

"Crack-Free" Repair Materials ... Are We There Yet ?

Minnesota Concrete Council

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BASF Corp - Construction Chemicals
February 16, 2012

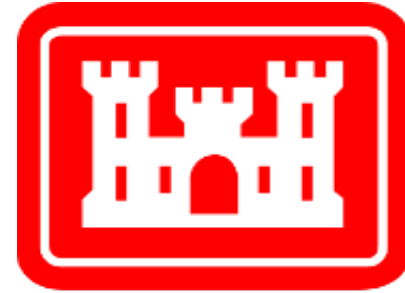
Objectives

- Articulate the challenges that lead to premature failure of concrete repairs
- Understand the repair industry's strategy to improve quality and durability of concrete repairs
- Use performance based specifications to generate better repairs
- Properly assess the benefits of the newest ASTM test method for determining crack resistance in repair materials

The Challenge with Repairs

A little more than 50% of repairs performed on the Corps structures are performing satisfactorily, which is an unacceptable rate.

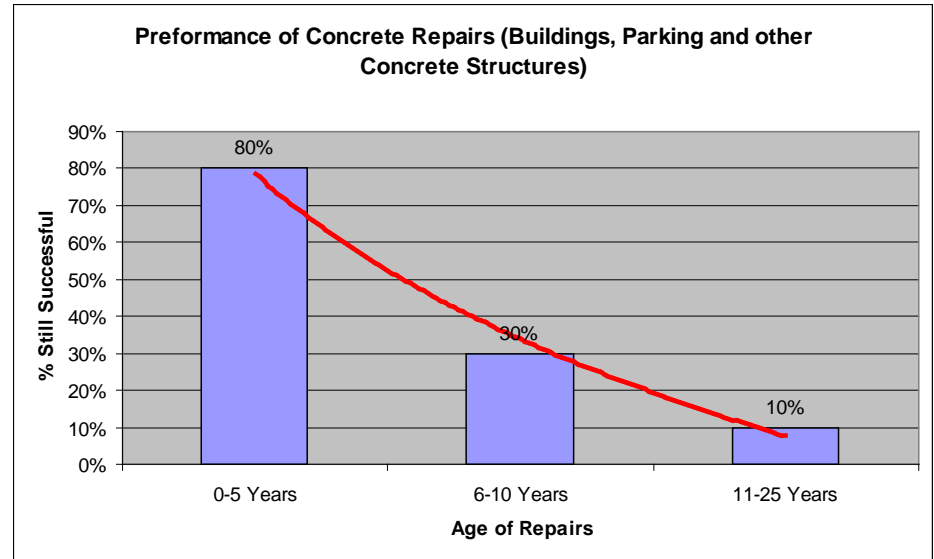
Most repairs
don't last



**US Army Corps
of Engineers®**

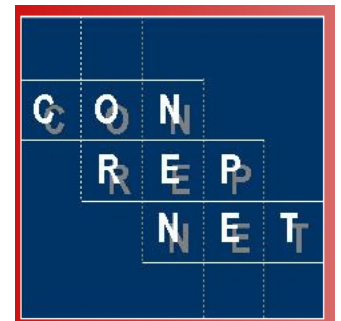
Most Repairs Don't Last

- BRE Studies (UK)
- Survey of 215 structures
- 20% or repairs unsatisfactory within six years
- 70% of repairs unsatisfactory within 10 years

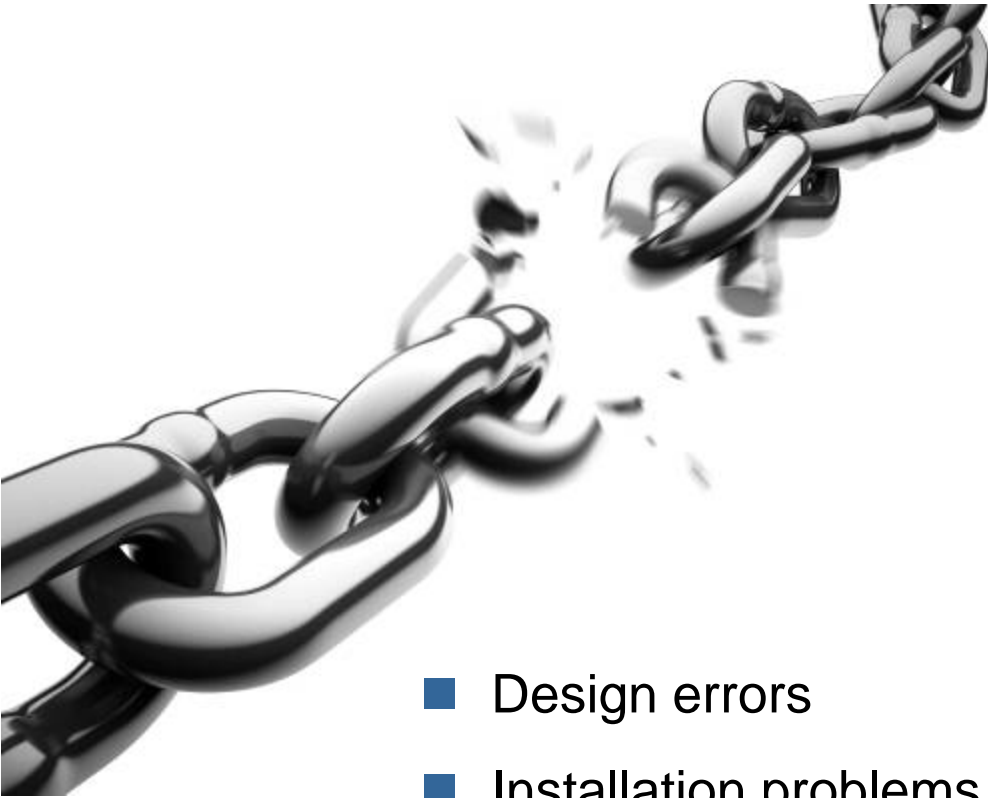


Is this
acceptable
performance?

<http://projects.bre.co.uk/conrepnet/pages/default.htm>



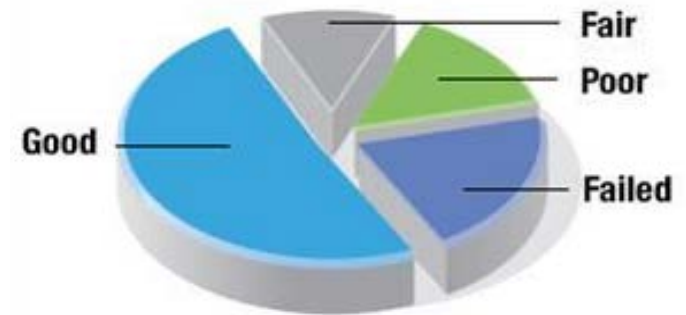
Why Do Repairs Fail?



- Design errors
- Installation problems
- Material performance

Performance of Repairs

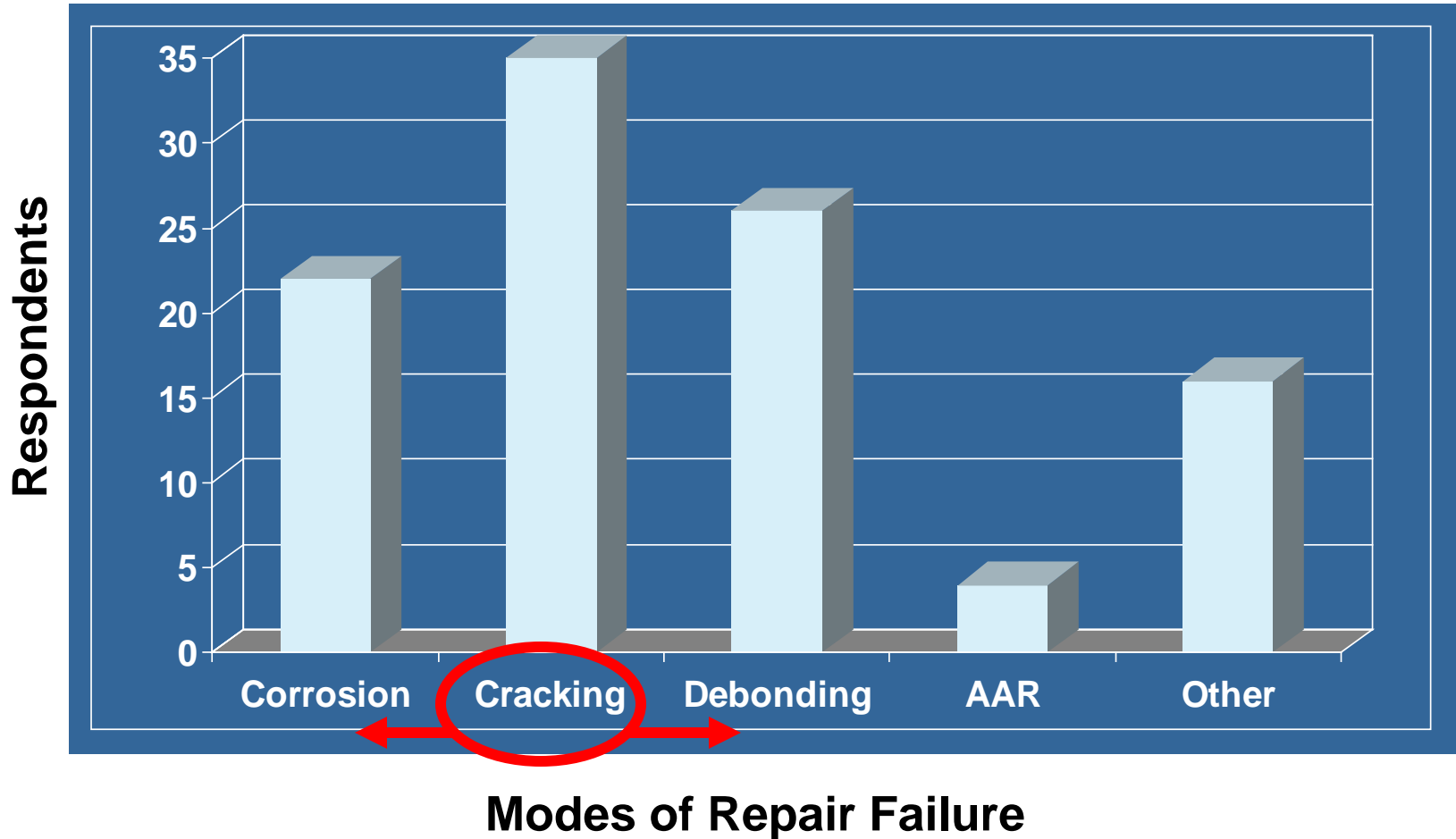
Causes: Design, Installation, Materials



Source: US Army Corps. of Engineers REMR-CS2 Report

The # 1 Problem with Repairs

“Three certainties in life: death, taxes, and concrete will crack”



