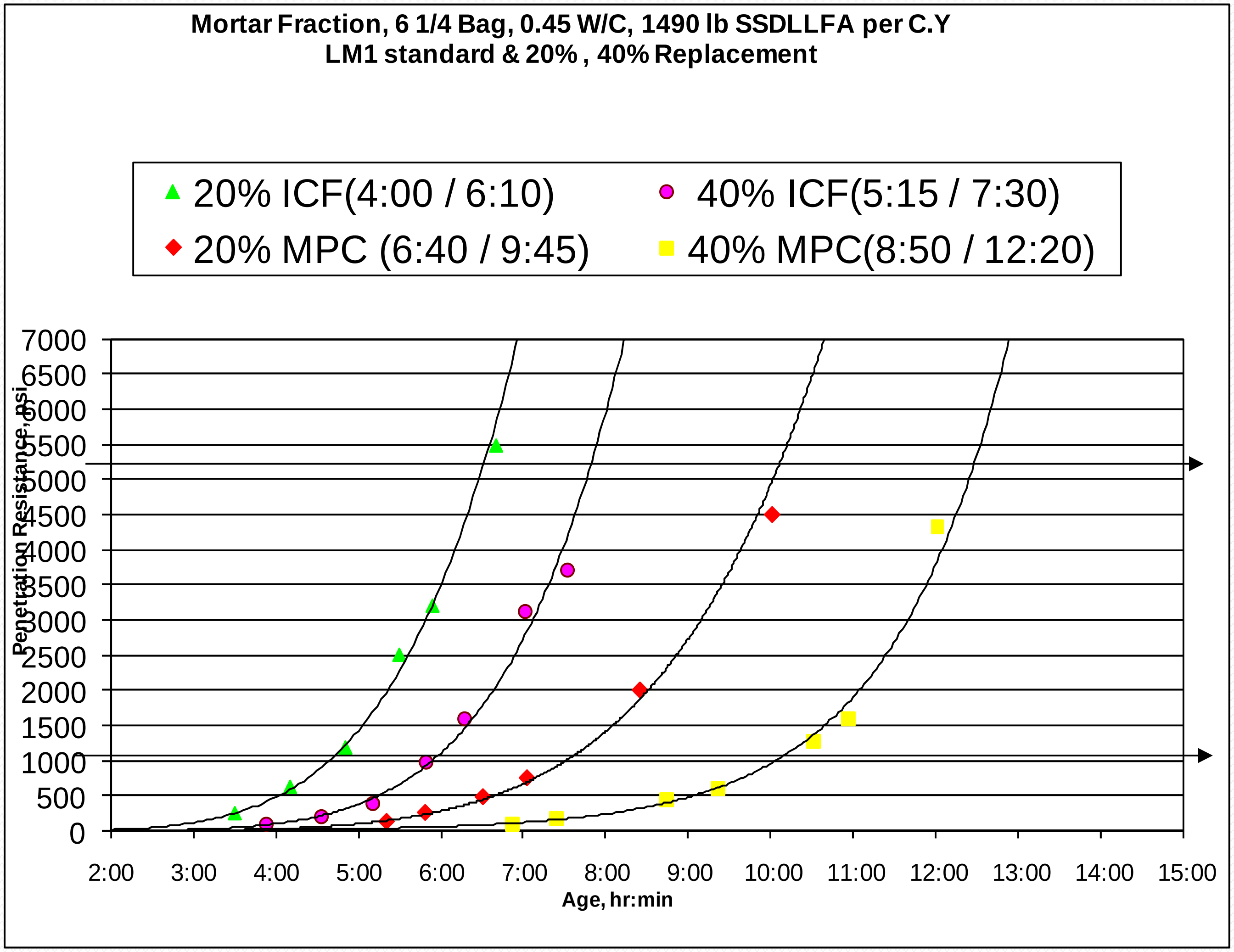
Performance Requirements

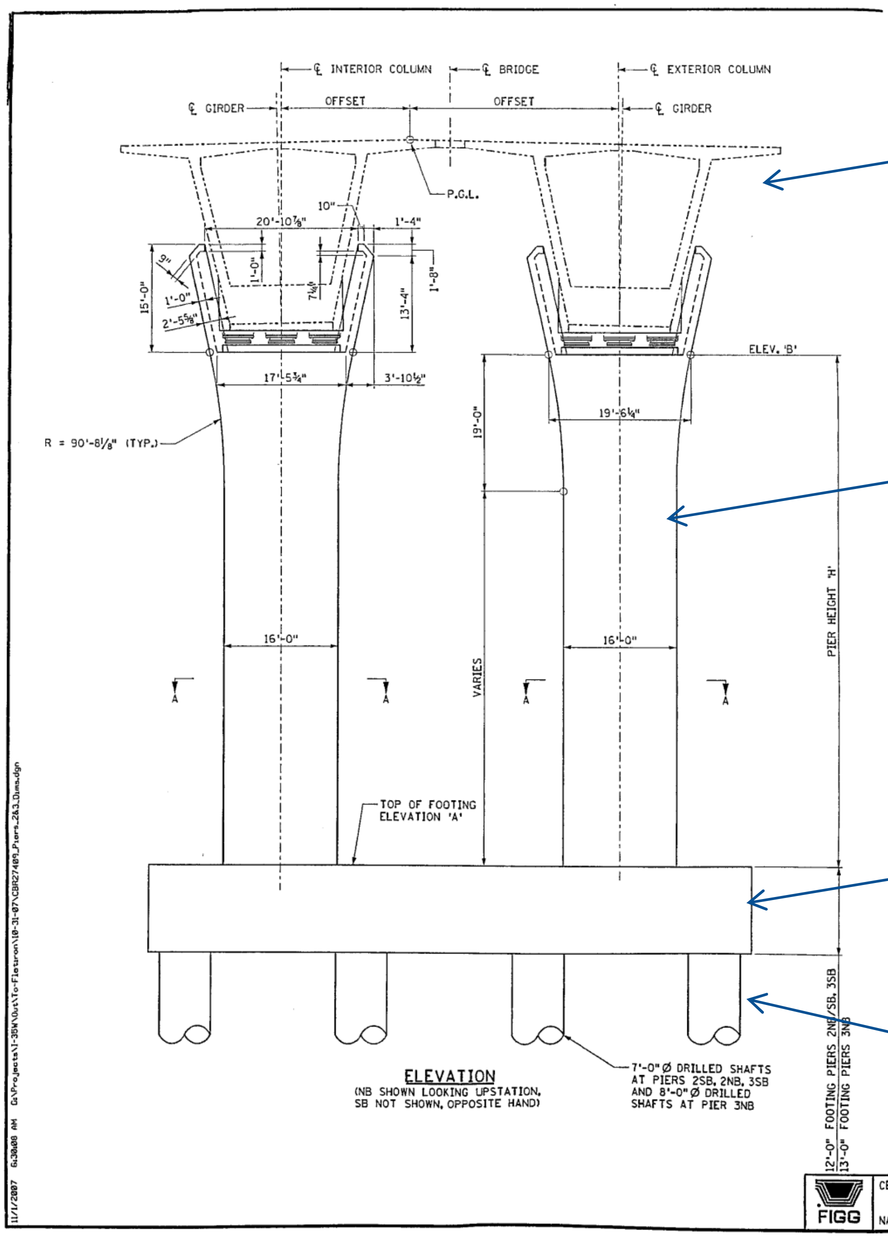
- There was a requirement for low permeability to water and aggressive chemicals such as chloride.
  - low permeability in the concrete itself
  - low shrinkage so that the concrete does not contain excessive cracking which short circuits the concrete as a protective layer.
- The concrete needed to flow into congested reinforcement, into complicated forms and into shafts that could not be inspected visually.
- The concrete should have as small an environmental impact as possible

