Bridge Deck Cracking

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Columbus, OH
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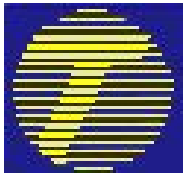
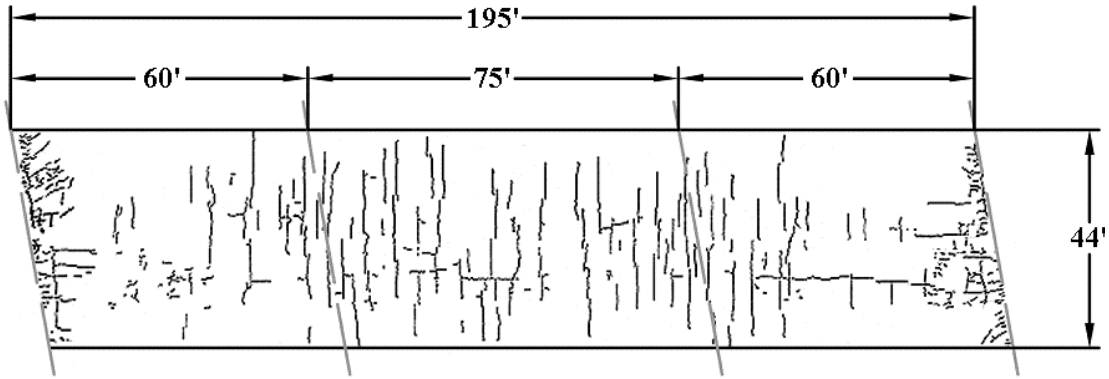
Research Sponsors



Outline

- Scope
- Findings
- Specifications
- Field Experience
- Technologies Under Active Study
- Conclusions



Scope of Work

Beginning in 1991

Initiated bridge deck crack surveys using standardized methods (150+ decks)

Established principal factors controlling cracking

Scope of Work

Beginning in 2005

Constructed 25 bridge decks under Low Cracking High-Performance Concrete (LC-HPC) specifications (17 in Kansas)

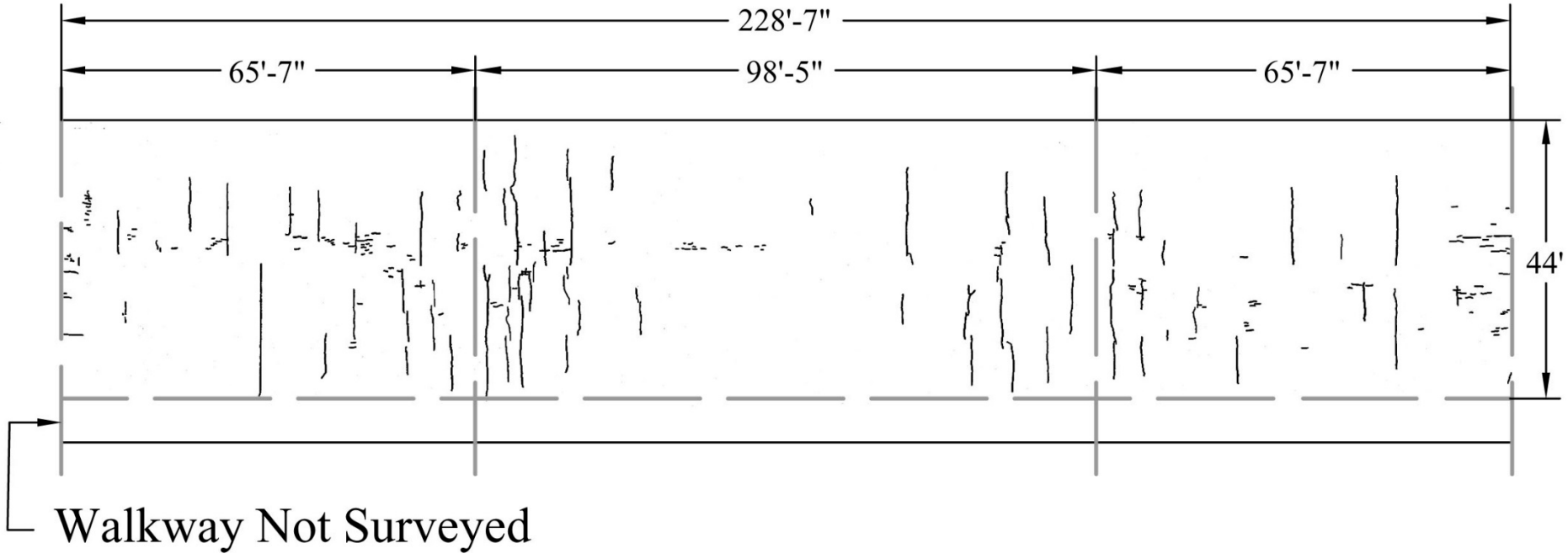
Most bridges in study have steel girders

Findings

What's not a major concern

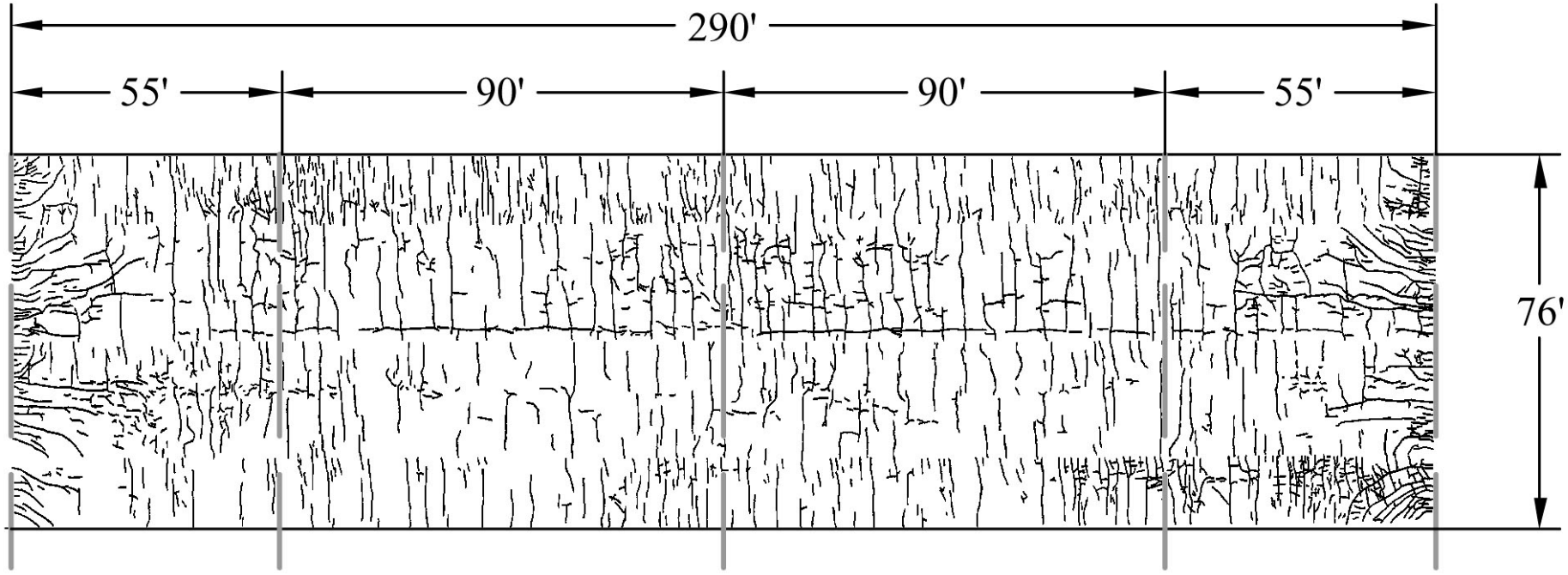
Moment region and load-induced stresses in the deck