Design Challenges for Engineers



- Project assessment
- Product selection
- Product comparison
- Specifications
- Project control

Installation Challenges for Contractors



- Correct product selection
- Surface preparation
- Mixing
- Placement
- Finishing
- Skilled labor

Material Challenges for Manufacturers

- R&D expertise
- R&D cost recovery
- Formulation design - balancing physical & handling properties
- Competitive environment



The Industry Responds

Cross industry cooperation

- Every discipline in restoration
 - *Engineers, researchers*
 - *Contractors, owners*
 - *Manufacturers, academics*

Establish goals to improve

- Concrete repair & protection
 - *Efficiency*
 - *Safety*
 - *Quality*

Vision 2020
A Vision for the Concrete Repair, Protection
and Strengthening Industry

The logo features the year '2020' in a large, bold, blue font. The word 'VISION' is written in a smaller, white, sans-serif font, with each letter placed inside a circular cutout within the corresponding digit of '2020'.

Blue Print for the Industry

1. Mechanism for industry cooperation
2. Speed process of document creation
3. Create repair code
4. Performance based specifications
5. Improve cracking resistance
6. Worker friendly materials and methods
7. Performance modeling system
8. Industry strategic research plan
9. Increase industry professionals
10. Better contract documents
11. Owner education tools
12. Condition assessment standards
13. Special repair systems

Vision 2020
A Vision for the Concrete Repair, Protection
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2020
V I S I O N

ICRI Data Sheet Protocol

Data Sheet Protocol provides:

- Logical
- Standardized
- Reporting of repair material information

To avoid:

- Design errors
- Improper material selection
- Installation errors
- Failed repairs



INTERNATIONAL
CONCRETE REPAIR
INSTITUTE



ACI / ICRI Data Sheet Protocol

Physical & Durability Properties



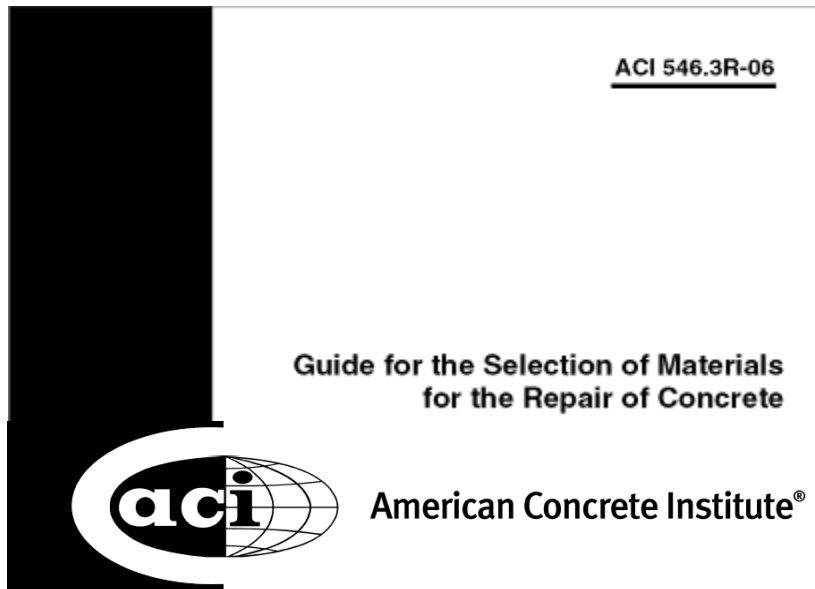
INTERNATIONAL
CONCRETE REPAIR
INSTITUTE



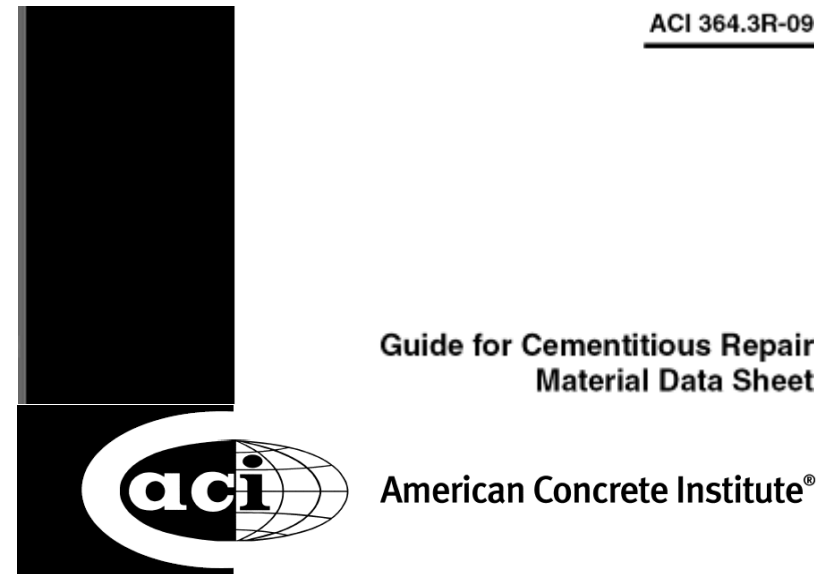
- Bond strength
- Compressive strength
- Direct tensile strength
- Length change (shrinkage)
- Modulus of elasticity
- Compressive creep
- Cracking resistance
- Flexural strength
- Freezing and thawing resistance
- Scaling resistance
- Rapid chloride permeability
- Chloride ponding
- Sulfate resistance
- Chemical resistance
- Splitting tensile strength
- Coefficient of thermal expansion

If repairs crack
all other
properties are
compromised

Performance Requirements



- Guide for all types of repair materials
- Different tests & properties
- Range of values
- State-of-the-art