A six sack mixture

Siberia of North America

Flyash is not a constant



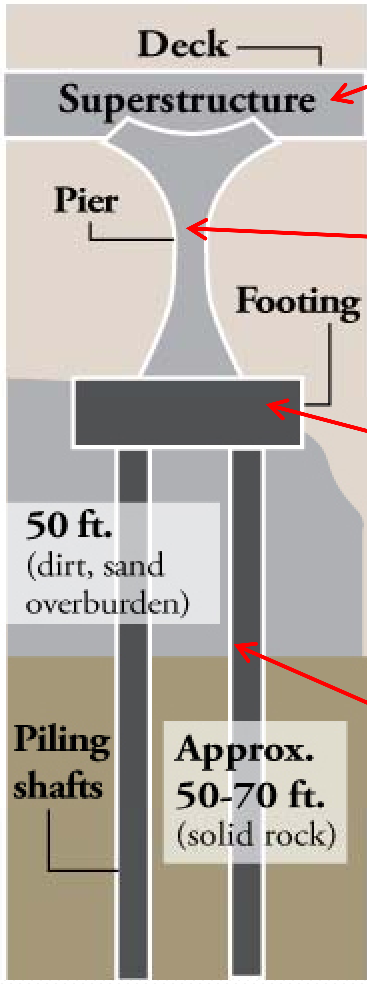


Superstructure
Chloride
Freeze Thaw
Scaling
Creep and
Shrinkage

Piers
Mass Concrete
Freeze-Thaw Exposure
Chlorides

Footing
Mass Concrete
Freeze-Thaw Exposure
Chlorides

Shafts
Consolidation
Freeze Thaw
Chlorides /
Permeability

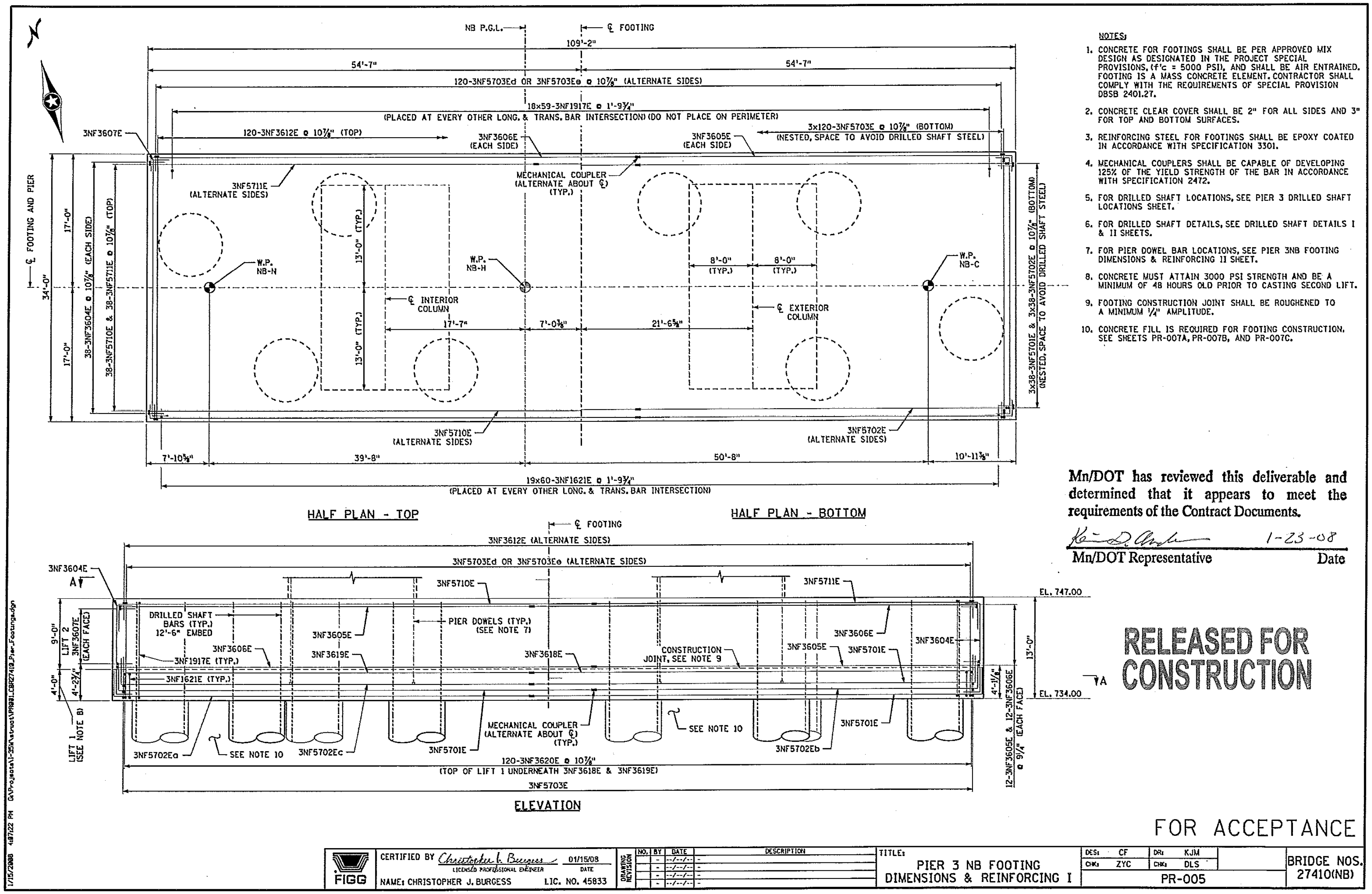


6500 psi concrete
70 percent OPC

4000 psi concrete
18 percent OPC

5000 psi SCC w 40 percent OPC

5000 psi SCC w 40 percent OPC



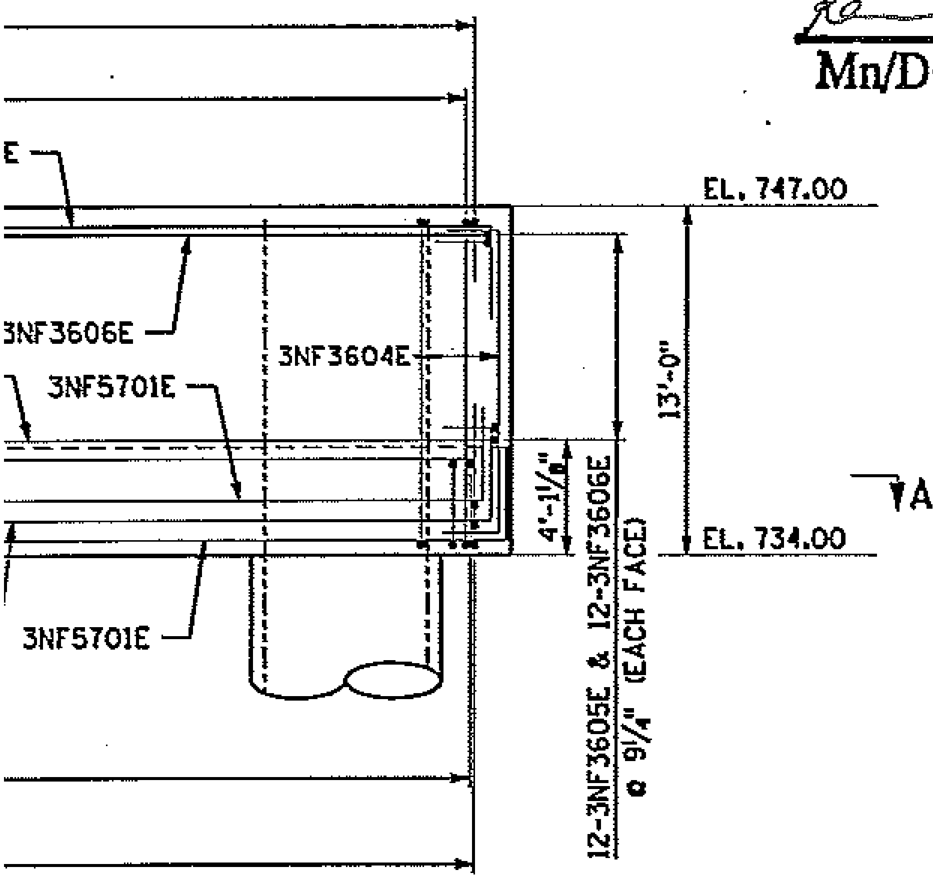
NOTES:
1. CONCRETE FOR FOOTINGS SHALL BE PER APPROVED MIX DESIGN AS DESIGNATED IN THE PROJECT SPECIAL PROVISIONS, (f'c = 5000 PSI), AND SHALL BE AIR ENTRAINED. FOOTING IS A MASS CONCRETE ELEMENT. CONTRACTOR SHALL COMPLY WITH THE REQUIREMENTS OF SPECIAL PROVISION DBSB 2401.27.
2. CONCRETE CLEAR COVER SHALL BE 2" FOR ALL SIDES AND 3" FOR TOP AND BOTTOM SURFACES.
3. REINFORCING STEEL FOR FOOTINGS SHALL BE EPOXY COATED IN ACCORDANCE WITH SPECIFICATION 3301.
4. MECHANICAL COUPLERS SHALL BE CAPABLE OF DEVELOPING 125% OF THE YIELD STRENGTH OF THE BAR IN ACCORDANCE WITH SPECIFICATION 2472.