Moment region



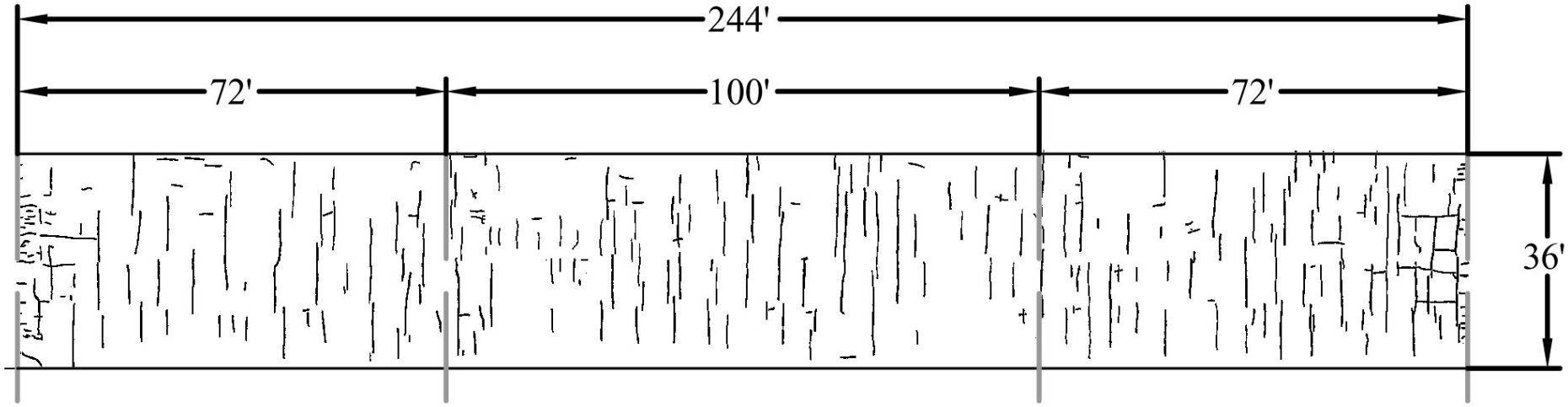
7% Silica Fume Overlay

Moment region



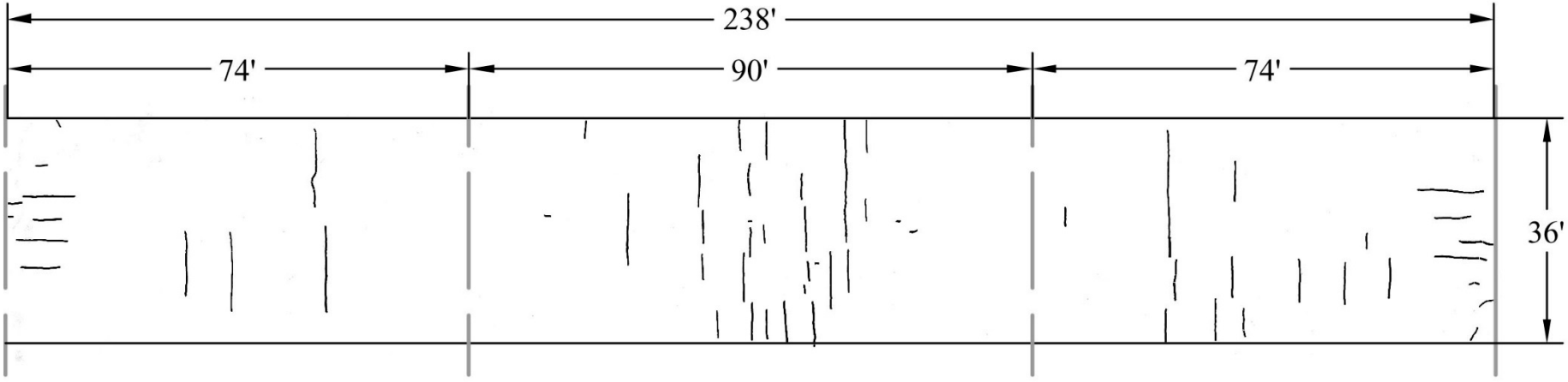
Conventional Overlay

Moment region



Monolithic

Moment region

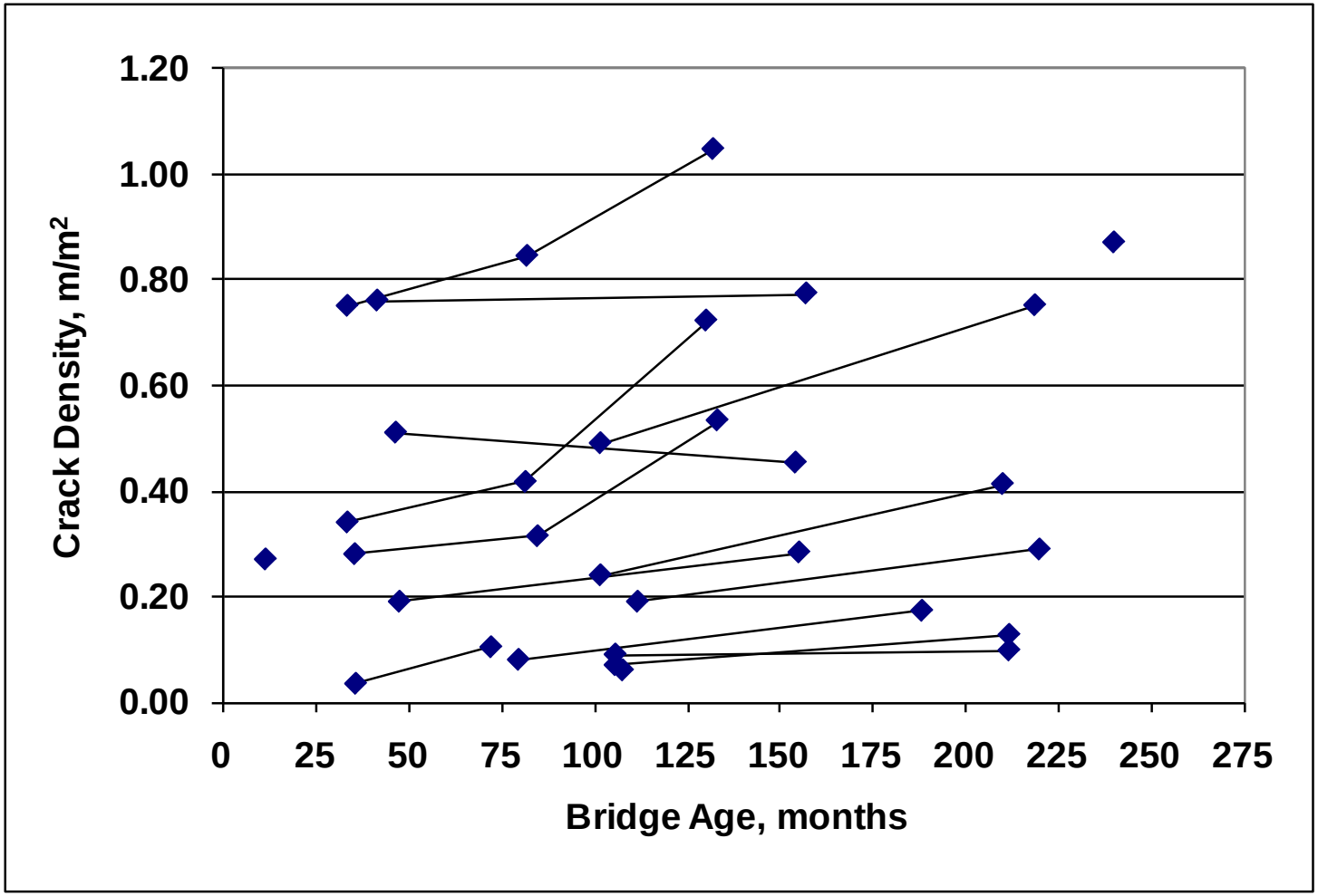


Monolithic

Factors

- Age
- Bridge Deck Type
- Material Effects
- Site Conditions – Temperature
- Curing
- Date of Construction

Age


1.20
1.00
0.80
0.60
0.40
0.20
0.00
Crack Density, m/m²
0
25
50
75
100
125
150
175
200
225
250
275
Bridge Age, months

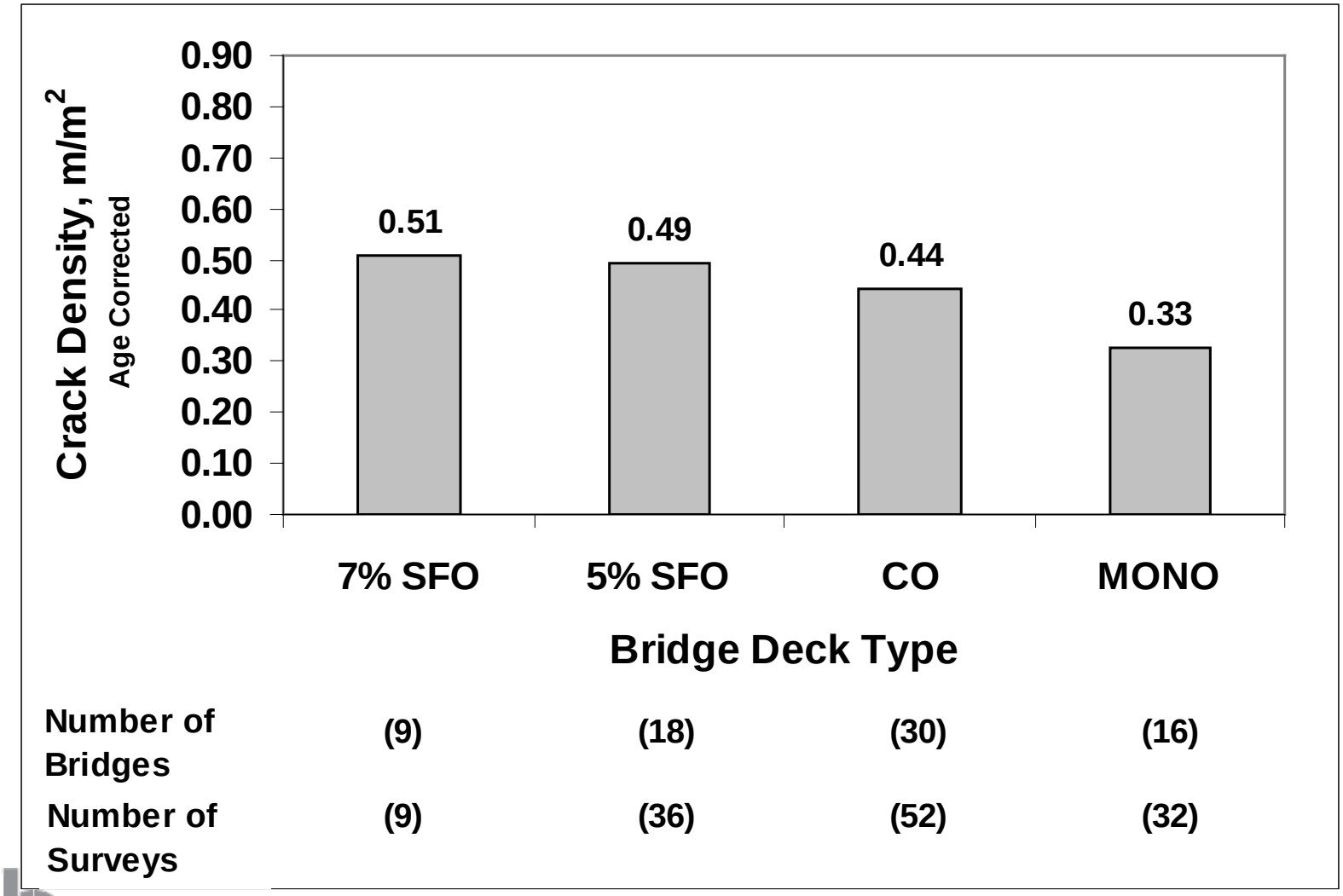
Bridge Deck Type

Monolithic

Conventional Overlay

Silica Fume Overlay

Bridge Deck Type

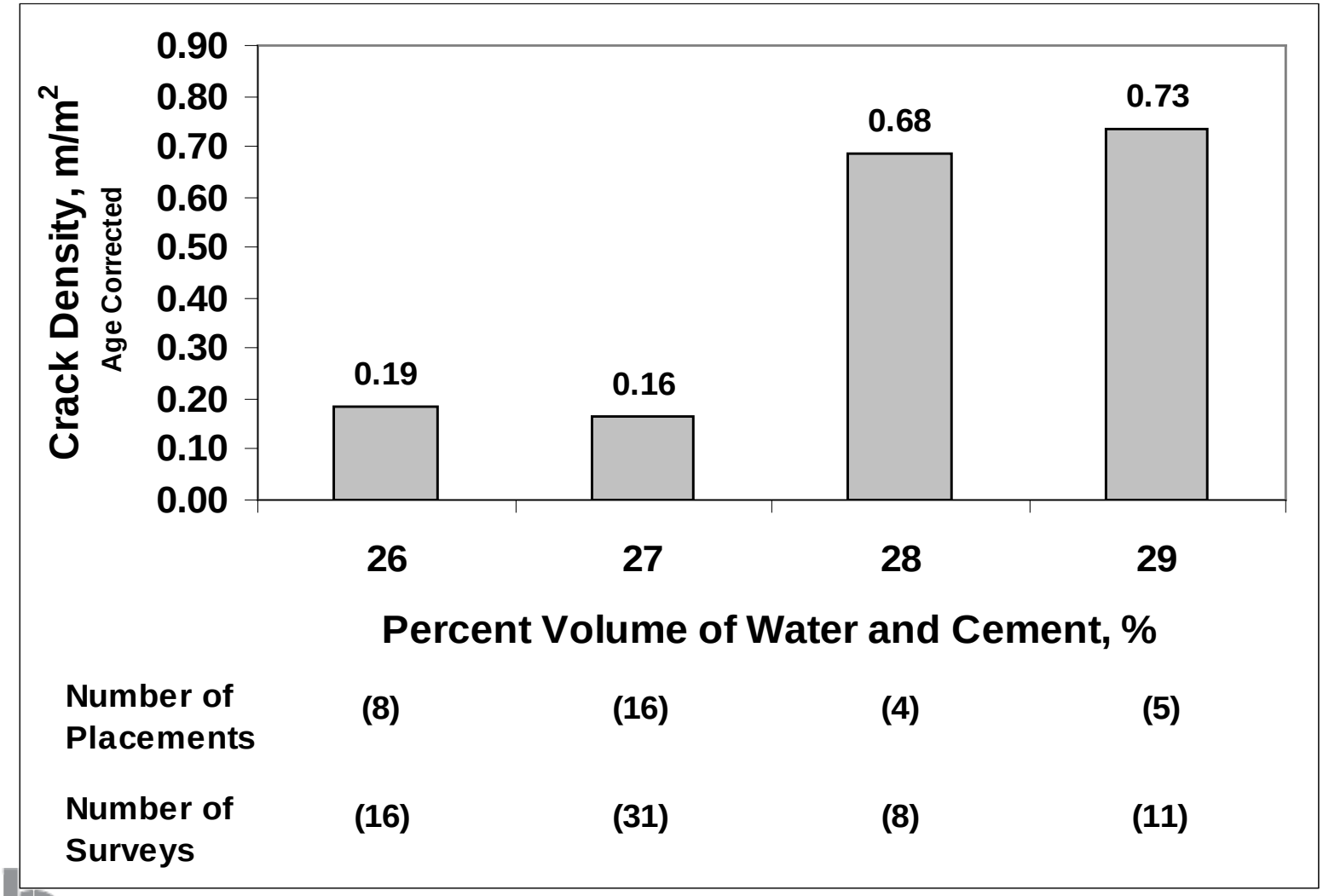


Number of Bridges	(9)	(18)	(30)	(16)
Number of Surveys	(9)	(36)	(52)	(32)