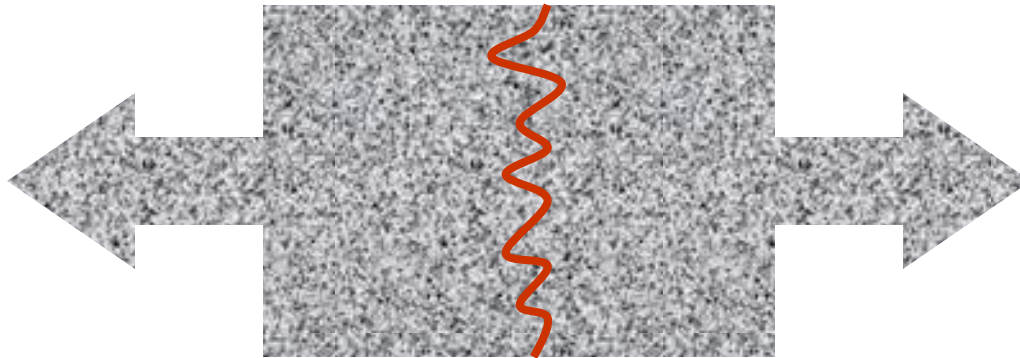


- Tests for Cementitious Materials
- What should be reported
- State-of-the-art

Solving the Problem of Cracking

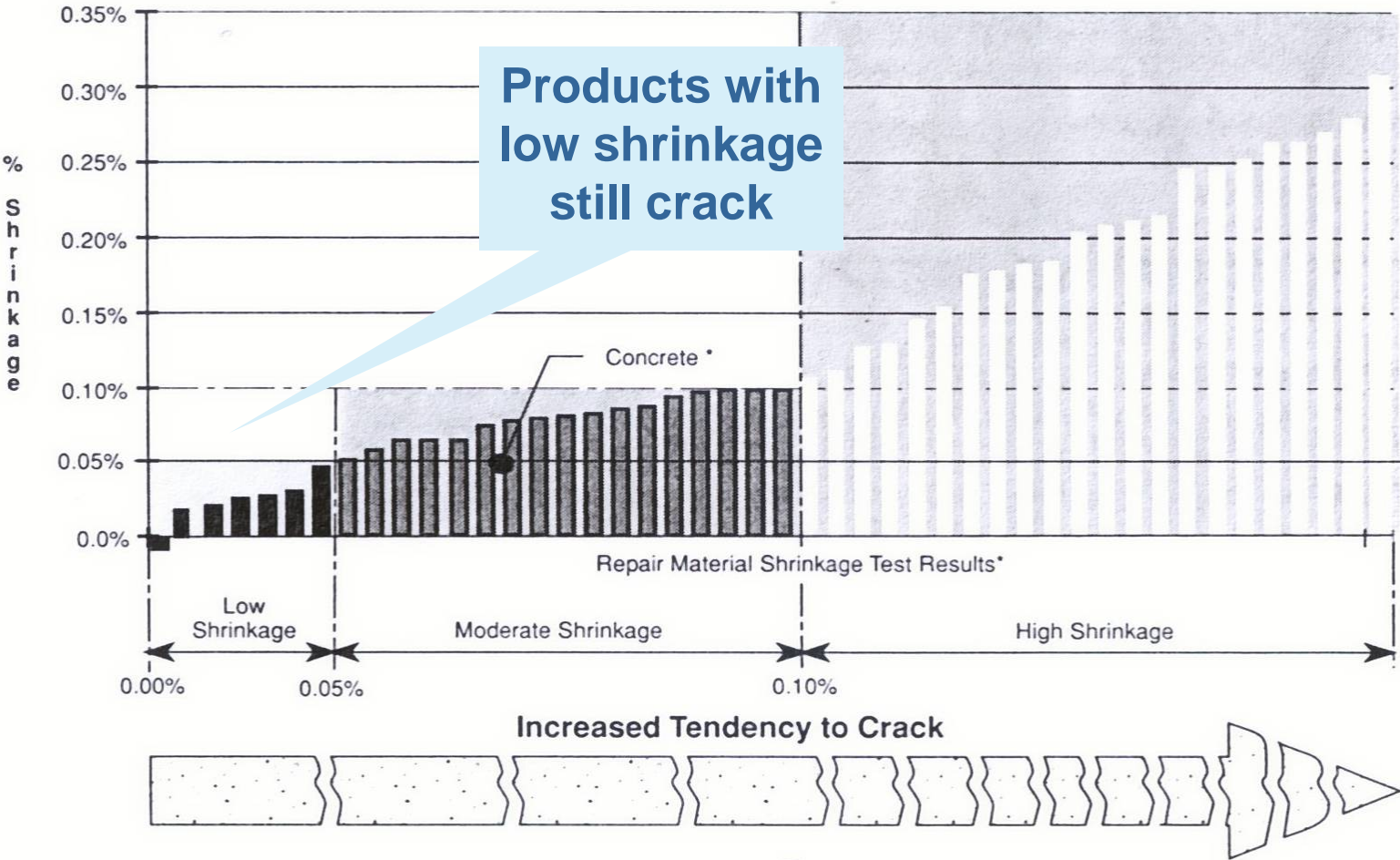
Why does concrete crack?

The simple answer:



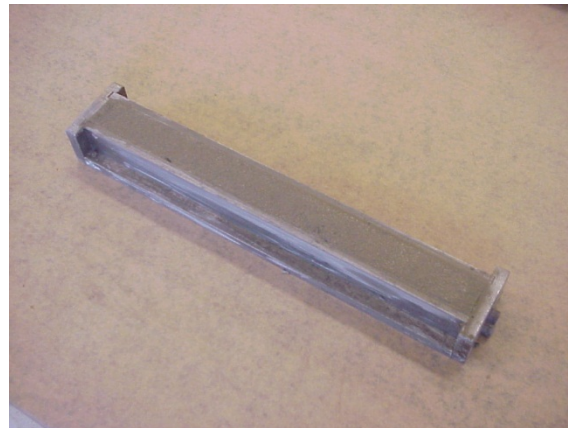
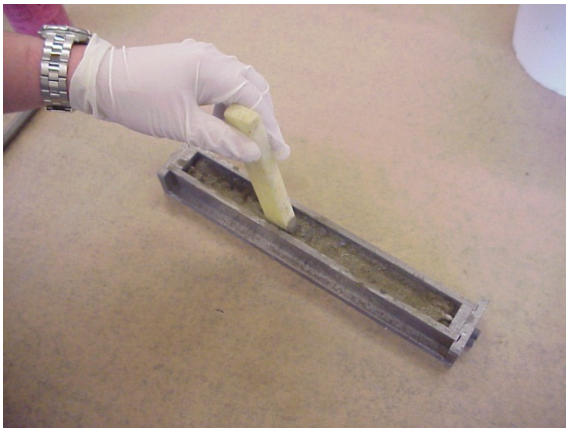
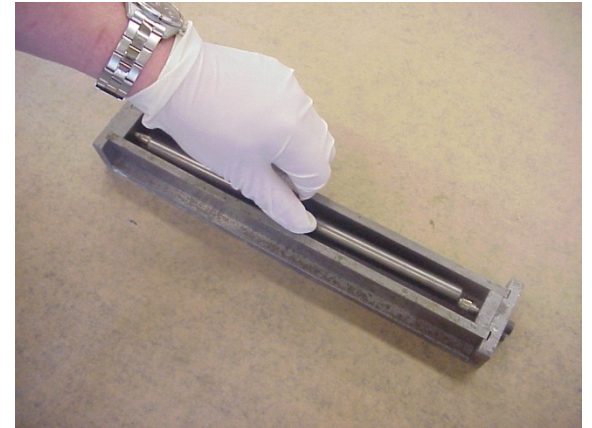
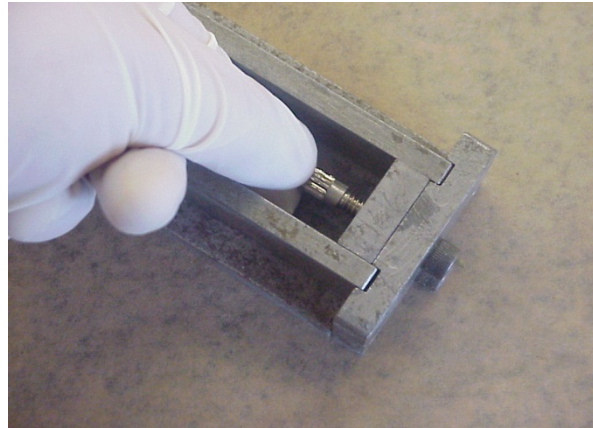
Because tensile strength is exceeded