5. FOR DRILLED SHAFT LOCATIONS, SEE PIER 3 DRILLED SHAFT LOCATIONS SHEET.
6. FOR DRILLED SHAFT DETAILS, SEE DRILLED SHAFT DETAILS I & II SHEETS.
7. FOR PIER DOWEL BAR LOCATIONS, SEE PIER 3NB FOOTING DIMENSIONS & REINFORCING II SHEET.
8. CONCRETE MUST ATTAIN 3000 PSI STRENGTH AND BE A MINIMUM OF 48 HOURS OLD PRIOR TO CASTING SECOND LIFT.
9. FOOTING CONSTRUCTION JOINT SHALL BE ROUGHENED TO A MINIMUM 1/4" AMPLITUDE.
10. CONCRETE FILL IS REQUIRED FOR FOOTING CONSTRUCTION. SEE SHEETS PR-007A, PR-007B, AND PR-007C.
HALF PLAN - TOP
HALF PLAN - BOTTOM
ELEVATION
Mn/DOT has reviewed this deliverable and determined that it appears to meet the requirements of the Contract Documents.
1-23-08
Mn/DOT Representative
Date
RELEASED FOR CONSTRUCTION
FOR ACCEPTANCE
CERTIFIED BY
01/15/08
LICENSED PROFESSIONAL ENGINEER
DATE
NAME: CHRISTOPHER J. BURGESS
LIC. NO. 45833
FIGG
TITLE:
PIER 3 NB FOOTING DIMENSIONS & REINFORCING I
DES: CF
DR: KJM
CHK: ZYC
CHK: DLS
PR-005
BRIDGE NOS. 27410(NB)

Mn/DOT has reviewed this deliverable and determined that it appears to meet the requirements of the Contract Documents.