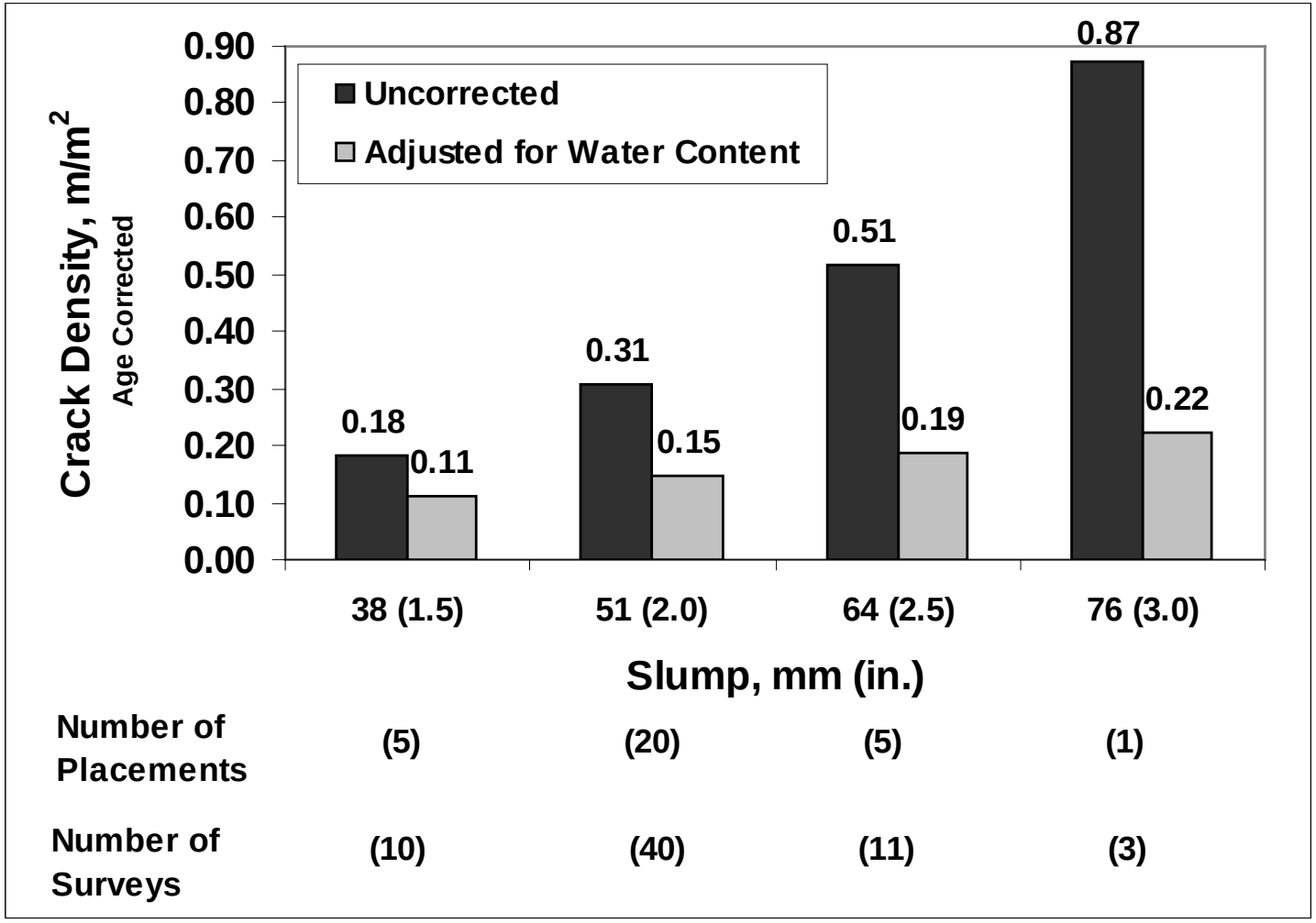
Material Effects

- Concrete Mixture Proportions
  - Water content
  - Cement content
  - Volume of cement paste
- Slump
- Compressive strength
- Air content

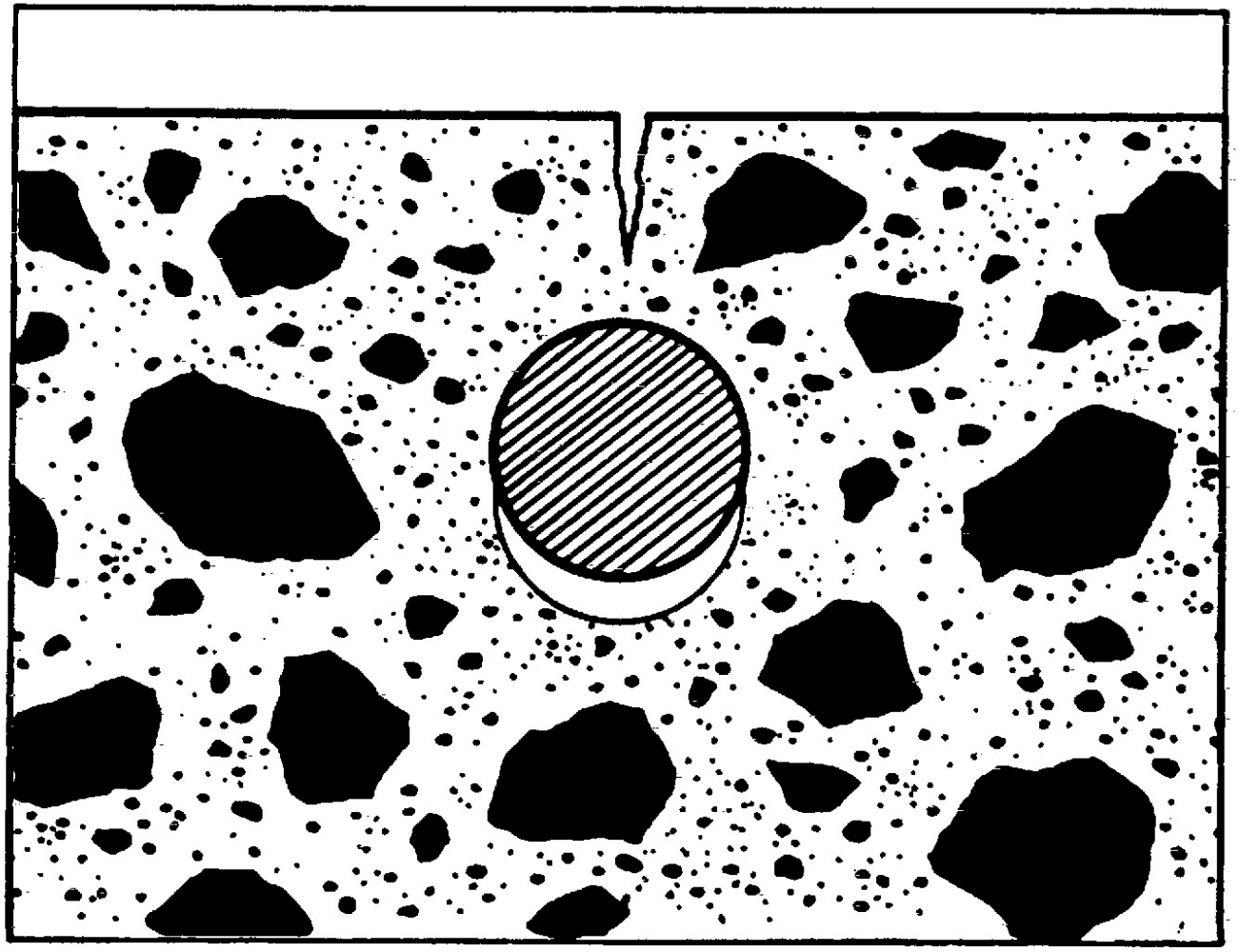
Paste Content



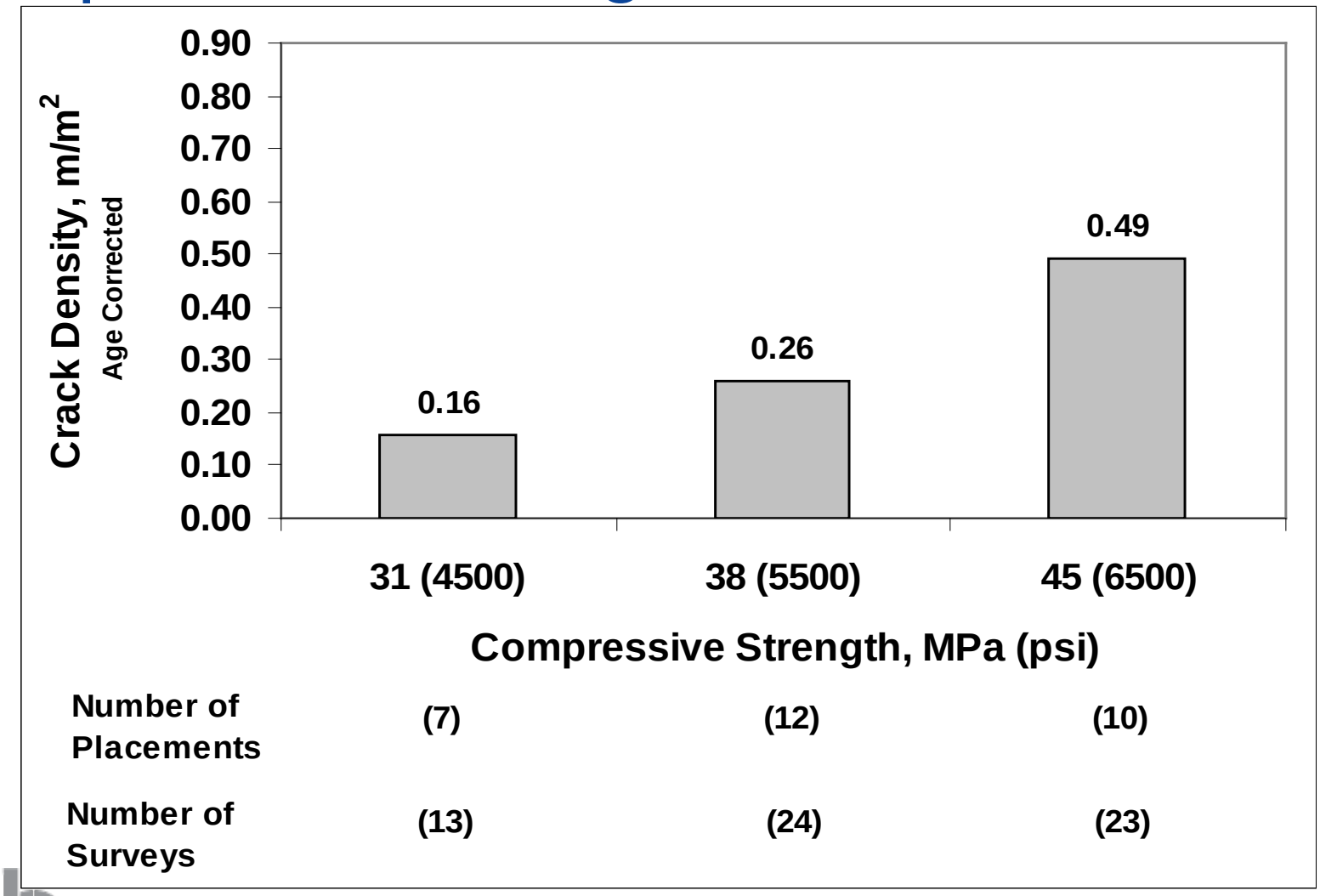
Slump


Crack Density, m/m^2
Age Corrected
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Uncorrected
Adjusted for Water Content
0.18
0.11
0.31
0.15
0.51
0.19
0.87
0.22
38 (1.5)
51 (2.0)
64 (2.5)
76 (3.0)
Slump, mm (in.)
Number of Placements
(5)
(20)
(5)
(1)
Number of Surveys
(10)
(40)
(11)
(3)