Shrinkage vs Tendency to Crack

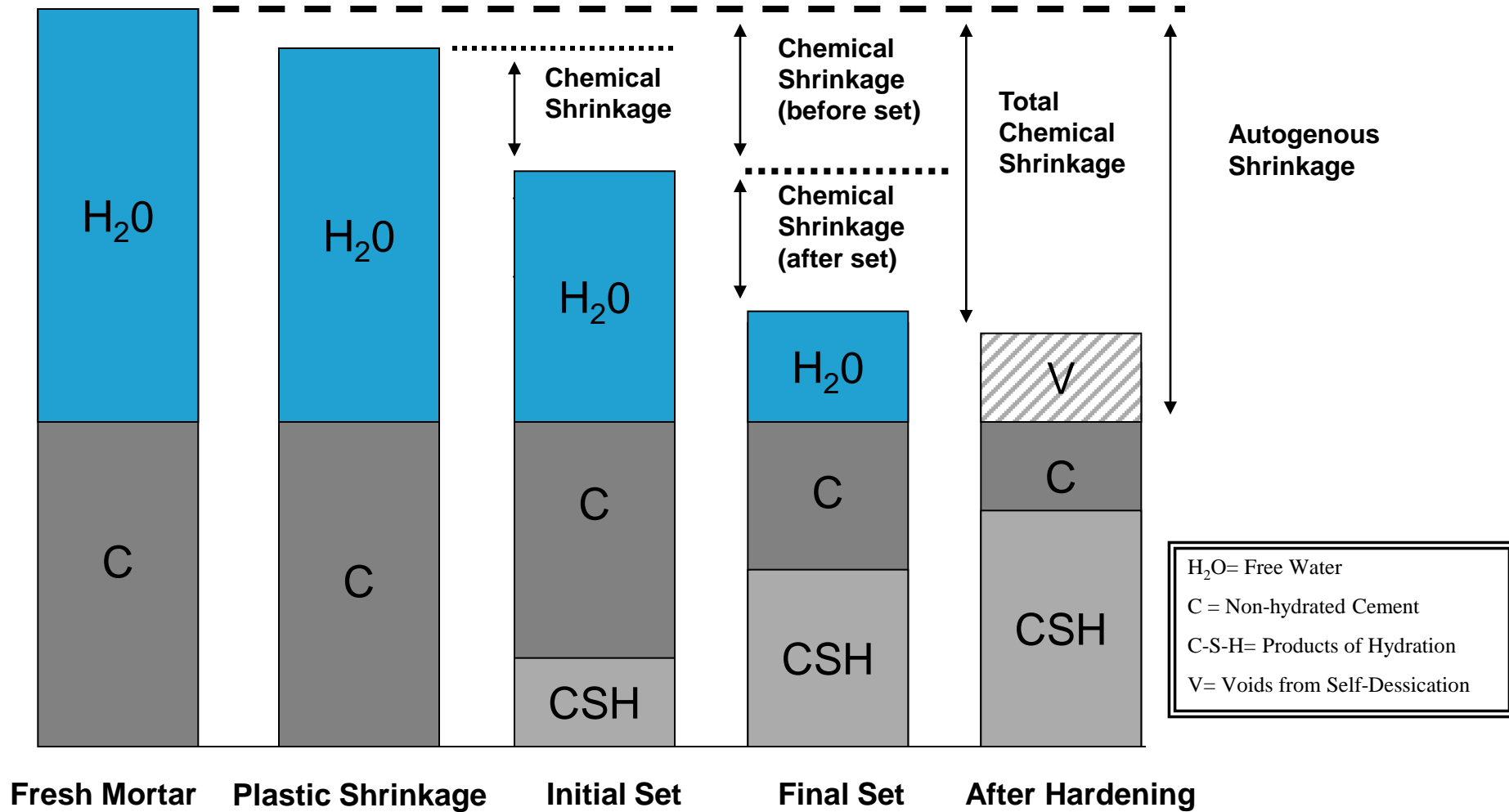


ASTM C 157

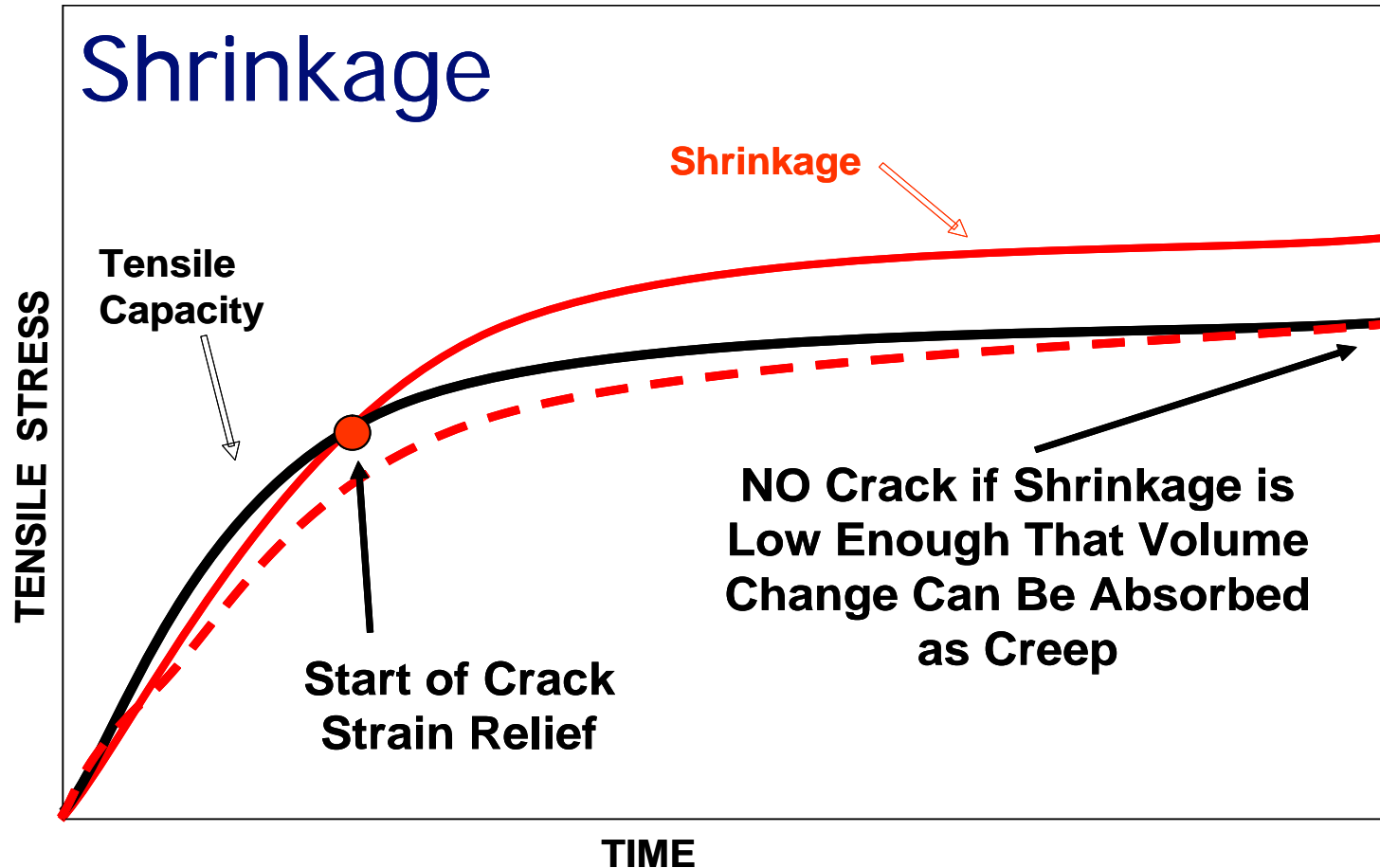
“Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete”