[signature] 1-23-08

Mn/DOT Representative Date

TTOM



RELEASED FOR CONSTRUCTION

FOR ACCEPTANCE

TITLE: PIER 3 NB FOOTING DIMENSIONS & REINFORCING I	DES: CF	DR: KJM		BRIDGE NOS. 27410(NB)
	CHK: ZYC	CHK: DLS		
	PR-005			


Abutment #5
Pier 4 SB
Pier 4 NB
10th Ave Bridge
Pier 3 SB
Pier 3 NB
Pier 2 NB
Pier 2 SB
North
Abutment #1

Shaft Concrete

- 60 Percent Pozzolan Replacement
- 24 inch spread
- Air entrained
- RCP
- Shrinkage
- Strength at 28 days (lab cure) 5500 psi
- Cores from 21 day old Shaft 10,250 psi


CEMSTONE

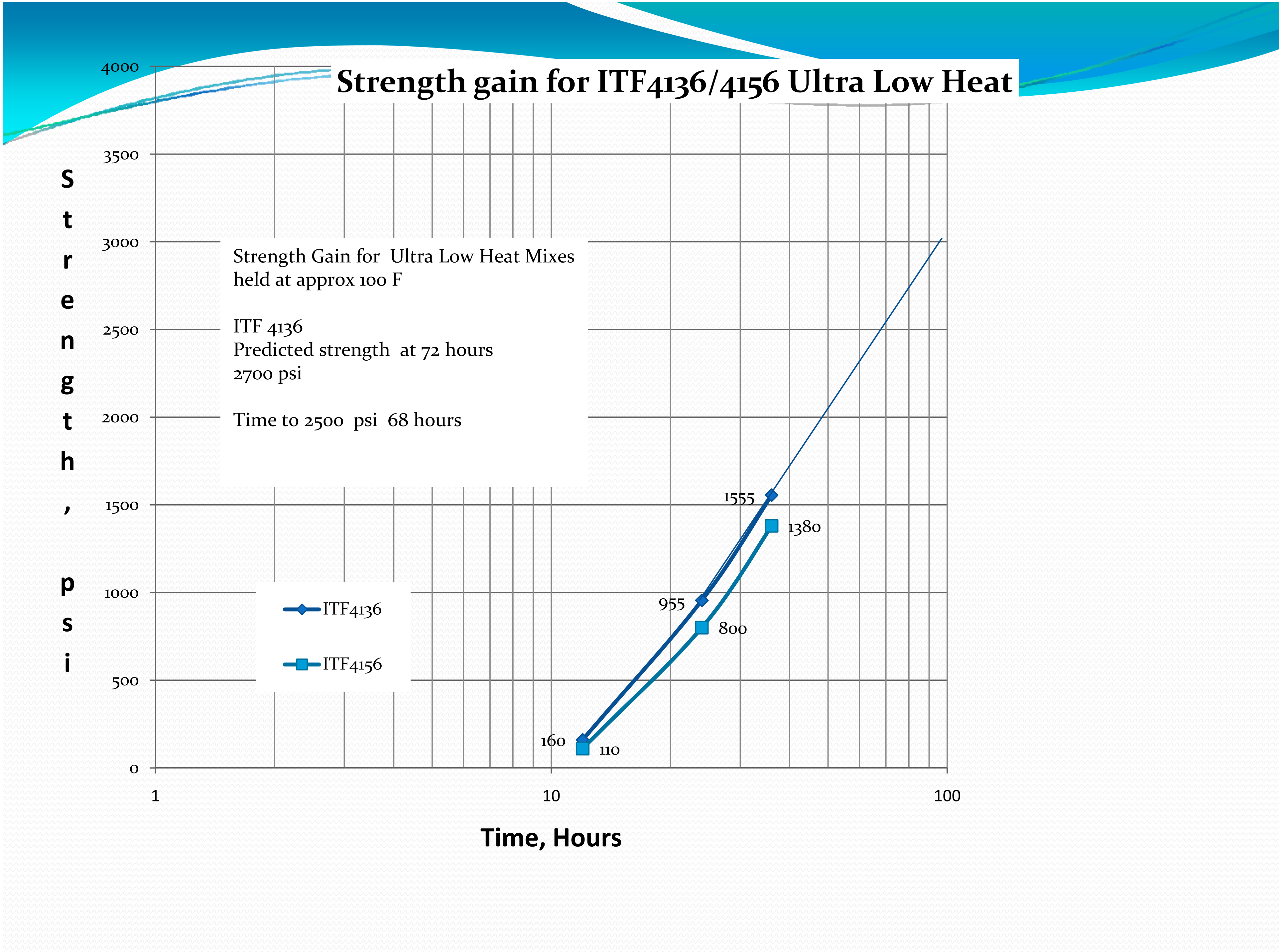
Footings

- 60 Percent Pozzolan Replacement
- 8 inch slump
- Air entrained
- RCP
- Shrinkage
- Strength at 28 days (lab cure)

Piers

- 60 Percent Pozzolan Replacement
- 24 inch spread
- Air entrained
- RCP
- Shrinkage
- Strength at 28 days (lab cure)
- Cores from 21 day old Shaft   10,250 psi