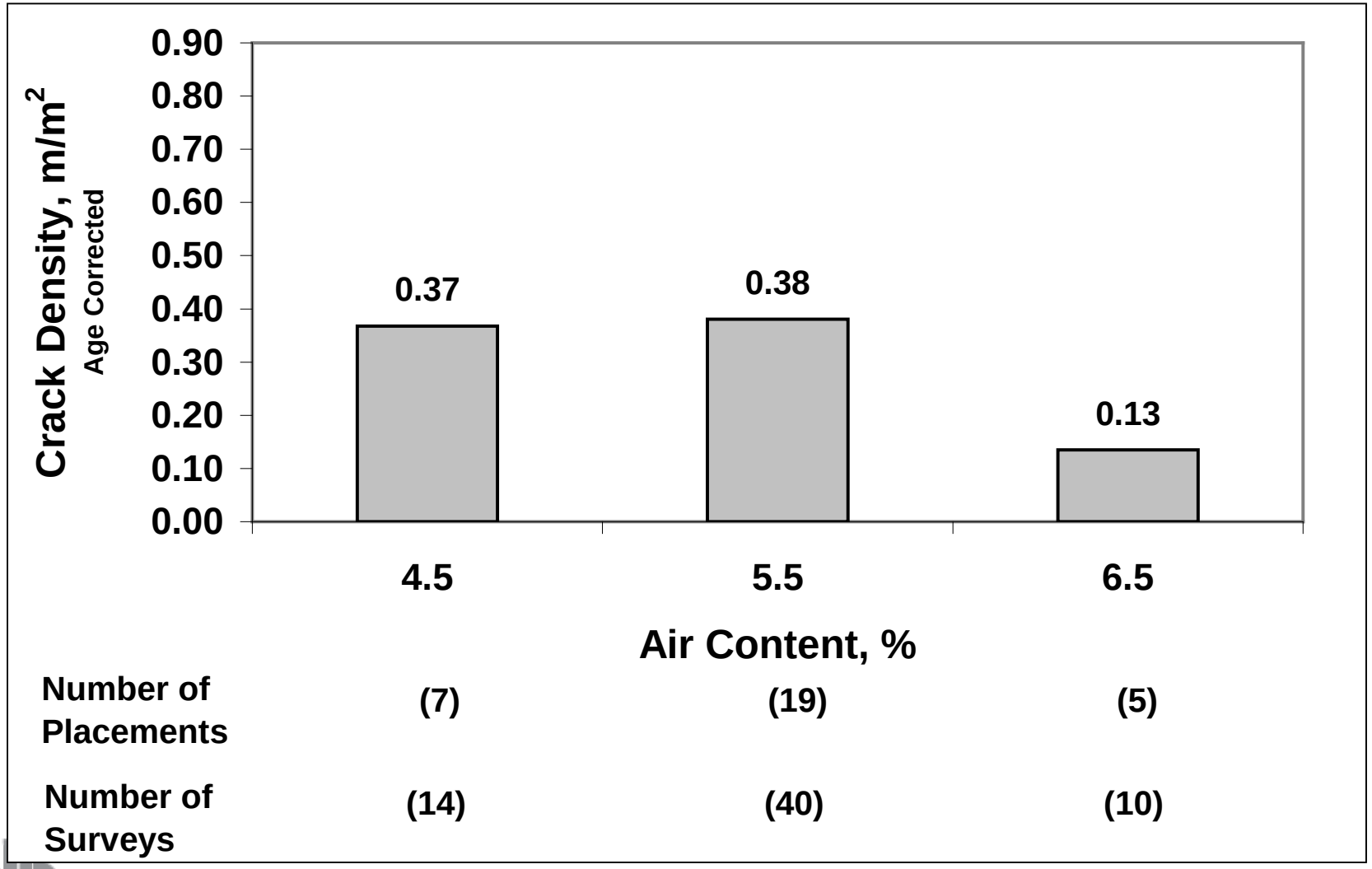
Settlement Cracking



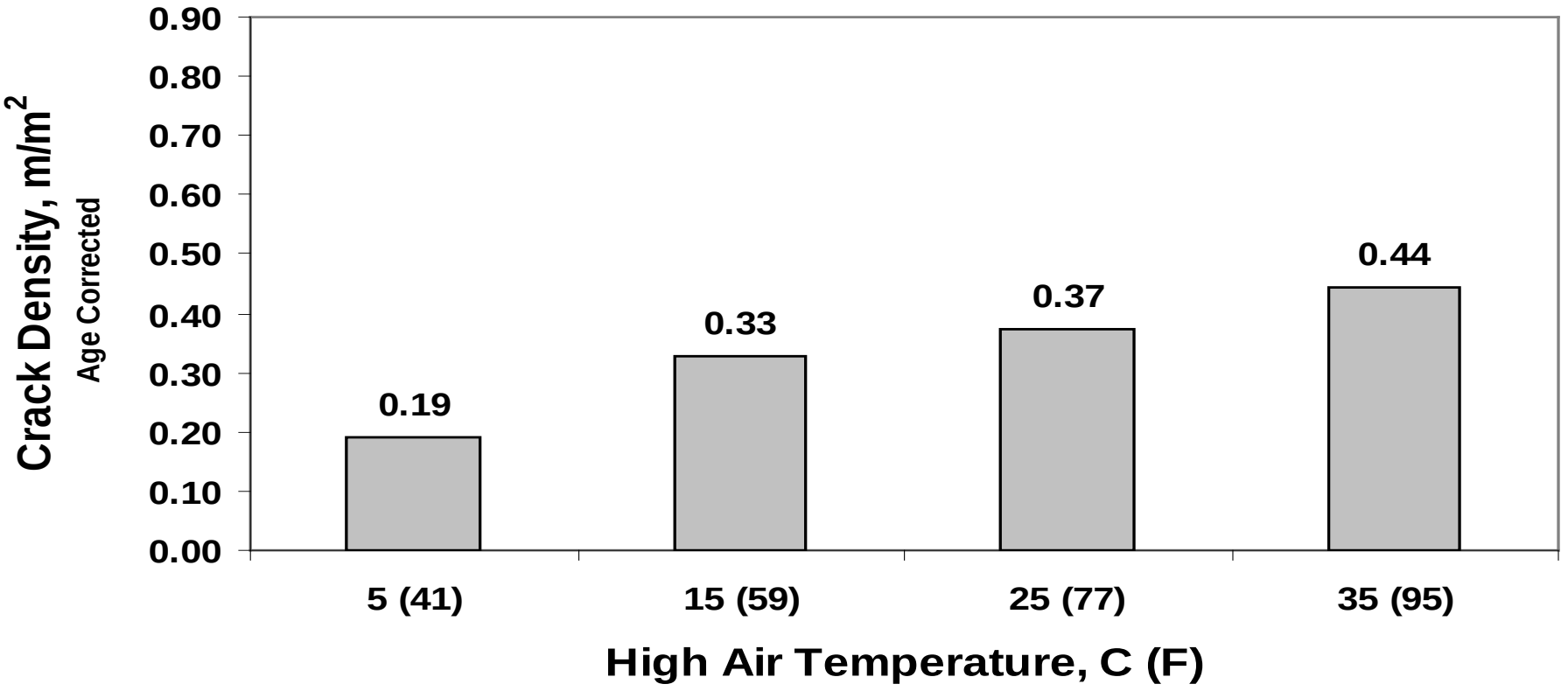
Compressive Strength



Air Content


Crack Density, m/m2
Age Corrected
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.37
0.38
0.13
4.5
5.5
6.5
Air Content, %
Number of Placements
(7)
(19)
(5)
Number of Surveys
(14)
(40)
(10)

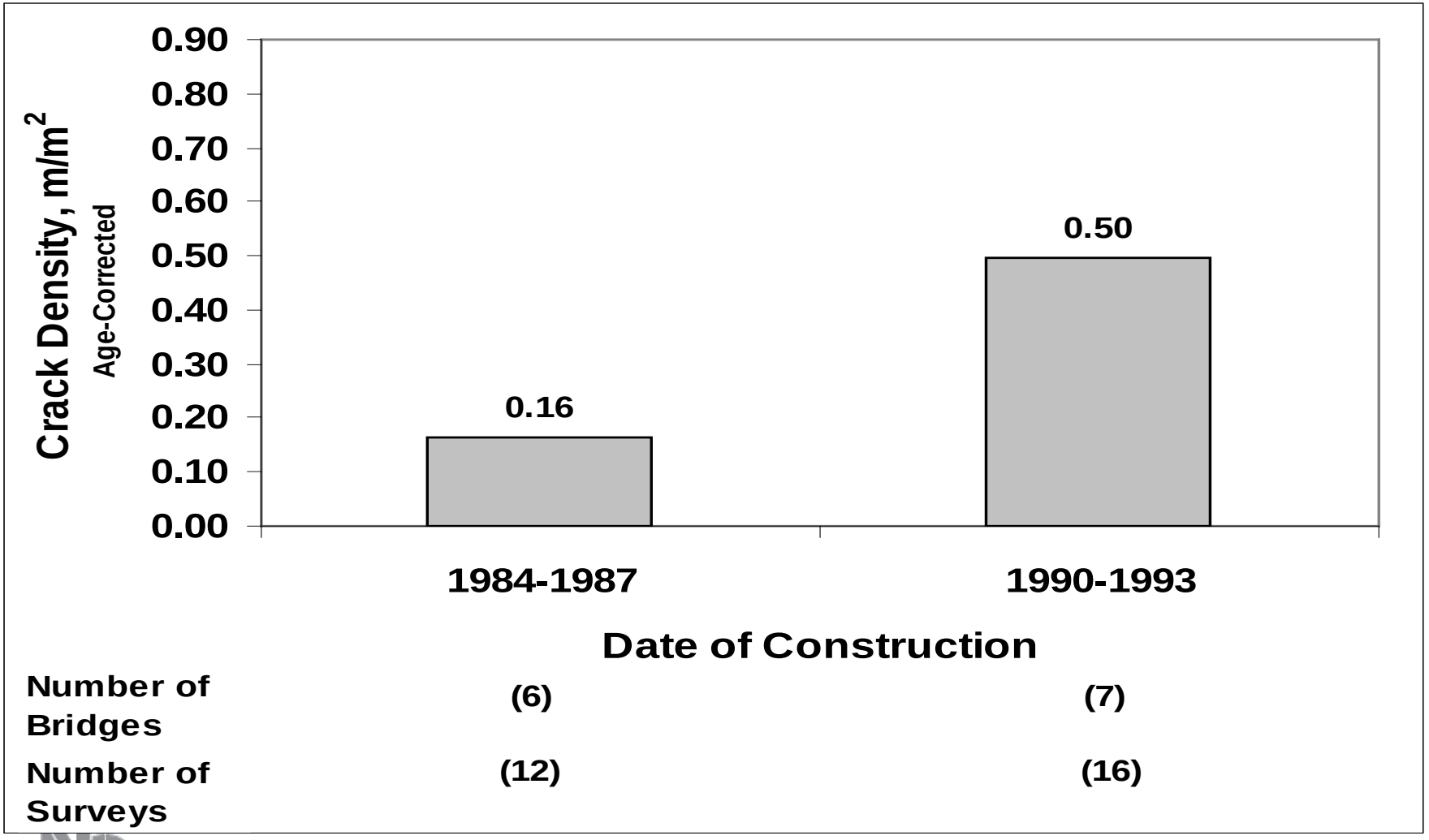
High Air Temperature



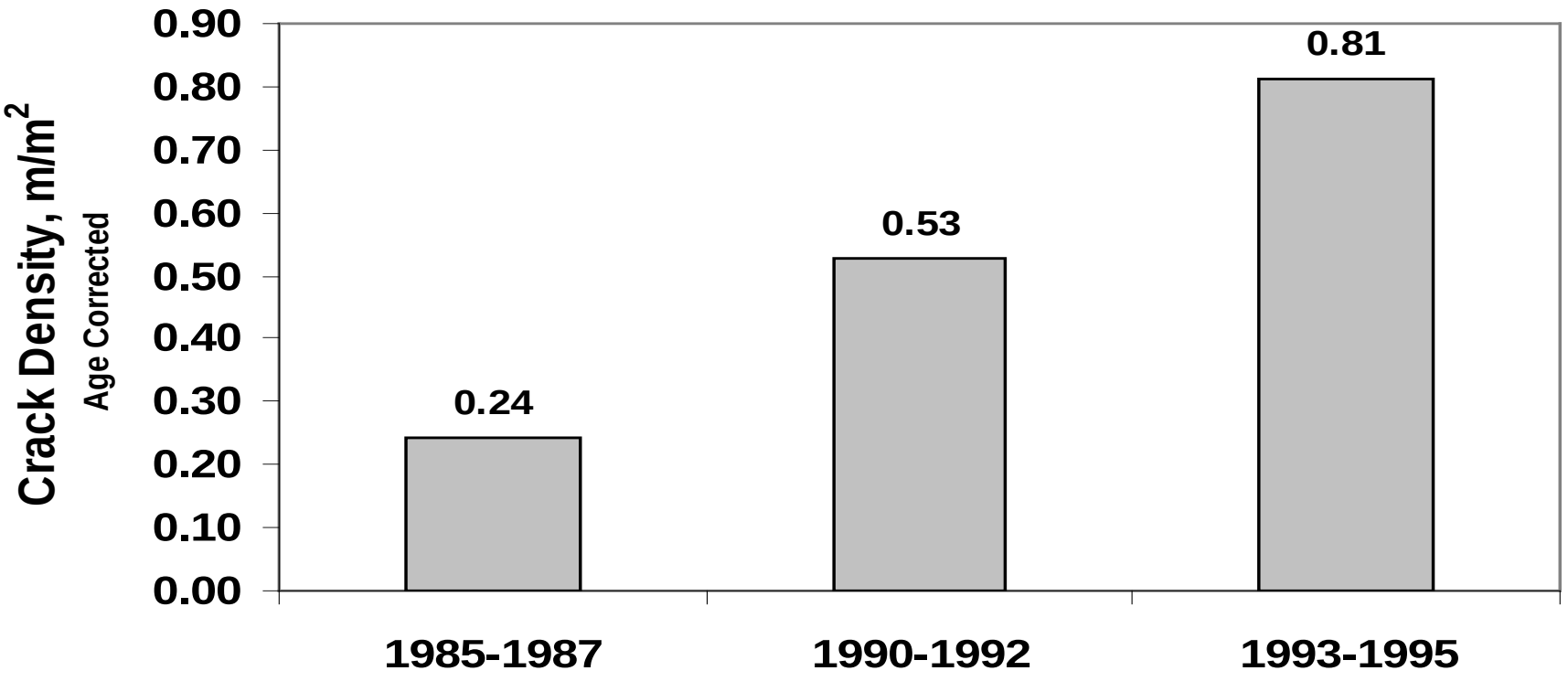
Number of Placements	(4)	(15)	(9)	(4)
Number of Surveys	(8)	(31)	(17)	(9)