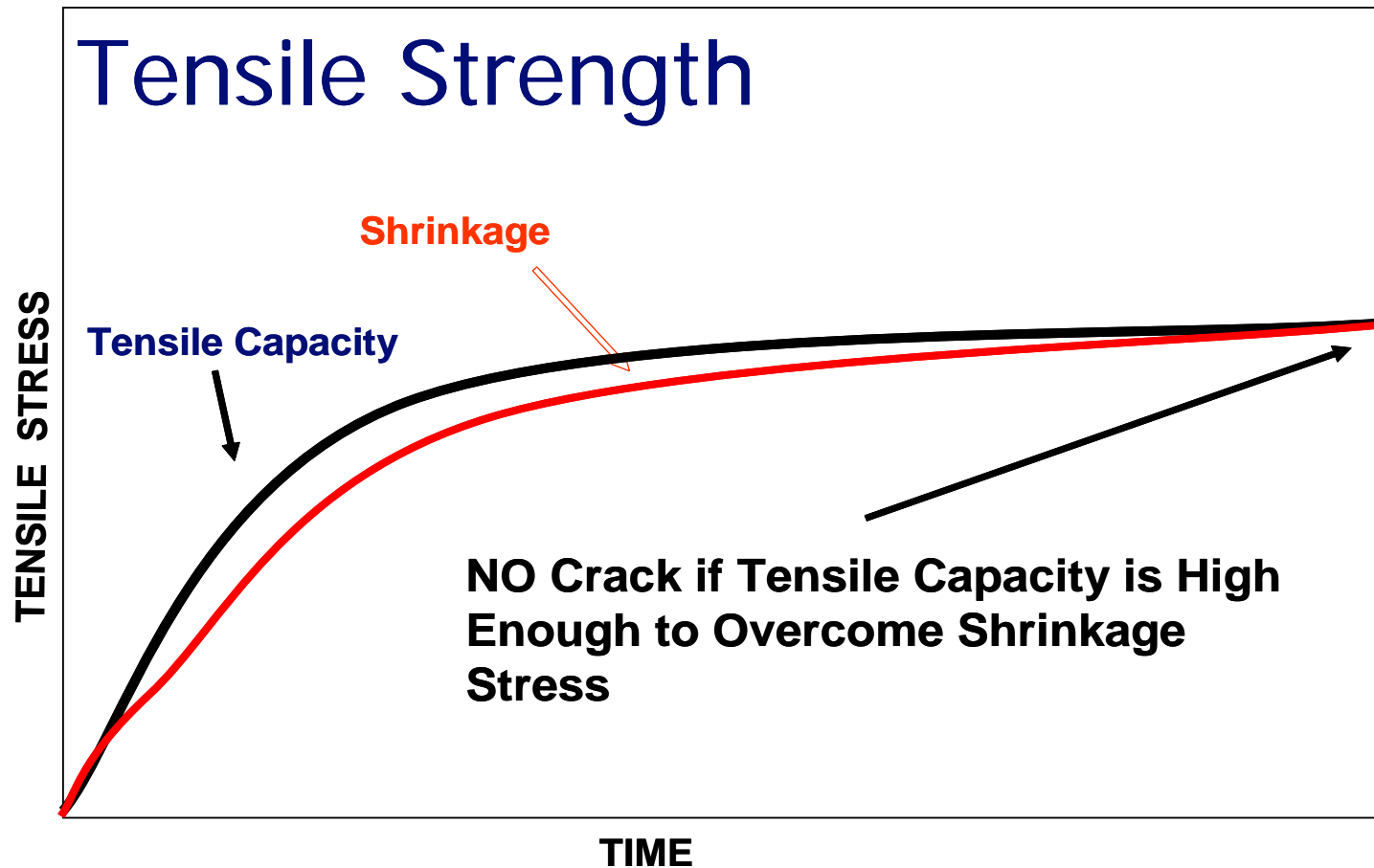
Autogenous Shrinkage



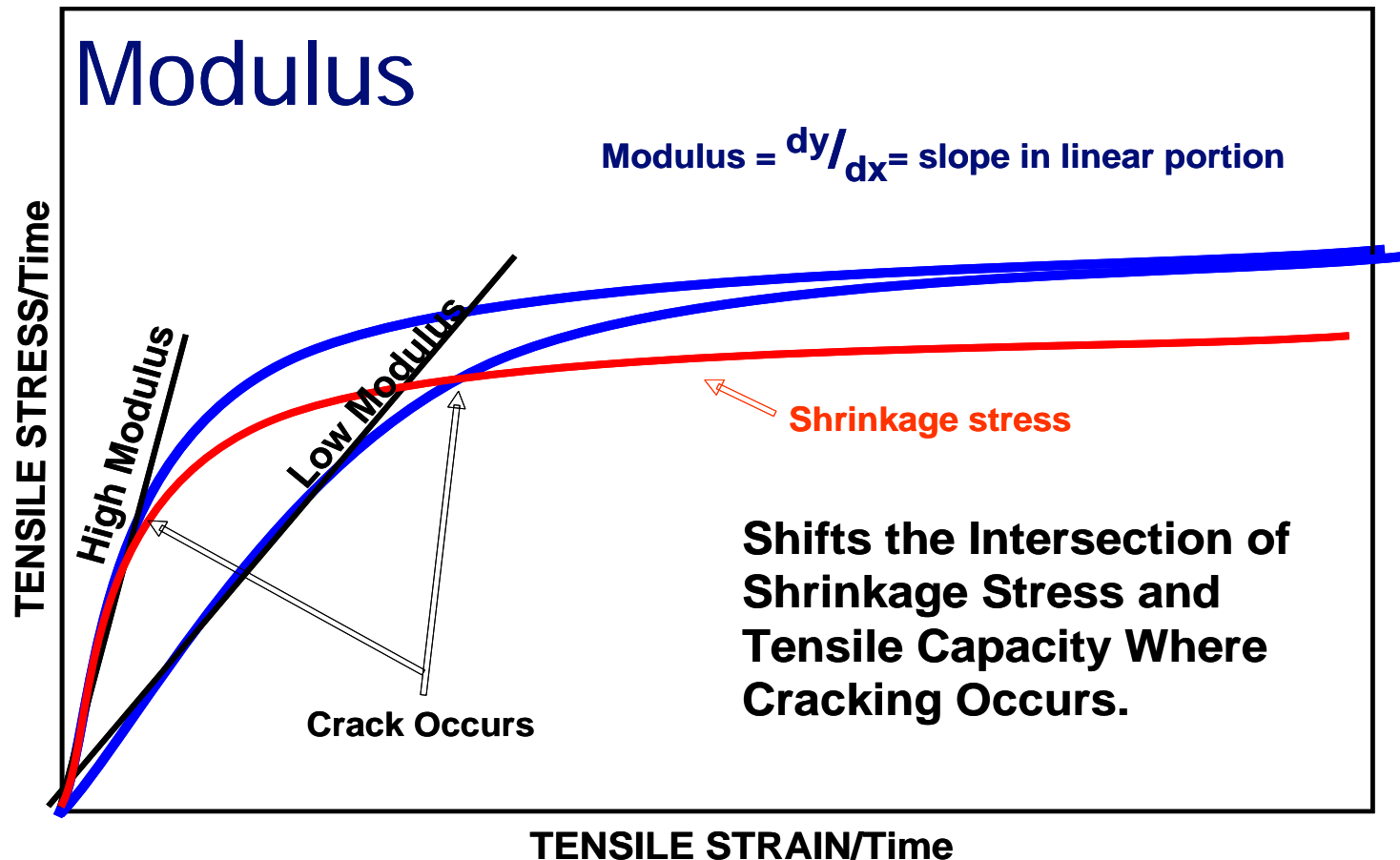
Properties that Contribute to Cracking



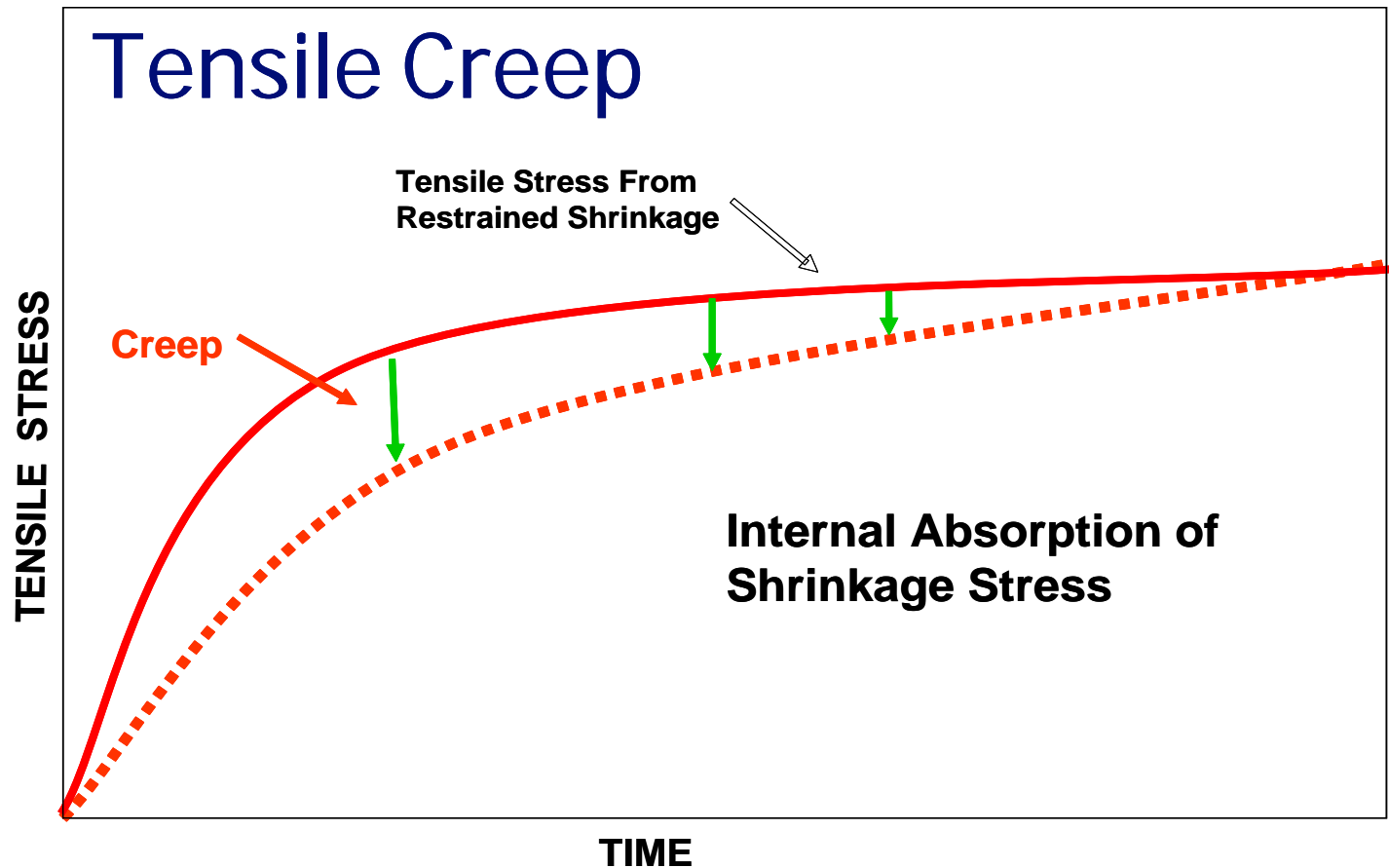
Properties that Contribute to Cracking



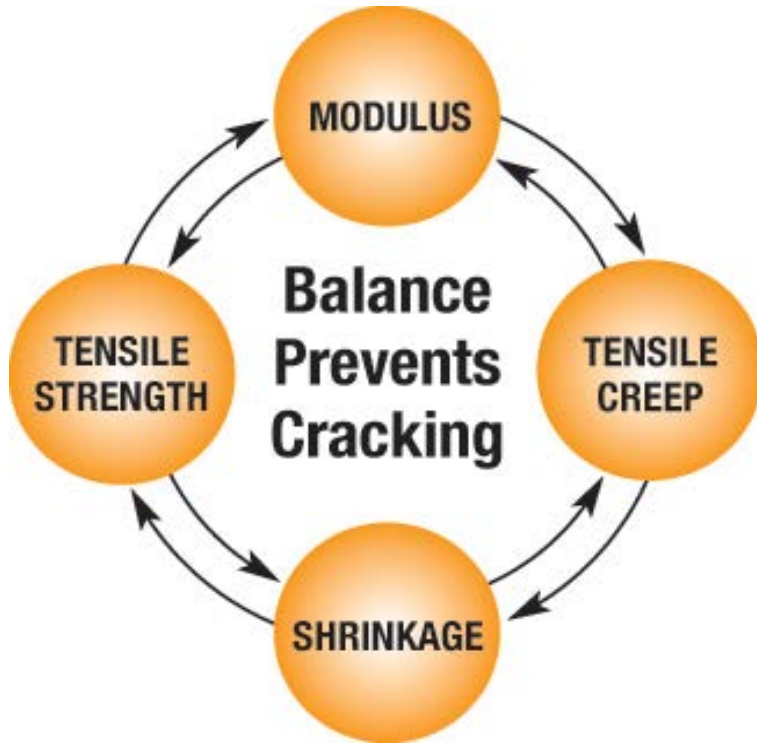
Properties that Contribute to Cracking



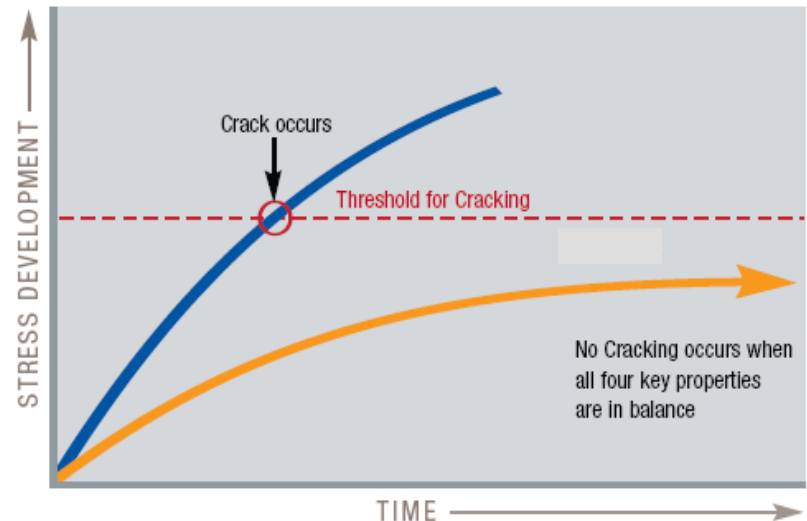
Properties that Contribute to Cracking



The Answer



- Its more than shrinkage
- Materials with low shrinkage can and do crack
- The answer is balance