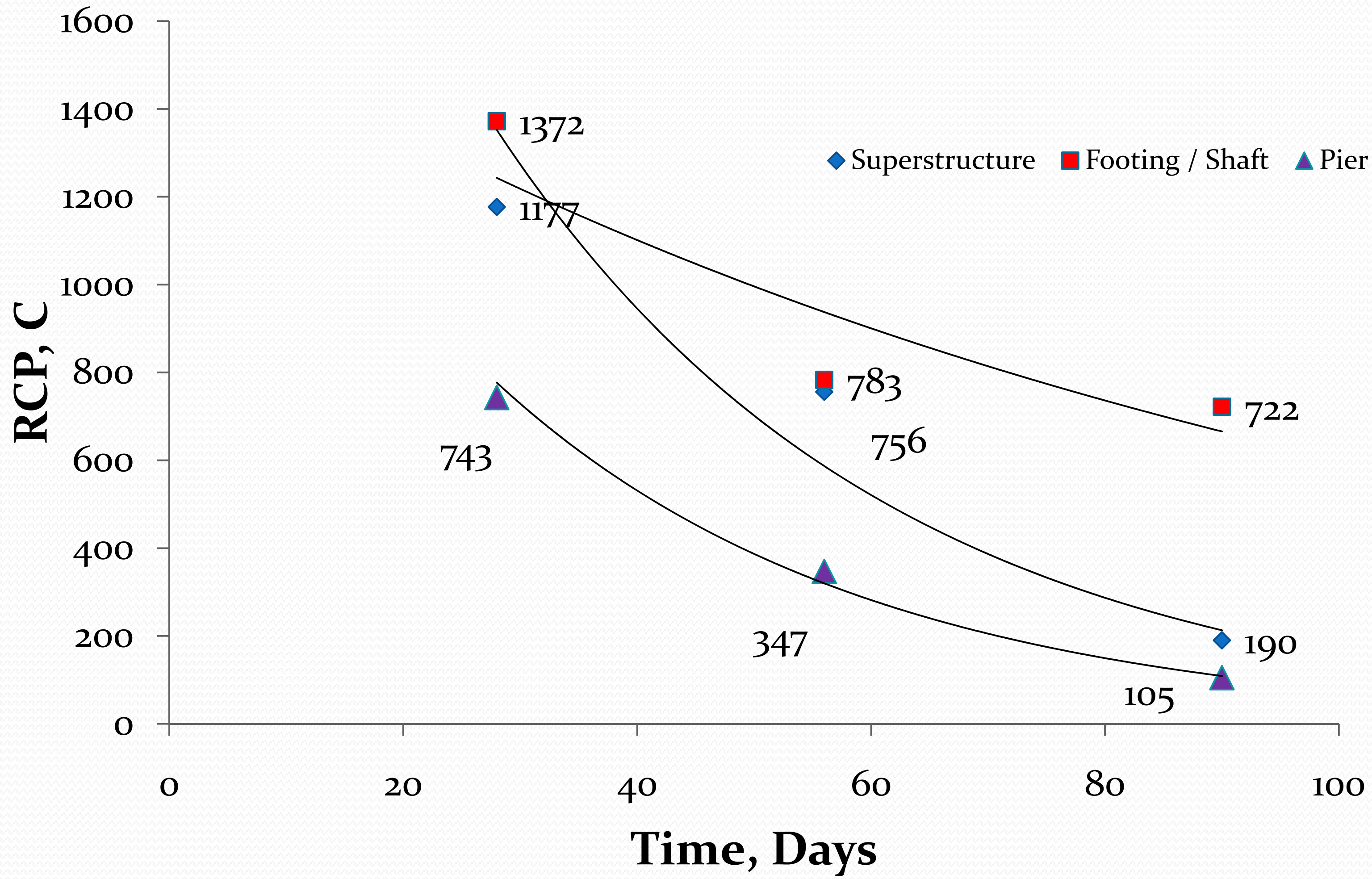

02/04/2008
Genie
KOMATSU

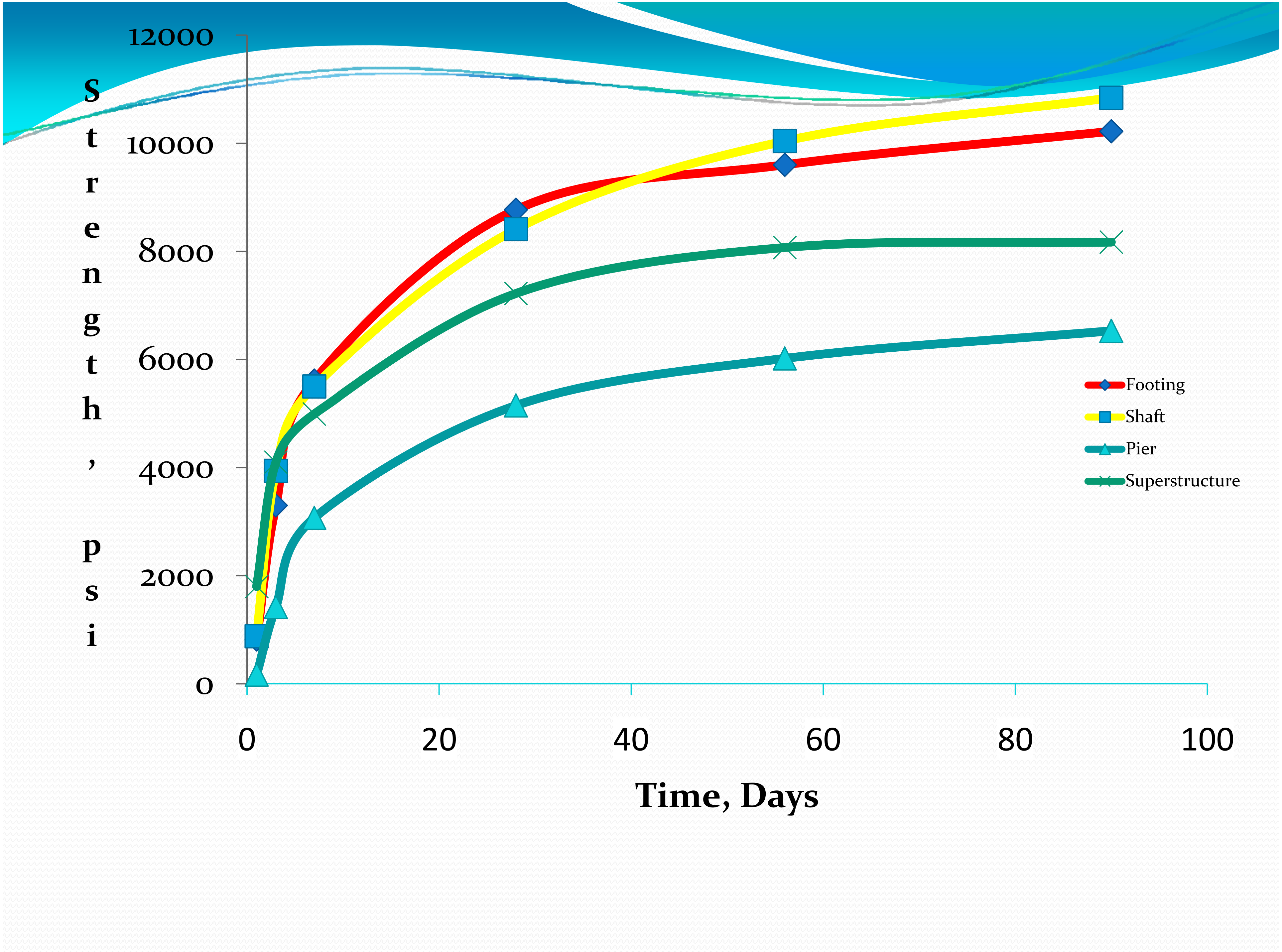


Strength gain for ITF4136/4156 Ultra Low Heat
Strength Gain for Ultra Low Heat Mixes held at approx 100 F
ITF 4136
Predicted strength at 72 hours
2700 psi
Time to 2500 psi 68 hours
ITF4136
ITF4156
1555
1380
955
800
160
110
4000
3500
3000
2500
2000
1500
1000
500
0
1
10
100
Strength, psi
Time, Hours