Date of Construction

Date of Construction - Monolithic

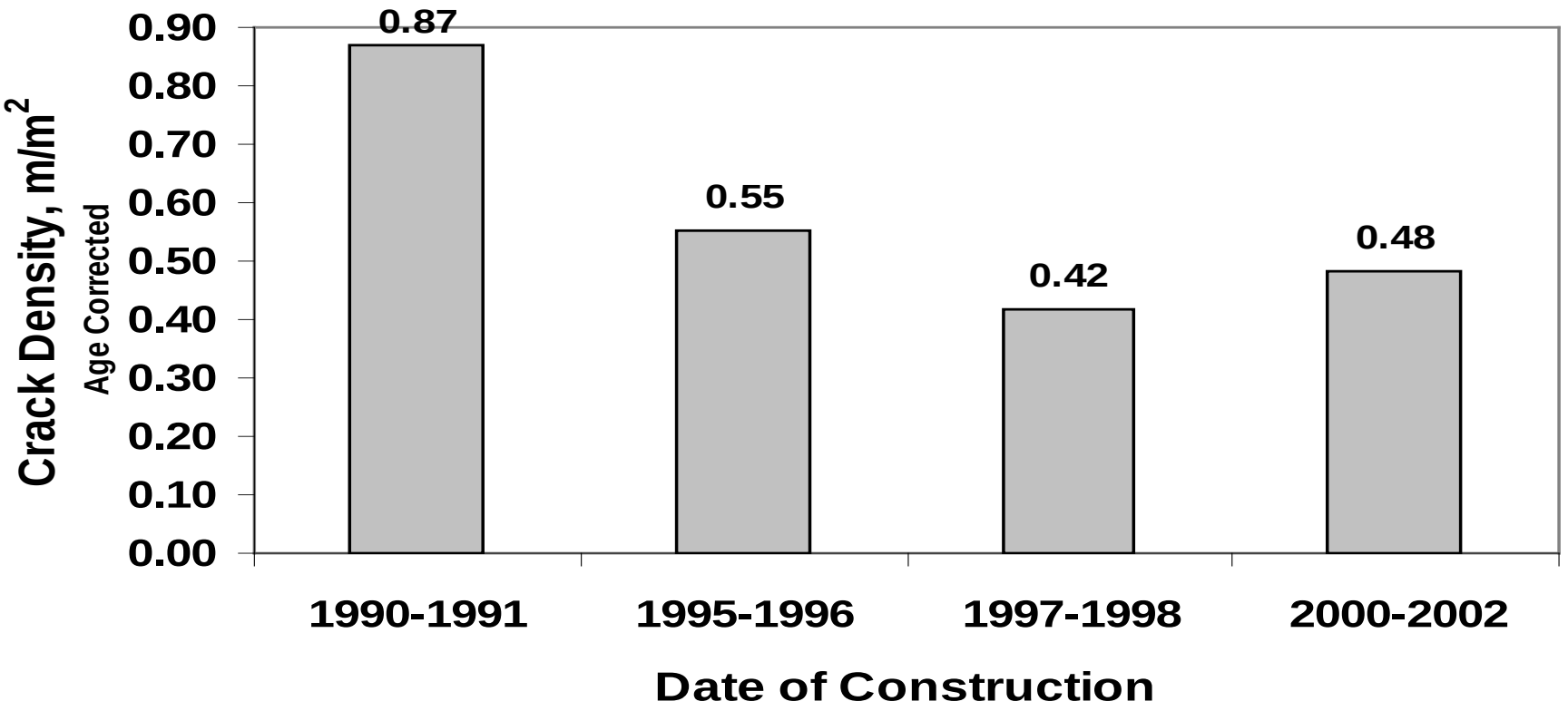


Date of Construction - Conventional Overlays



Number of Bridges	(6)	(17)	(3)
Number of Surveys	(6)	(36)	(6)

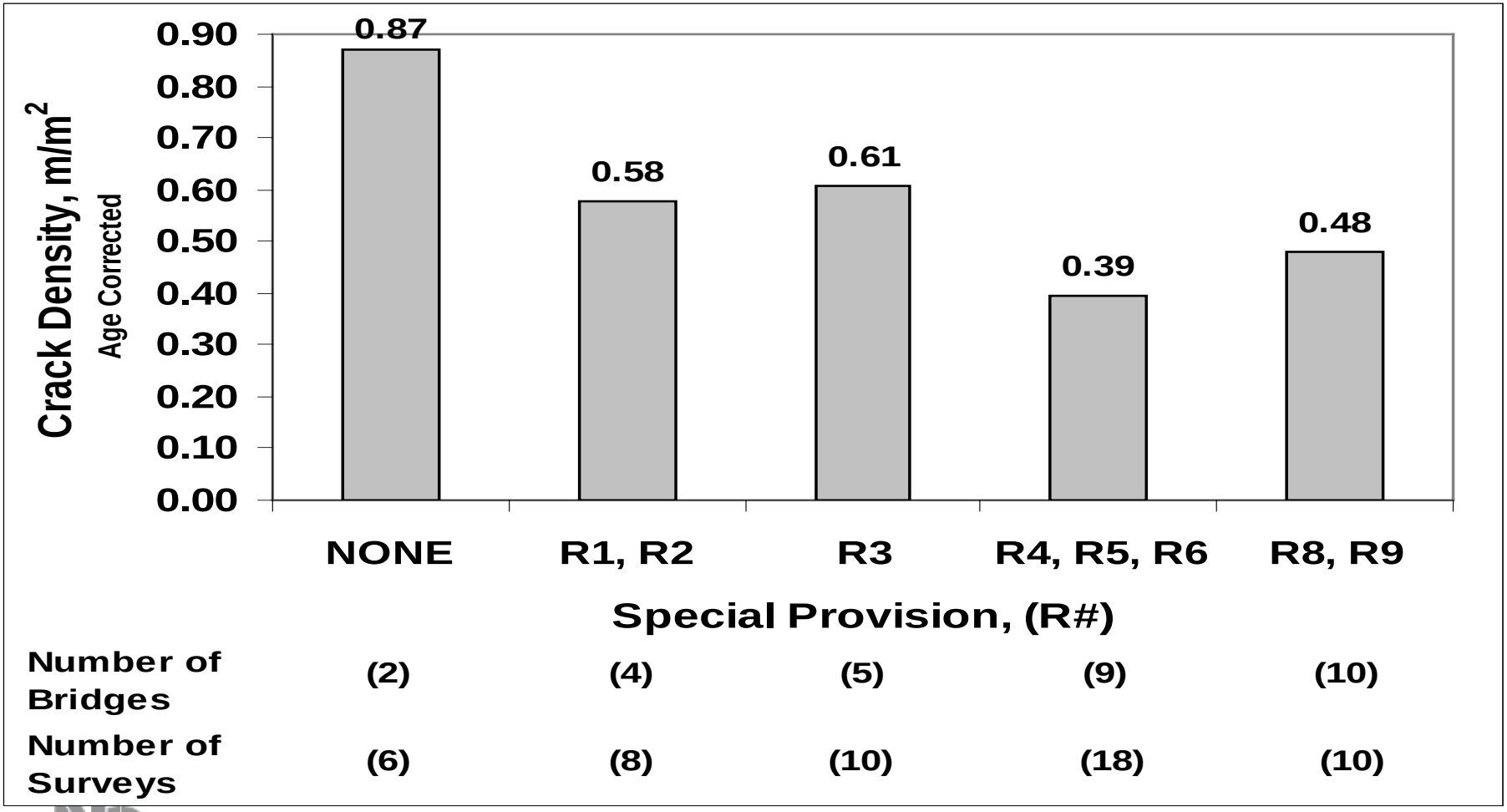
Date of Construction - Silica Fume Overlays



Number of Bridges	(2)	(10)	(8)	(10)
Number of Surveys	(6)	(20)	(16)	(10)

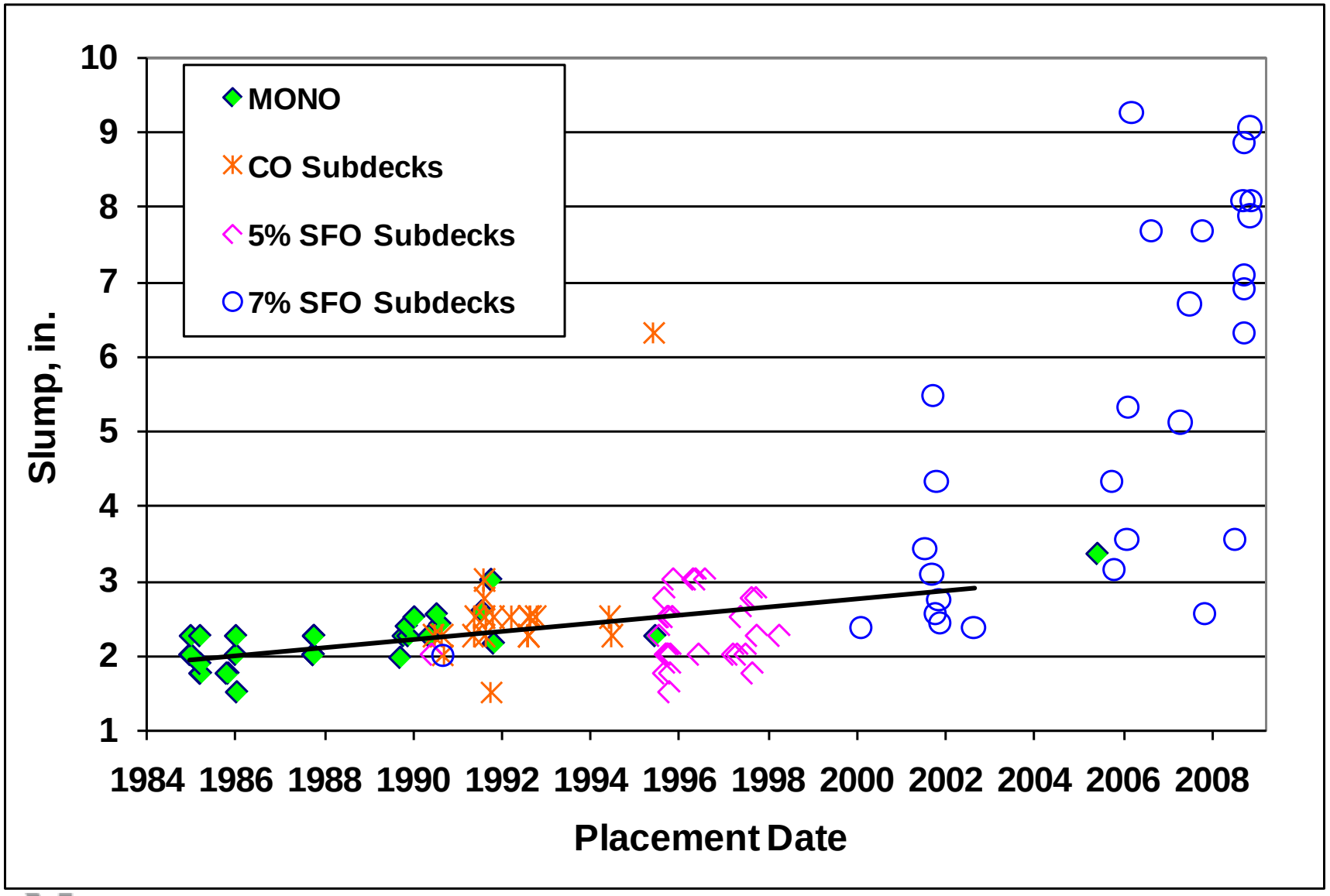
Control of early evaporation and improved curing

Control of early evaporation and improved curing - Silica Fume Overlays



Why increased cracking?