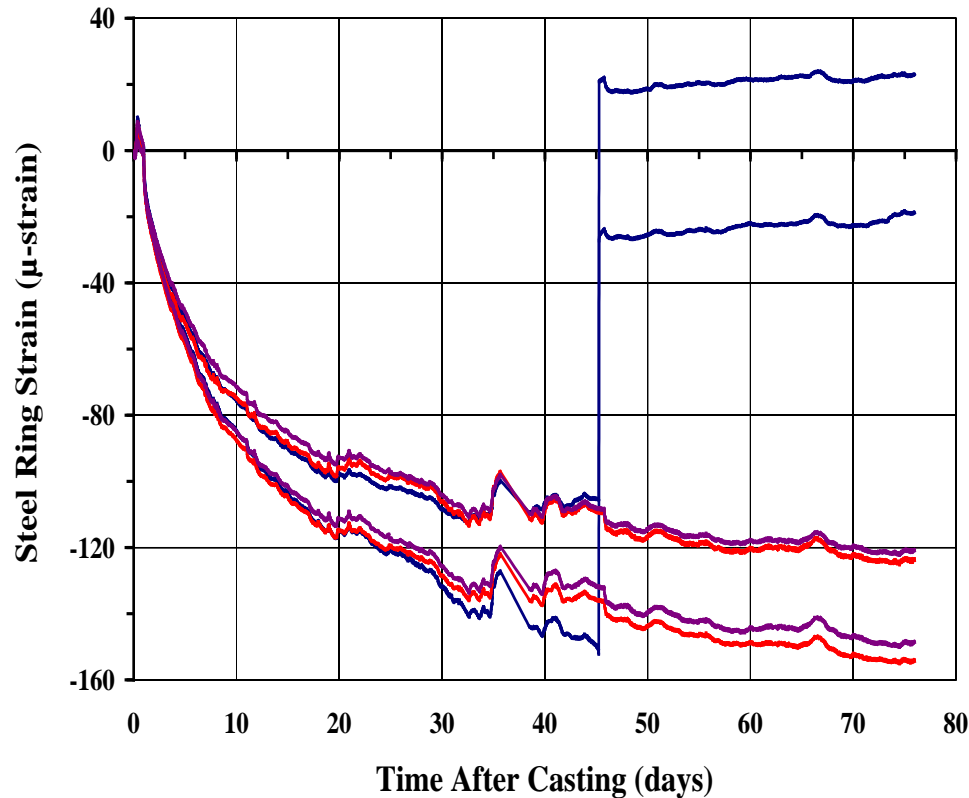
How is Cracking Performance Defined?



- Measures 4-forces of cracking
- Comparative test for materials
 - Accelerated - Days in the ring do not equal days in the field
 - Shows relationship between materials

Ring dimensions				Researchers and country (reference)
Diameter, mm (in.)		Thickness, mm (in.)	a/b	
External a	Internal b			
175 (6.9)	125 (4.9)	34 (1.3)	140	Carlson and Reading, U.S. (16)
405 (15.9)	325 (12.8)	80 (3.1)	1.23	Coutinho, Portugal (17)
125 (4.9)	100 (3.9)	25 (1.0)	1.25	
70 (2.8)	50 (2.0)	20 (0.8)	1.40	Popov, Opentliker, and Derugin, USSR (18)
40 (1.6)	30 (1.2)	—	1.33	Stolnikov and Litvinova, USSR (18)
57 (2.2)	27 (1.1)	20 (0.8)	2.11	Lernit, France (18)
100 (3.9)	68 (2.7)	32 (1.3)	1.47	Kondo, Japan (18)
660 (25.9)	508 (20.0)	102 (4.0)	1.3	Swamy, Banduopadhyay, and Stavrides, UK (19)
374 (14.7)	304 (12.0)	140 (5.5)	1.23	Shah, Karagulor, and Sarigaphuti, U.S. (20)
155 (6.1)	115 (4.5)	50 (2.0)	1.35	Technical research center, Finland (21)
175 (6.9)	112.5 (4.4)	50 (2.0)	1.55	Fosroc, UK (22)
72 (2.8)	37 (1.5)	35 (1.4)	1.95	Golubkov, USSR (18)
190 (7.5)	90 (3.5)	100 (3.9)	2.11	Guidelines for Production of Lightweight Concrete Structures, USSR (23)
318 (12.5)	254 (10.0)	102 (4.0)	1.25	WDP/SPS, U.S. (24)

AASHTO Restrained Ring Method

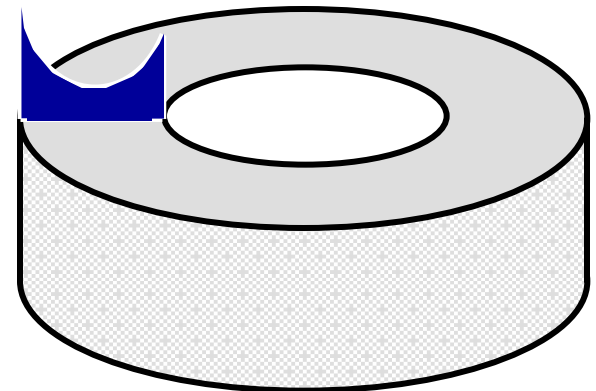


■ AASHTO ring is not sensitive enough for rapid comparative evaluation of materials due to degree of restraint

● AASHTO PP34-99 → 55 - 60%

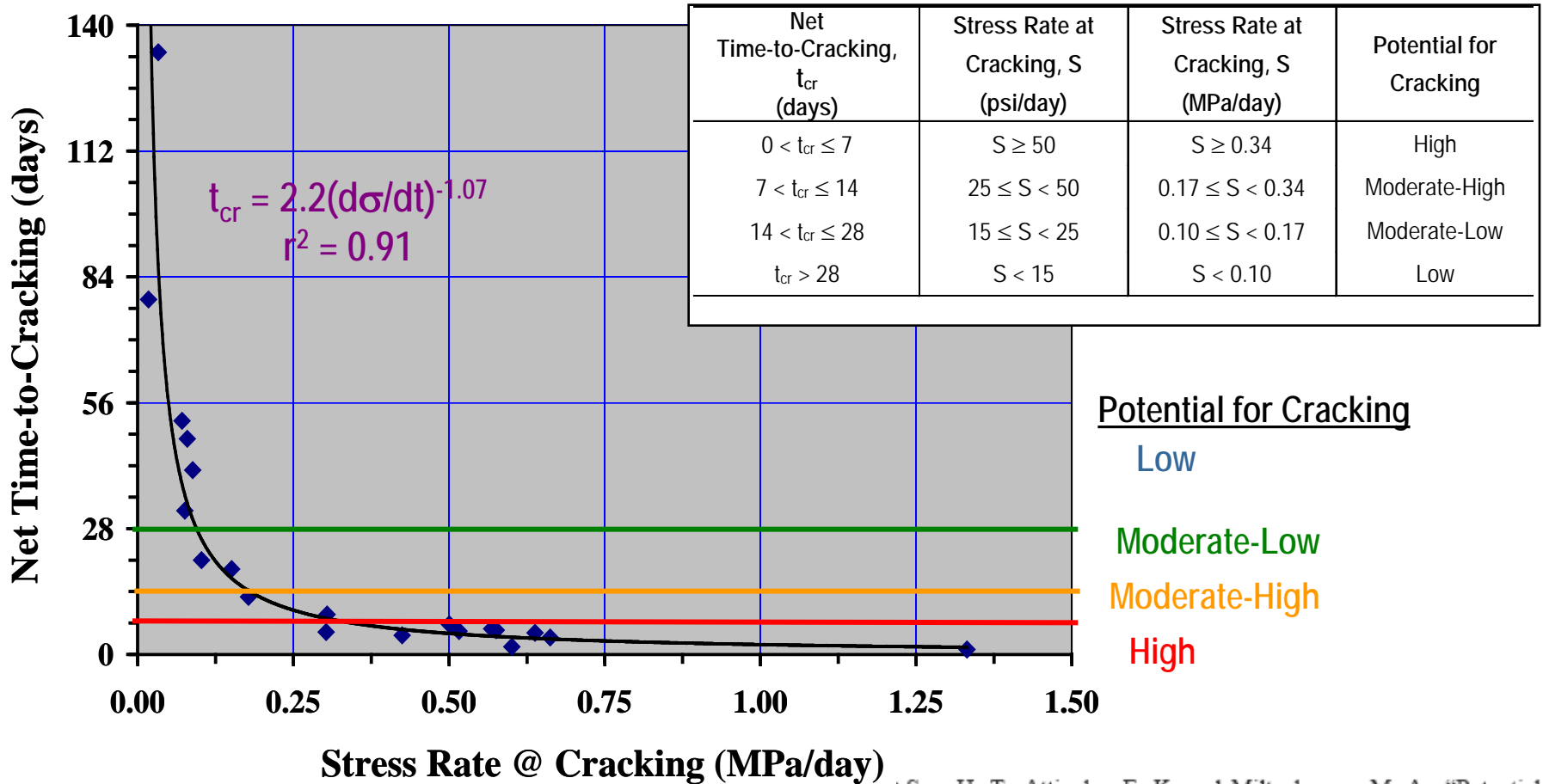
● ASTM C1581 → 70 - 75%

■ **Stress distribution peaks** at the outer and inner surfaces due to thickness of mortar