Superstructure

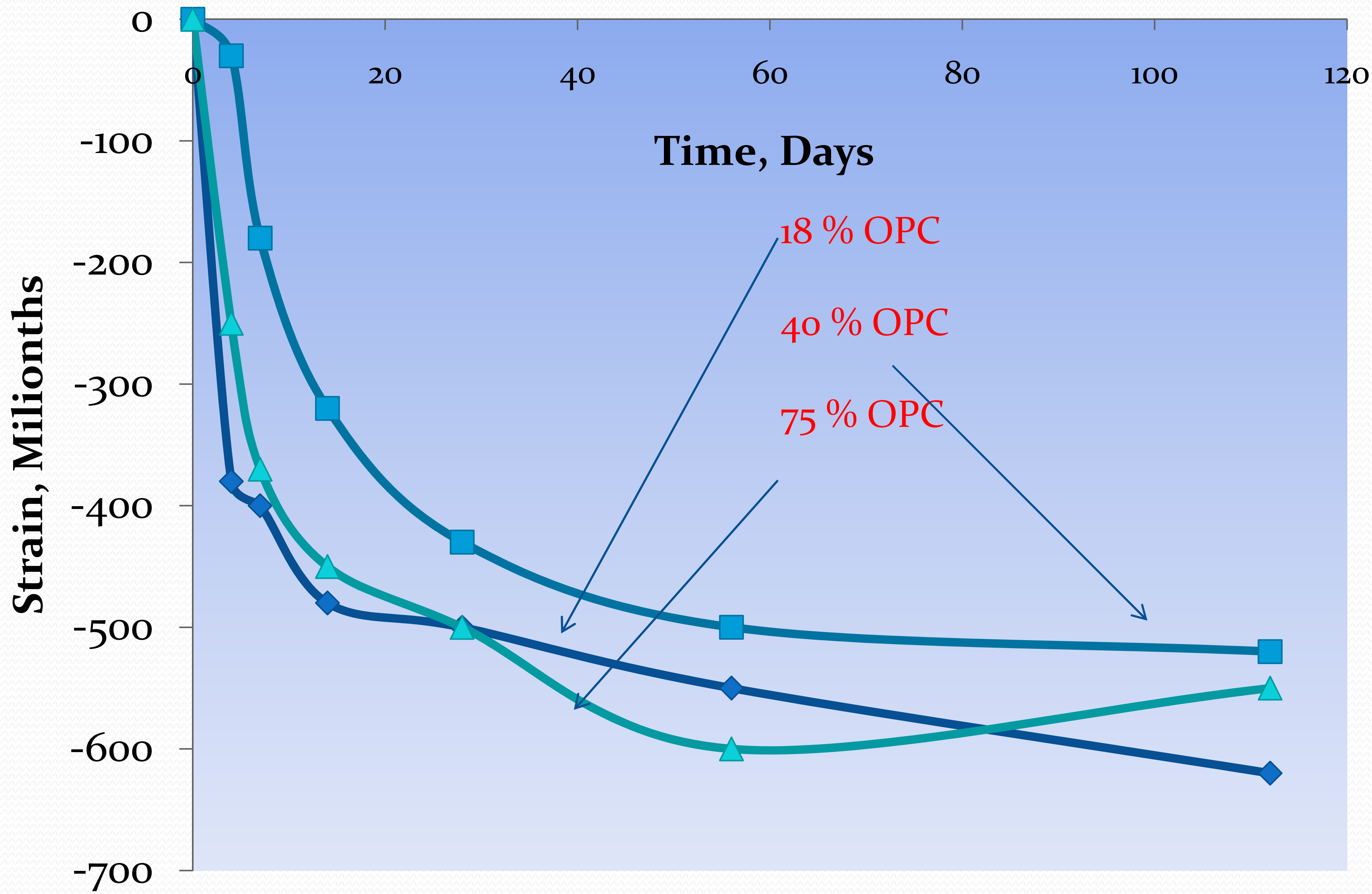
- 30 Percent Pozzolan Replacement
- 8 inch slump
- Air entrained
- RCP
- Shrinkage
- Modulus of Elasticity
- Strength at 28 days (lab cure)


RCP, C
1600
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
Time, Days
Superstructure
Footing / Shaft
Pier
1372
1177
783
756
722
743
347
190
105



Strength, psi
12000
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
Time, Days
Footing
Shaft
Pier
Superstructure

Shrinkage



0
-100
-200
-300
-400
-500
-600
-700
0
20
40
60
80
100
120
Time, Days
Strain, Milionths
18 % OPC
40 % OPC
75 % OPC

Production Controls

Questions?