- Cement fineness
- Concrete slump
- Placing equipment
- Finishing equipment


MONO
CO Subdecks
5% SFO Subdecks
7% SFO Subdecks
Slump, in.
10
9
8
7
6
5
4
3
2
1
1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008
Placement Date

Overall Approach

Work to reduce plastic, settlement, thermal and drying shrinkage cracking

Low cement & water contents

Low slump

Moderate, not high, strength

Control concrete temperature

Minimum finishing

Early start and extended curing

LC-HPC Specifications

- Optimized Aggregate Gradation
- Low-absorption Aggregate
- 1 inch Max Size Aggregate
- Cement Content $\leq$ 540 lb/yd^3
- w/c ratio = 0.43 – 0.45
- Air Content of 8 ± 1½%
- Designated slump 1½ – 3 in. (3½ in. max)
- Controlled temperature (55 – 70°F)
- Improved curing

Thermal Cracking

Rule of Thumb: Cracking will result when temperature of plastic concrete in deck exceeds temperature of girders by more than 36° F (20° C).

Concrete temperature control

55 – 70°F

50 – 75°F if approved by Engineer

Cold-weather concreting

Maintain temperature of both girders and deck

Alternatives to Pumping

- Concrete Buckets
- Conveyor Belts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Placing

- Air cuff/bladder valve on pump or limit drop with conveyor
- Filling end walls and diaphragms ahead of slab

Consolidation Requirements

Vertically mounted internal gang vibrators

Concrete Finishing

General Rule:

Less is More

- Pan or burlap drag
- Bullfloating
- No finishing aids!

Curing

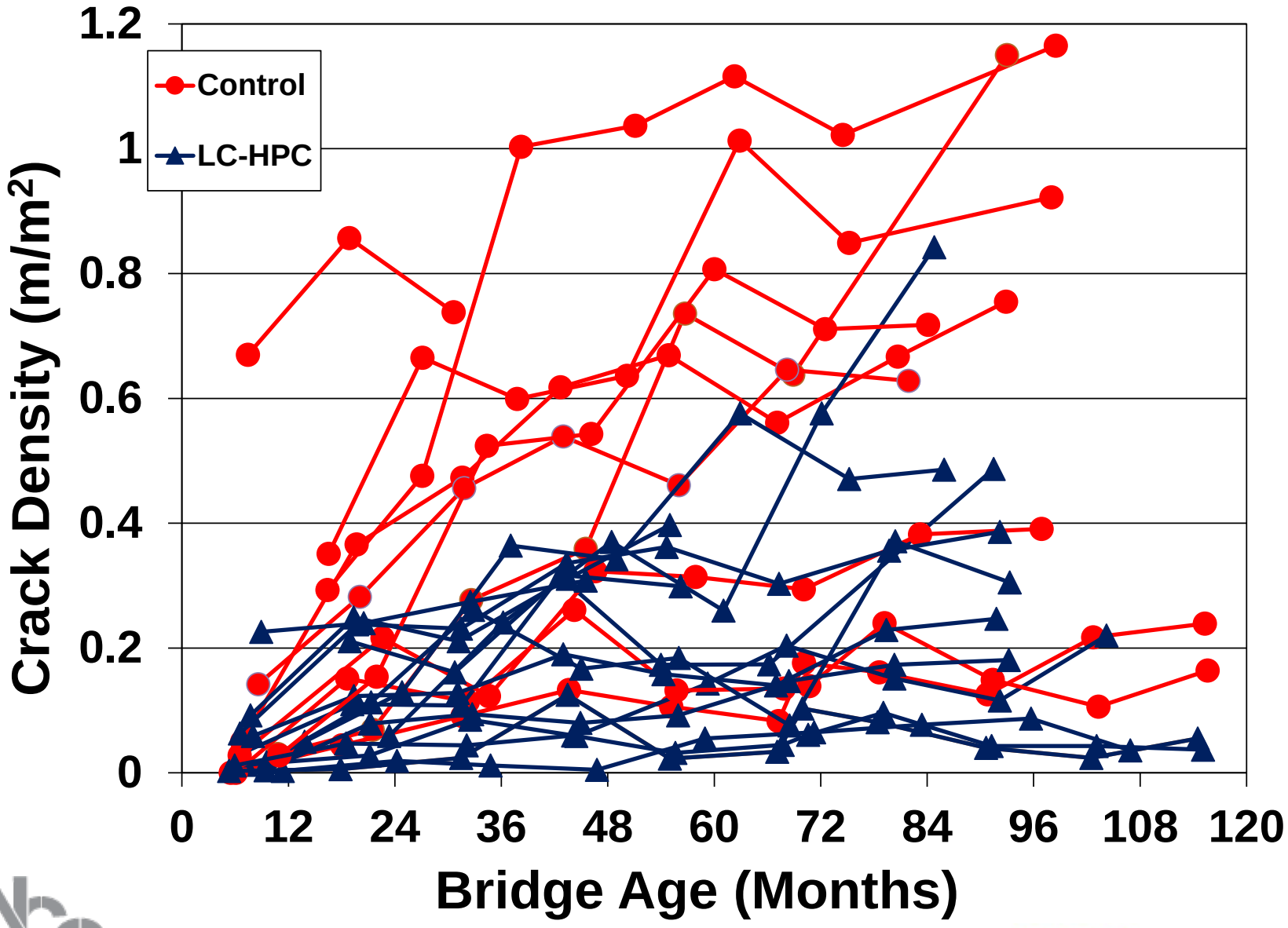
- Presoaked burlap
- Timely placement
- Constantly wet
  - Spray hoses
  - Soaker hoses
  - 14 days

Curing

14 days wet cure with burlap, soaker hoses, and plastic

Followed by curing compound to slow the rate of evaporation

Field Experience



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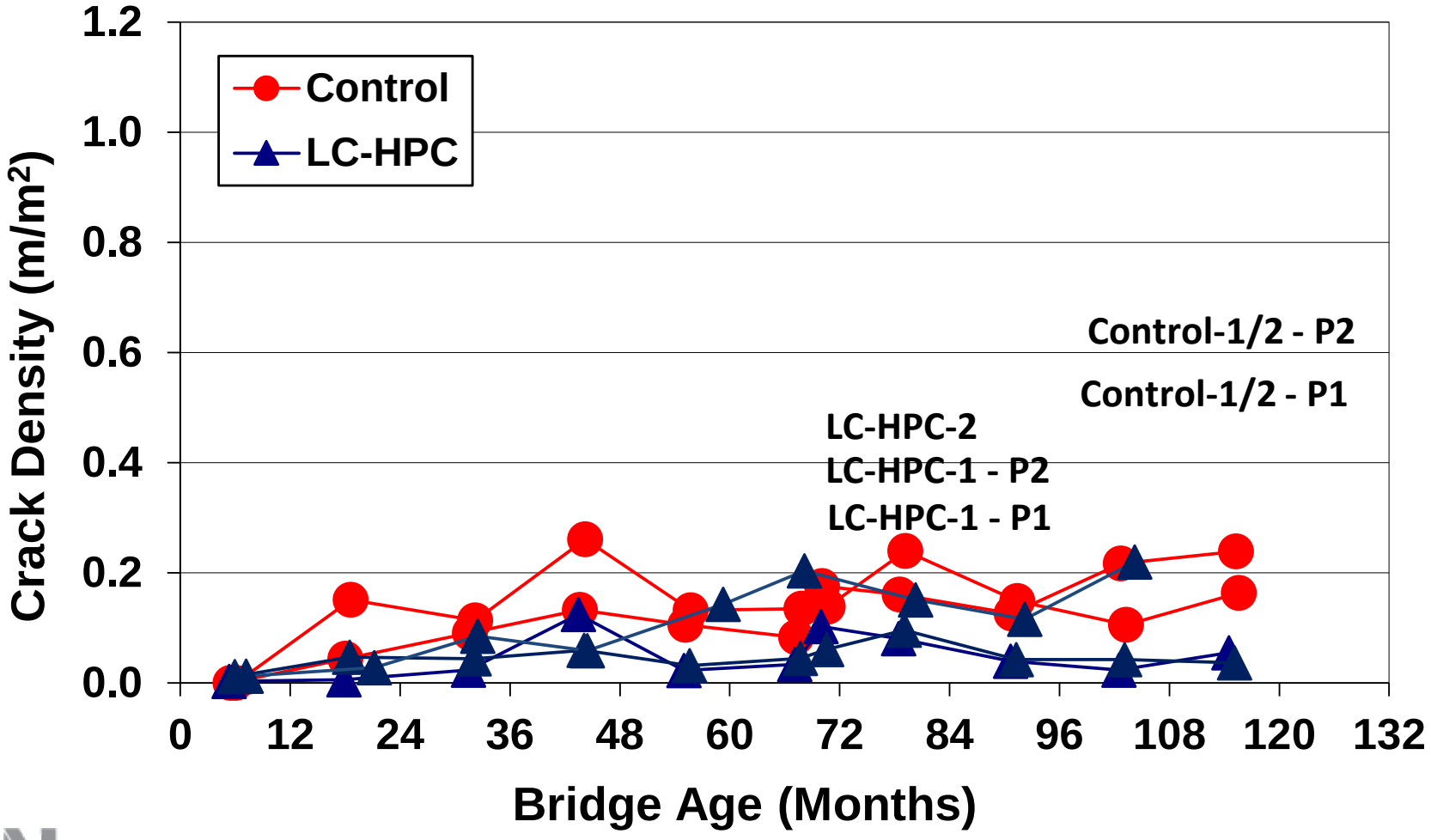
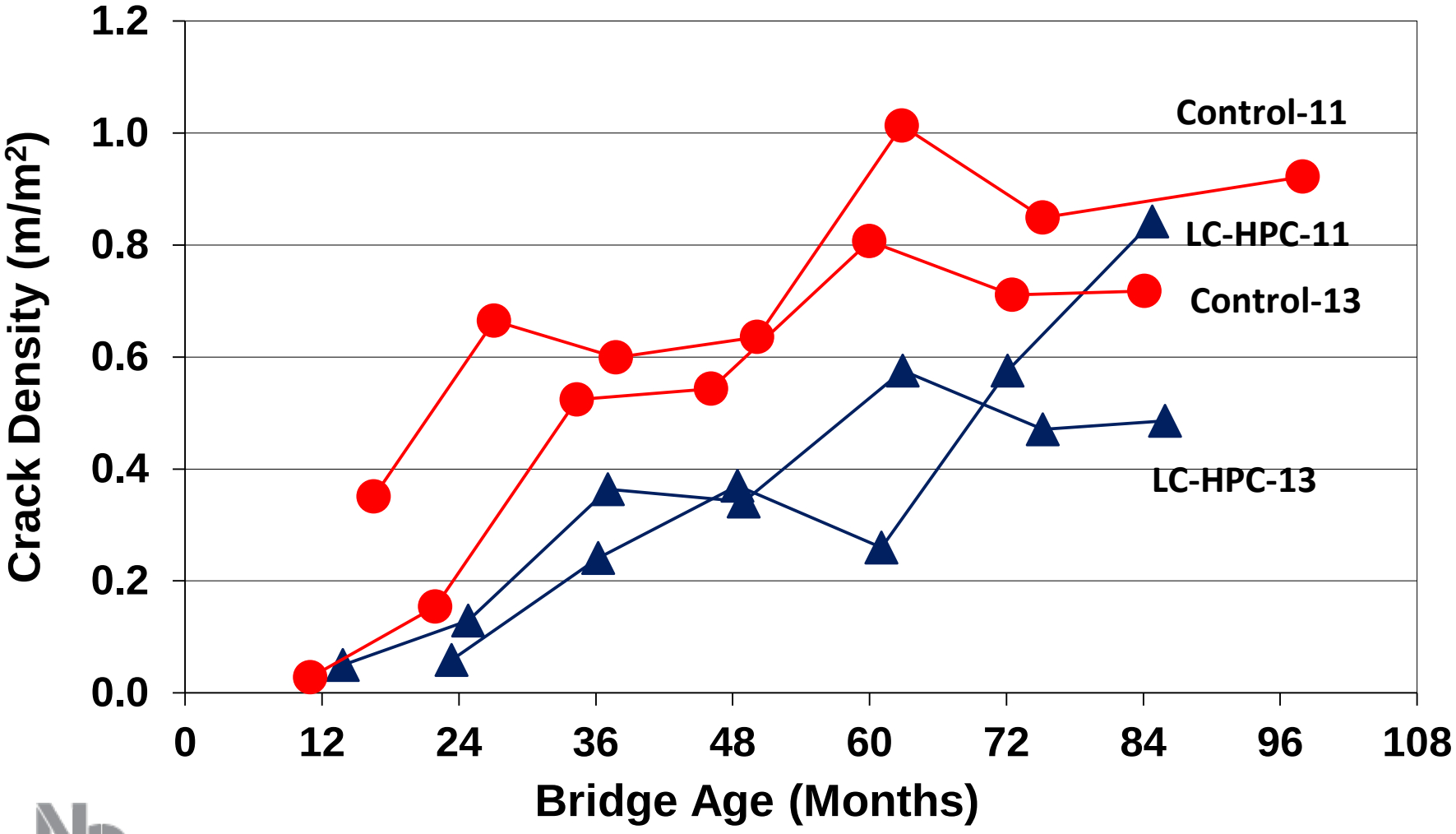
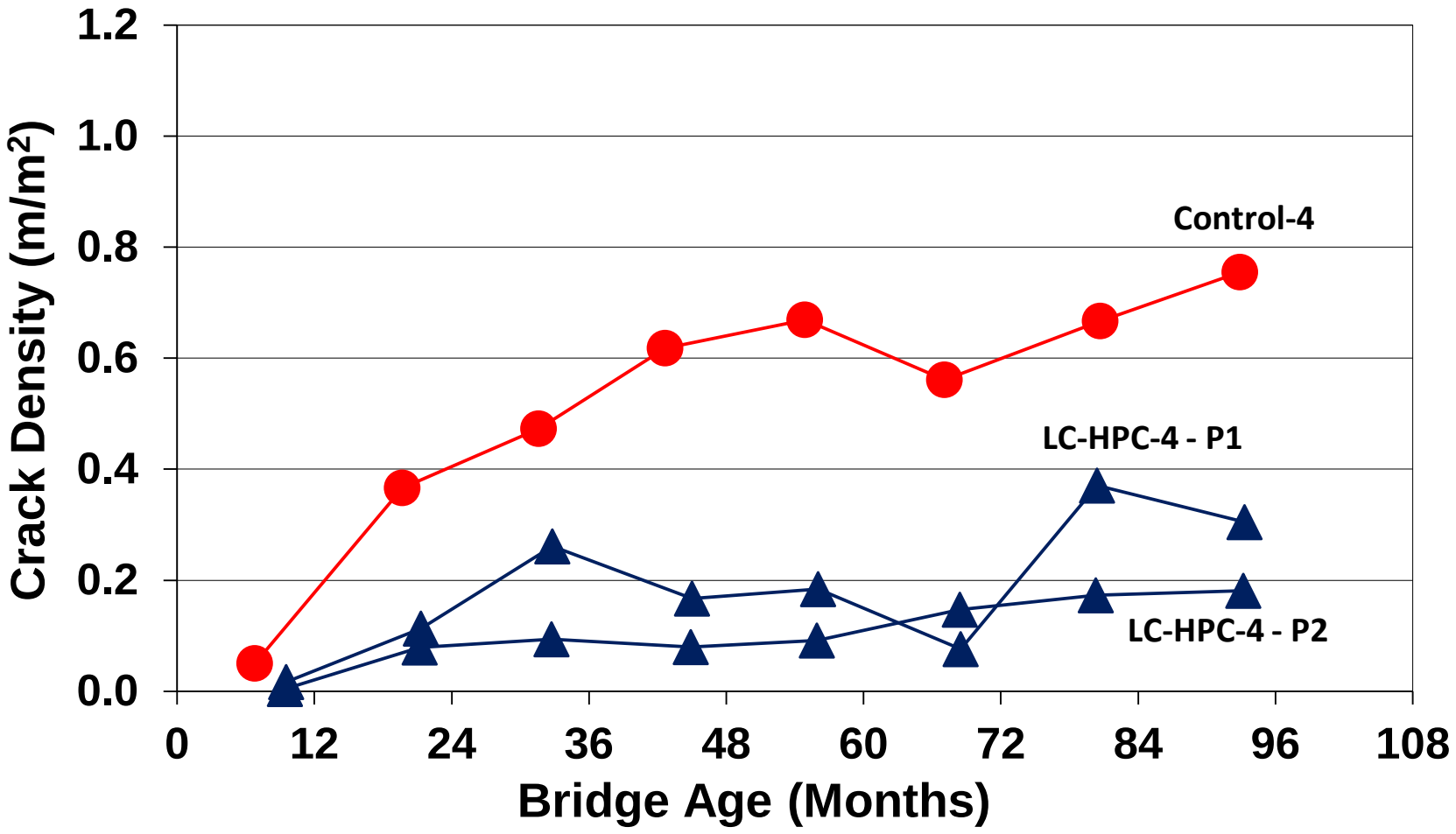
Bridges 1 and 2