Work done by B. Pease, A. Hossain and J. Weiss (Purdue University)

ASTM C1581 - Cracking Classification



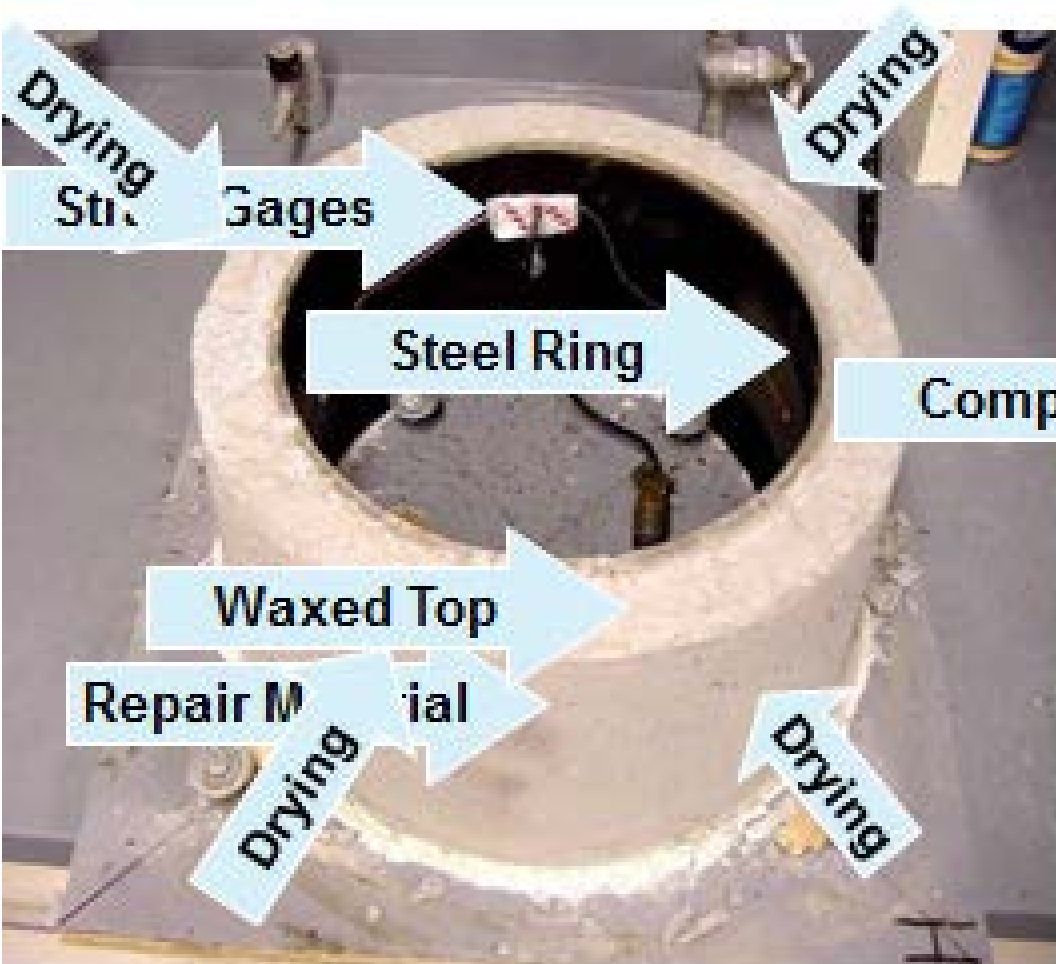
See, H. T., Attiogbe, E. K. and Miltenberger, M. A., "Potential for Restrained Shrinkage Cracking of Concrete and Mortar," *Proceedings of the ASTM Symposium on Early-Age Cracking of Concrete*, Dec. 2003.

ASTM C 1581 Cracking Potential

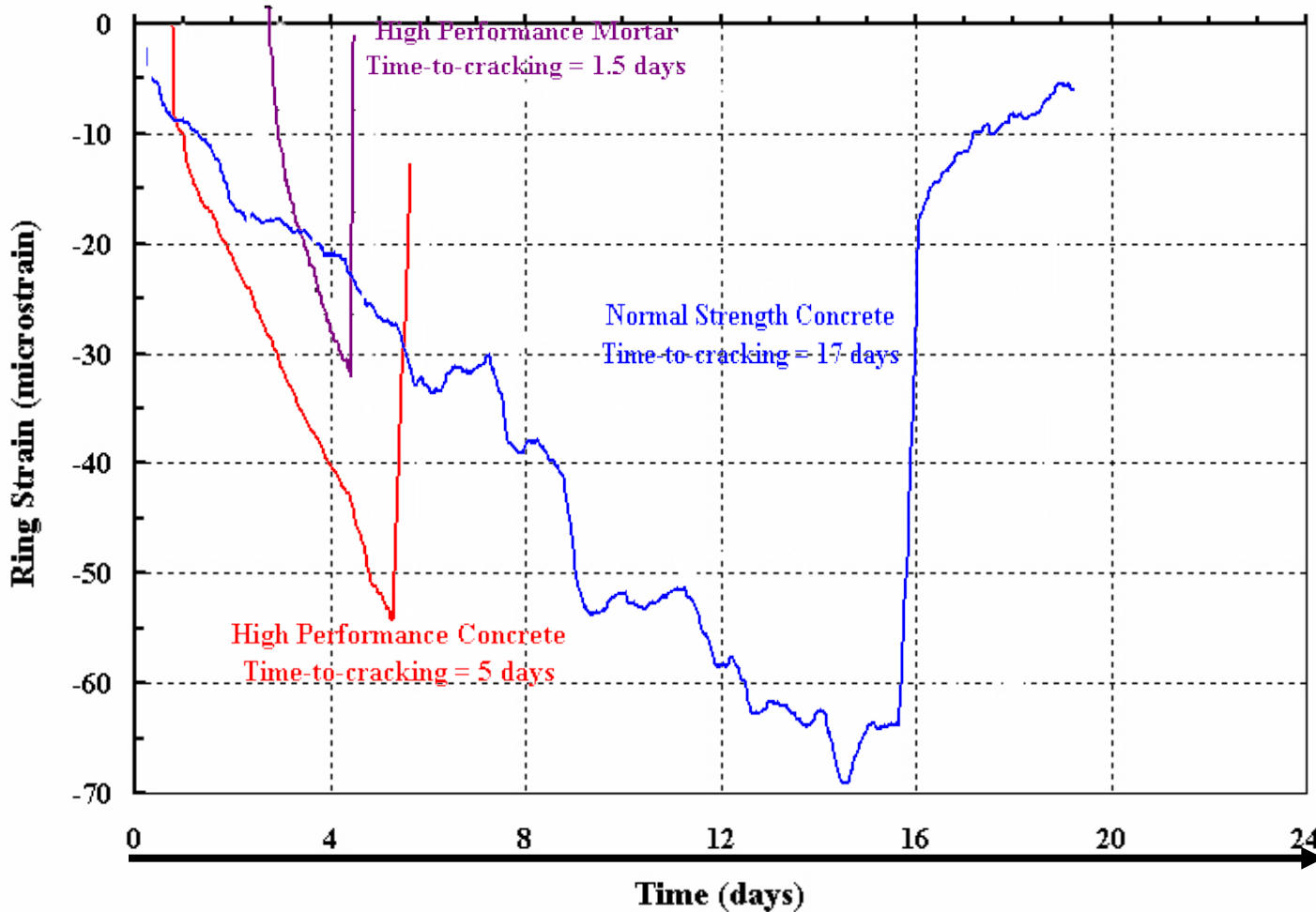


- Measures 4-forces of cracking
- ASTM requires test run for 28 days or until specimen cracks
- ICRI and ACI DSP requires test run for 60 days or until specimen cracks

How ASTM C1581 Works



What About “Regular Concrete”?



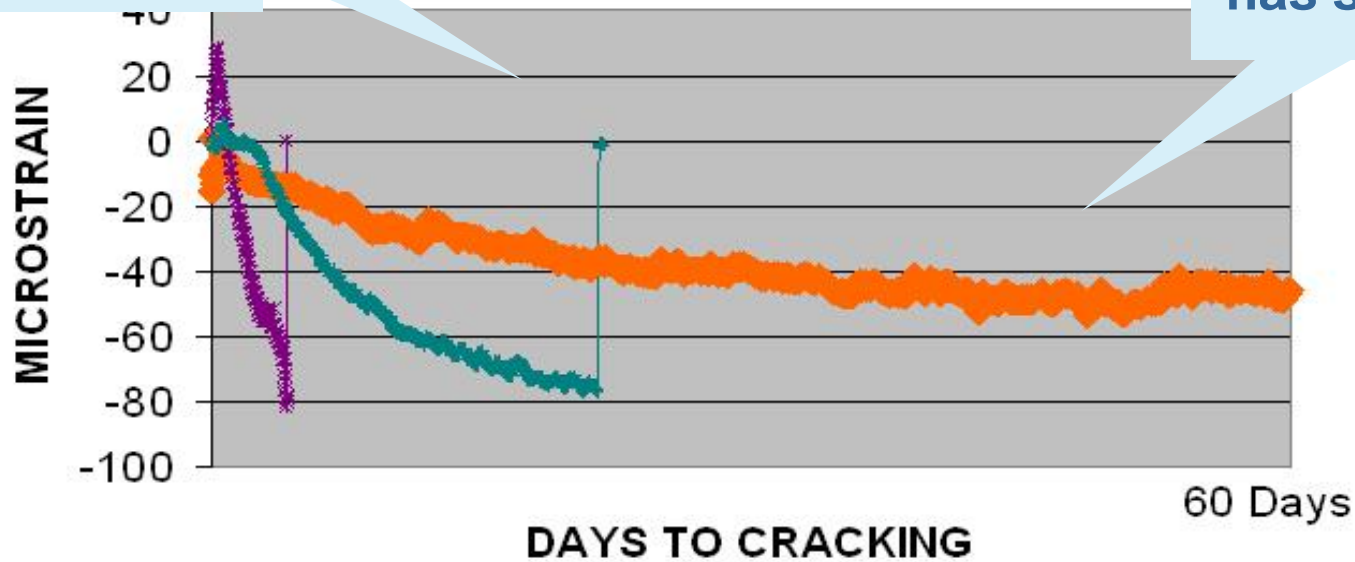
ICRI and ACI Data Sheet Protocol 60 days