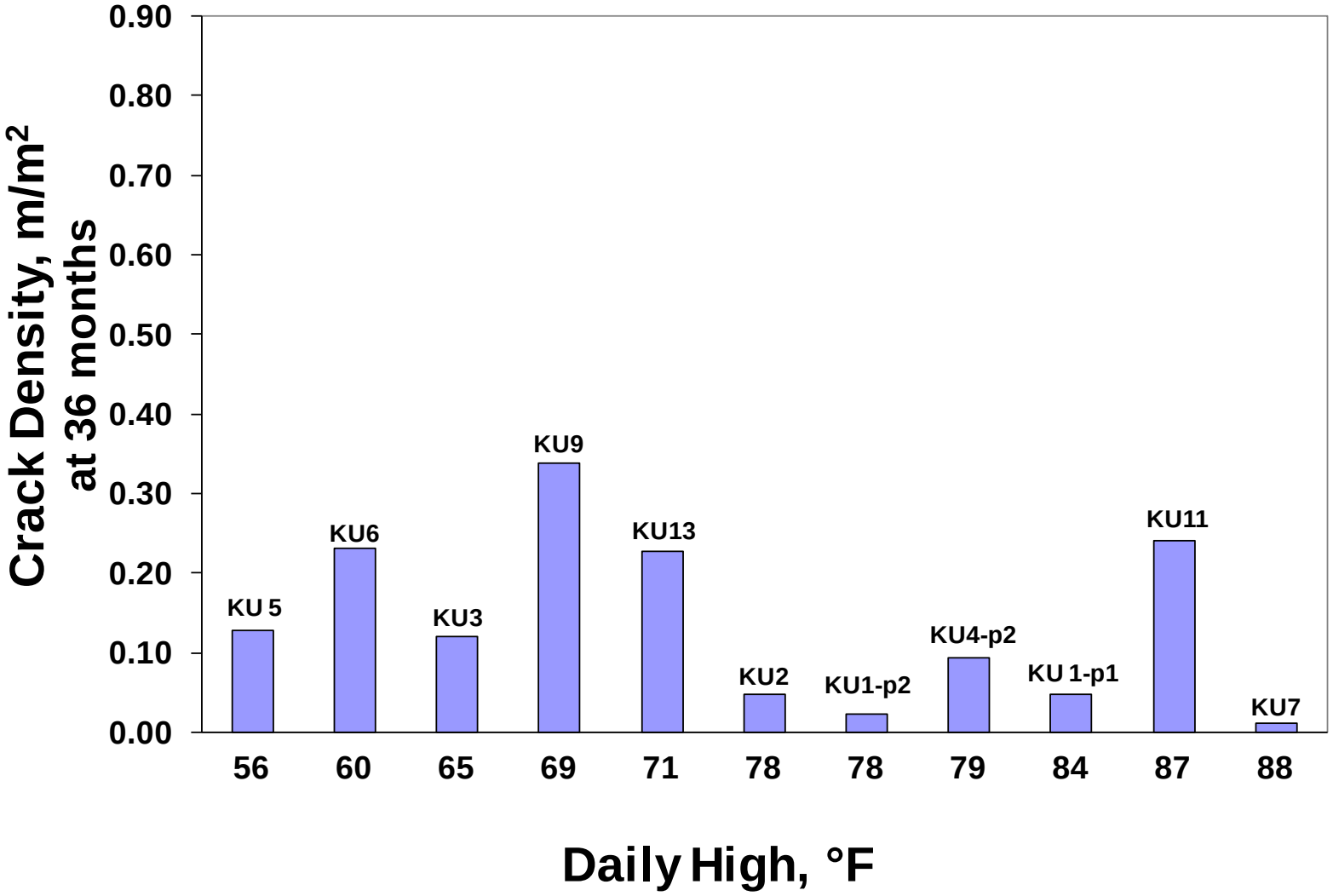
Bridges 11 and 13



Bridge 4


1.2
1.0
0.8
0.6
0.4
0.2
0.0
Crack Density (m/m²)
Control-4
LC-HPC-4 - P1
LC-HPC-4 - P2
0
12
24
36
48
60
72
84
96
108
Bridge Age (Months)

High Air Temperature

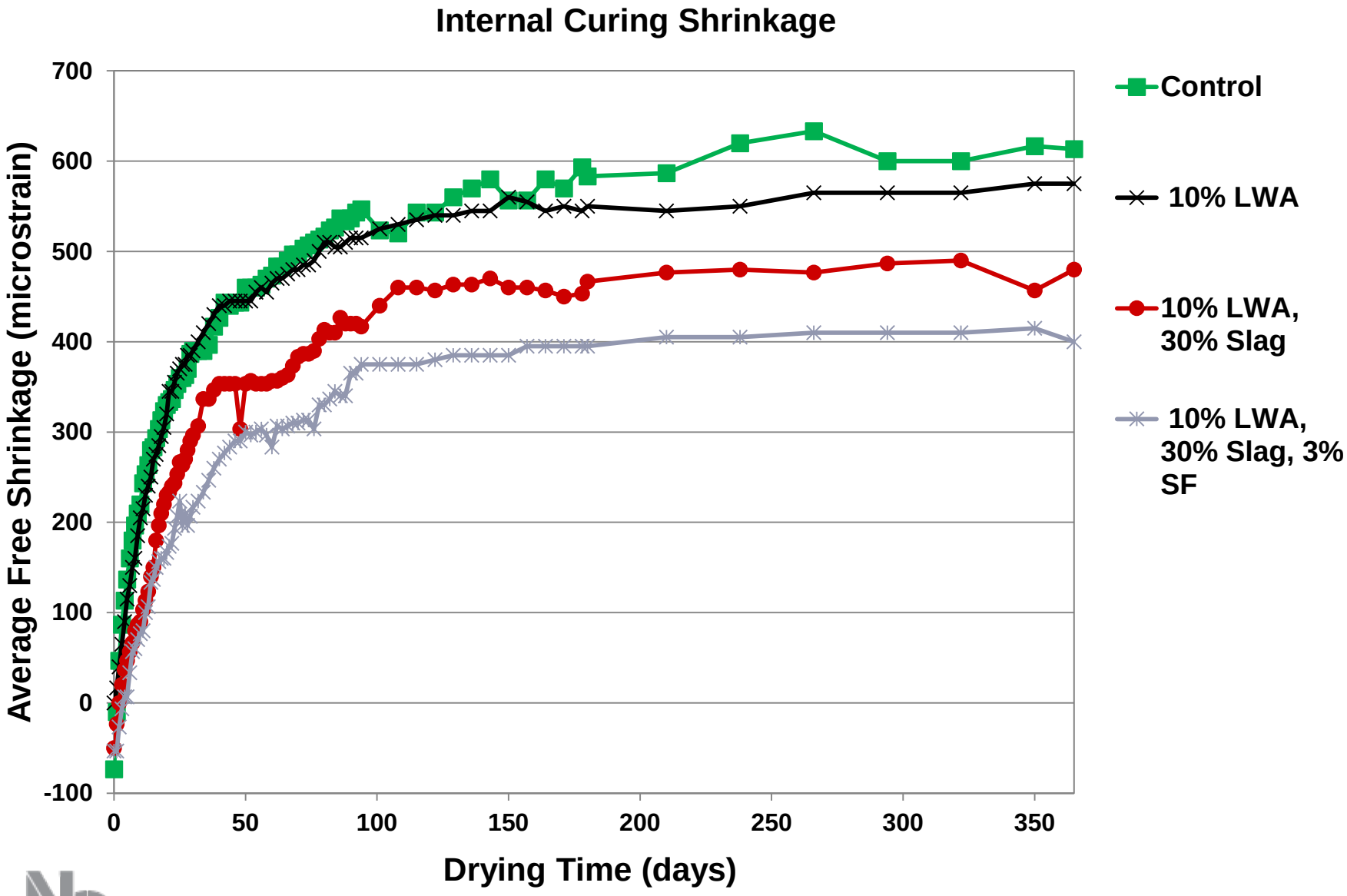


Technologies Under Active Study

- Internal curing with pre-wetted lightweight aggregate combined with slag cement and silica fume
- Shrinkage reducing admixtures
- Shrinkage compensating admixtures
- Rheology modifying admixtures
- Synthetic fibers

Reducing shrinkage cracking using:

- Internal curing with pre-wetted lightweight aggregate combined with slag cement and silica fume


Internal Curing Shrinkage
Average Free Shrinkage (microstrain)
700
600
500
400
300
200
100
0
-100
0
50
100
150
200
250
300
350
Drying Time (days)
Control
10% LWA
10% LWA, 30% Slag
10% LWA, 30% Slag, 3% SF

Reducing settlement cracking using:

- Rheology modifying admixtures
- Synthetic fibers

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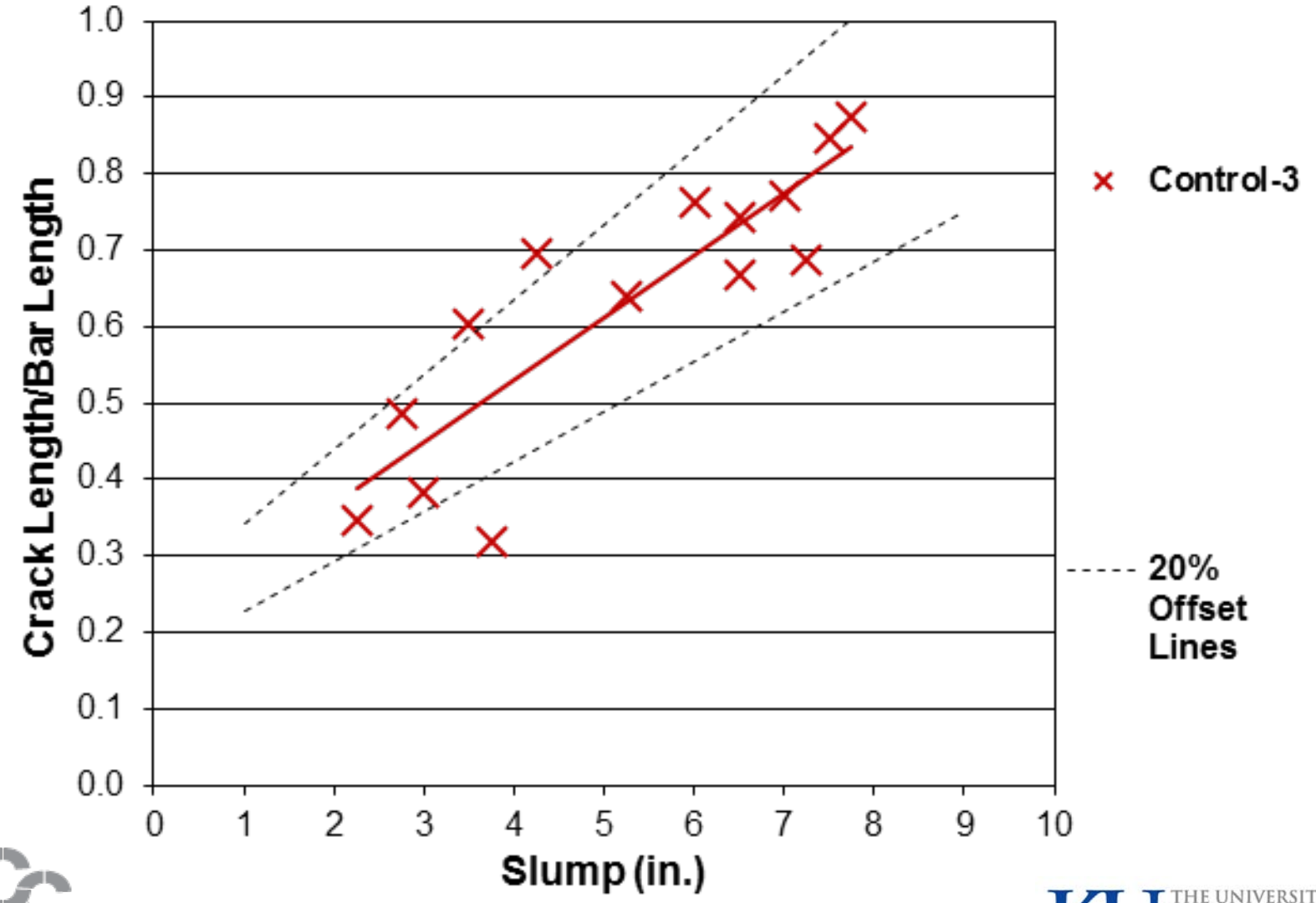
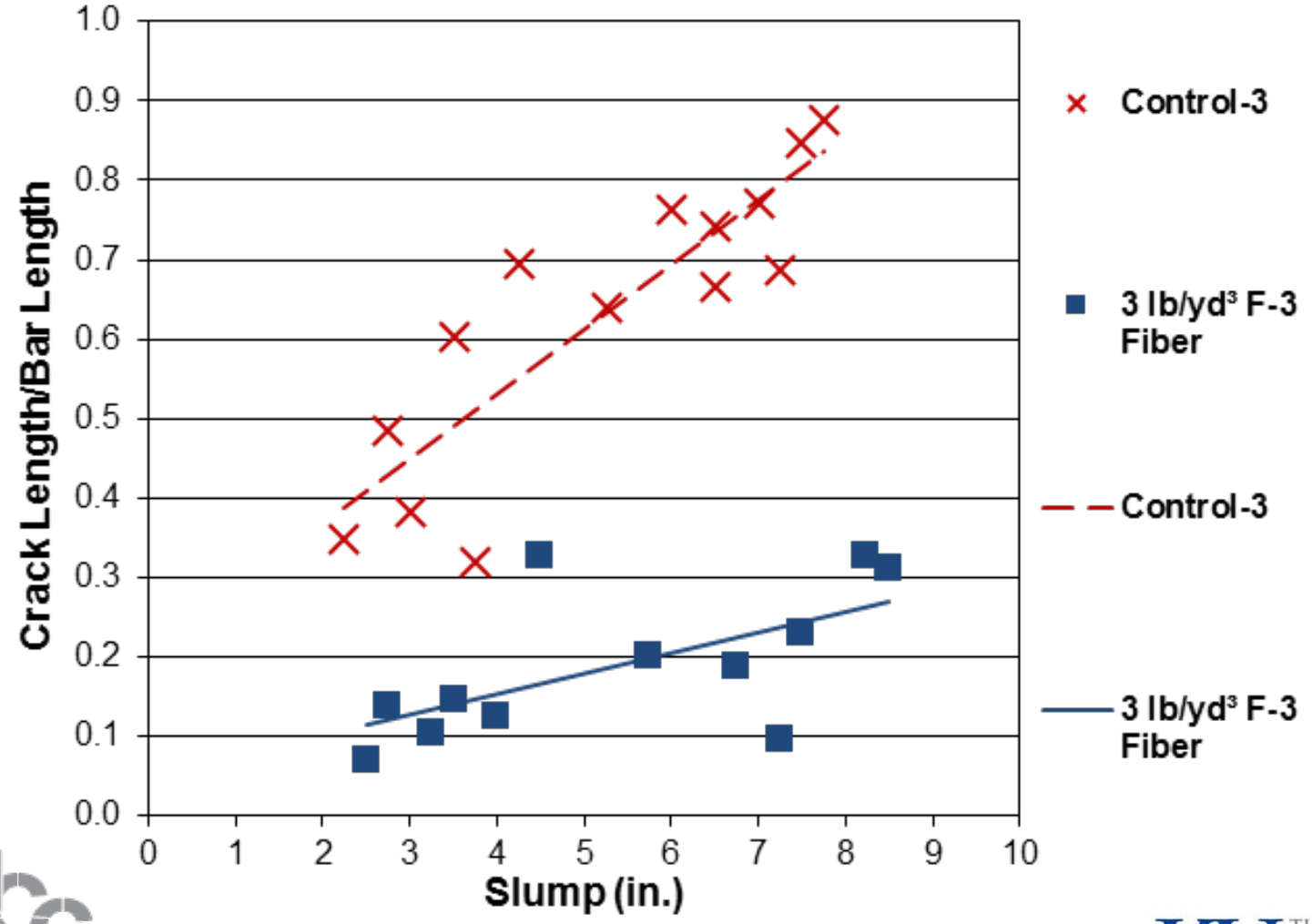
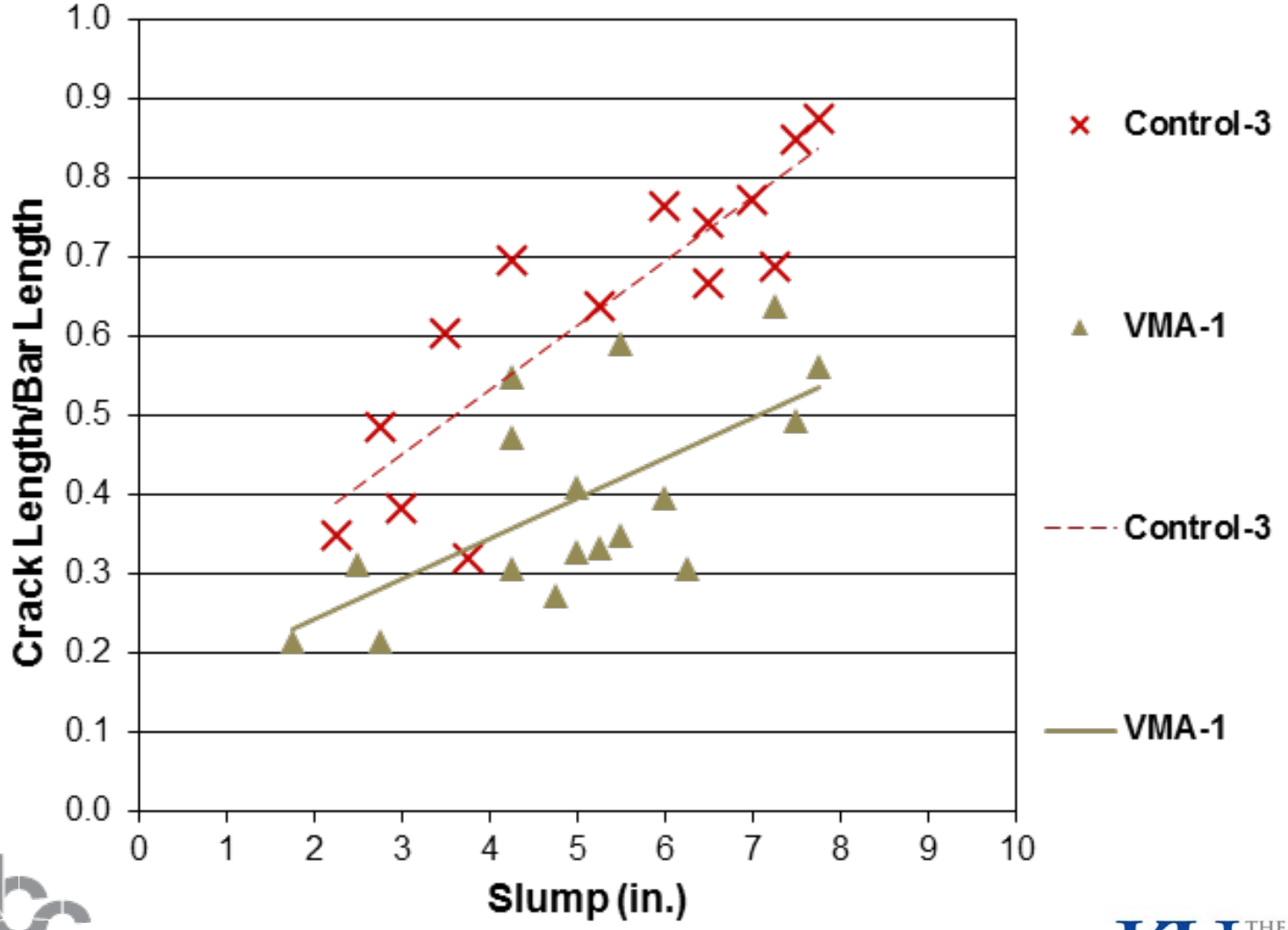
Control mixture



Synthetic fibers



Rheology modifying admixture



Conclusions

- Material properties and construction procedures are the principal factors controlling cracking in bridge decks

Conclusions

- Low-slump, moderate-strength concrete results in less cracking than high-slump, high-strength concrete

Conclusions

- Best performance requires adherence to all aspects of the specifications

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