ASTM C1581 Results

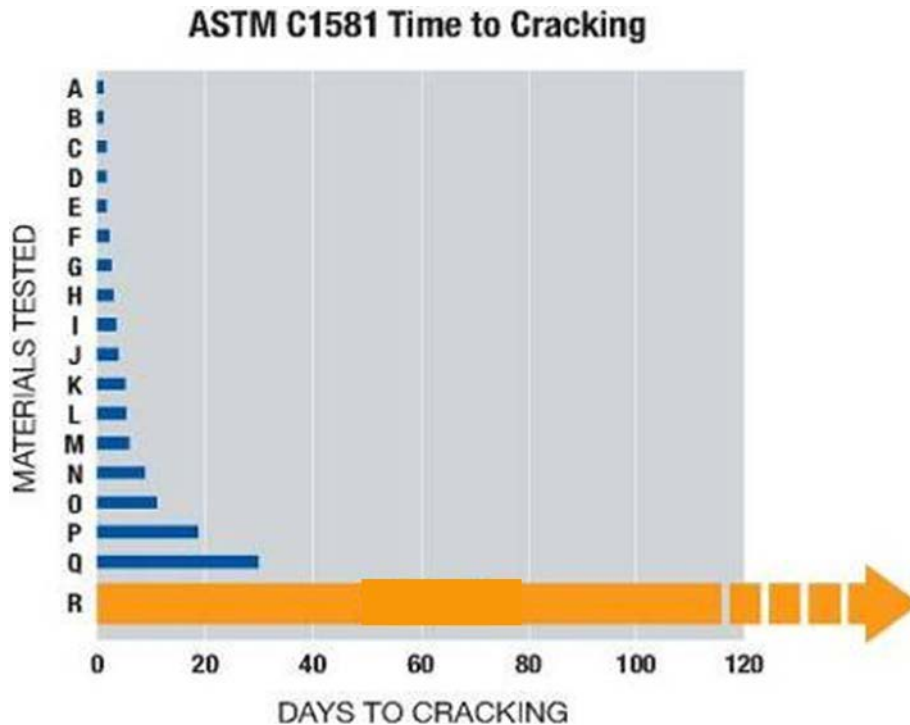
Straight line indicates cracking

ASTM C1581 Comparison

Flat line means stress development has stopped



Industry Ring Test Performance



- State of the industry cracking potential testing
- ASTM C1581 requirements driving innovation
- 3rd party testing provides validation, assurance and credibility

Review



- Concrete is a versatile, durable material
- Maintenance and restoration increases the useful life of concrete
- The repair industry's has a blue print to improve quality and durability of concrete repairs
- Performance based specifications like the ICRI and ACI DSP can lead to better repairs
- ASTM C1581 is the most reliable method for determining crack resistance in repair materials

Predicting Cracking Performance

Material Design and Selection ... Compromise and Balance

■ Cracking Resistance

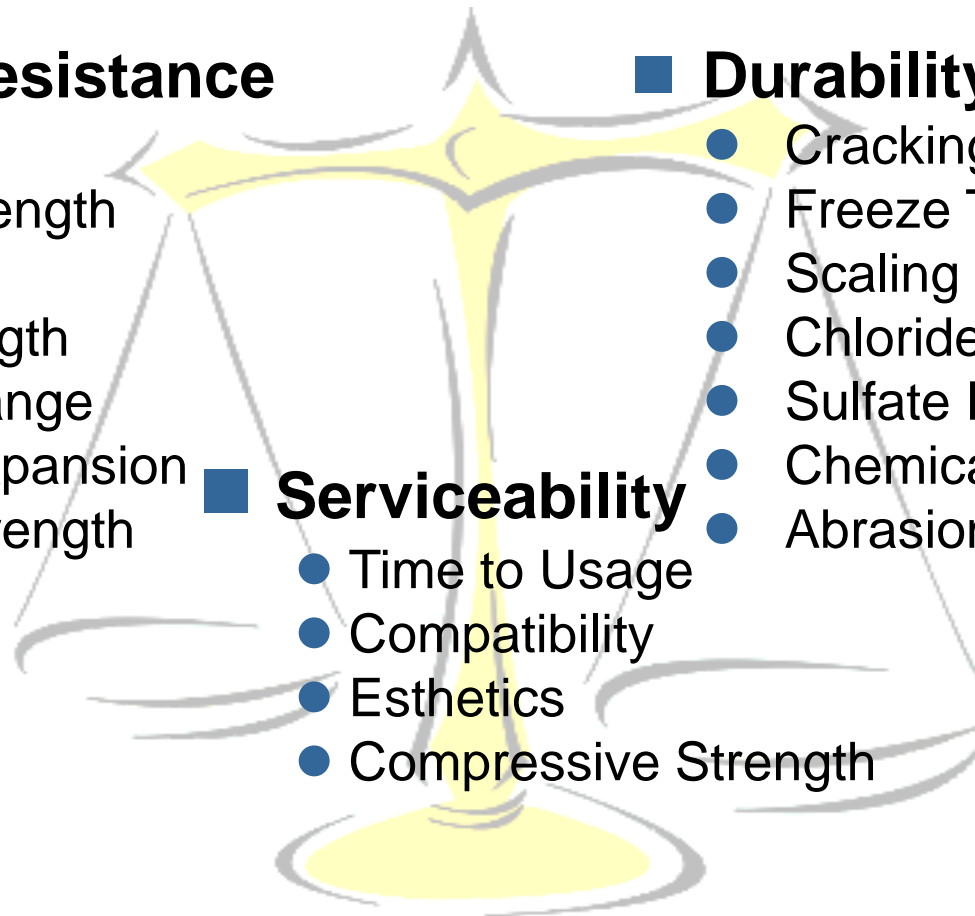
- Creep
- Tensile Strength
- Modulus
- Bond Strength
- Length Change
- Thermal Expansion
- Flexural Strength

■ Durability

- Cracking Resistance
- Freeze Thaw Resistance
- Scaling resistance
- Chloride Ion Permeability
- Sulfate Resistance
- Chemical Resistance
- Abrasion Resistance

■ Serviceability

- Time to Usage
- Compatibility
- Esthetics
- Compressive Strength



Repairs that Don't Crack Last Longer



DSP can keep you in control

- Reduce cracking
- Clear performance based specifications
- Quality control on site

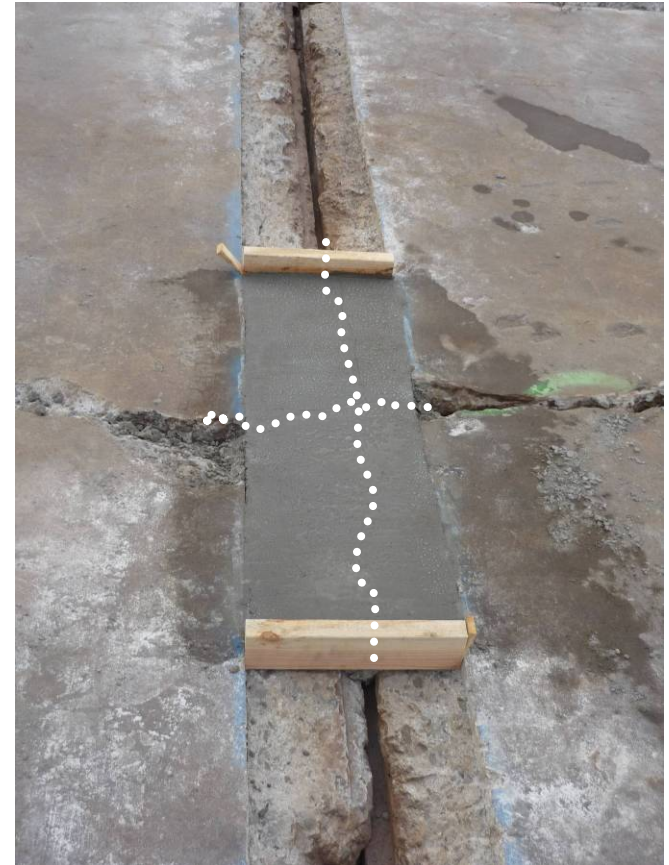
How to improve your repairs

- Implement DSP guidelines
- Require 60 day crack free performance in Ring Test
- Educate and follow industry guidelines

"Crack-Free" Repair Materials ... Are We There Yet ?

- Design errors
- Installation problems
- Material performance
- Loading effects
- Environmental effects

*... and other issues
can STILL cause
cracking.....*



Raise the Bar and Drive Innovation

... Cracking is not acceptable in concrete repair either



Thank You!

Any Questions?

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