State of The Concrete Repair Industry

Strategy & Tactics For Improvement

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structural

ICRI

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Agenda

- Defining the Concrete Repair Industry
- Why make improvement
- Technology impacts
- Reducing poor performance - tactics
- Vision 2020 Plan
- What The Future Holds

Historical U.S. Ready Mixed Concrete Production

Cubic Yards, millions

410
359
308
256
205
154
103
51
0

1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005

Cummulative 9 Billion Cu Yds

Source- NRMCA

$$ Cost of Repair/Rehab/Prot/WP/Upgrades

- 9 Billion Cu Yds in Place In USA
  - 32 cu yd per person
  - ~ 1 cubic mile

- $18-21 Billion / year spent on Repair and Maintenance of Concrete

Bridges

- $8 B
- (Source Cost of Corrosion Study NACE)
- Decks, Superstructure Components, Substructure Components
- There are 235,000 conventionally reinforced concrete and 108,000 using prestressed concrete. 15% of these bridges are structurally deficient because of corrosion and other related deterioration. Seismic retrofit. Use of surface repair systems, remove and replacement, protective coatings, membranes, pile jacketing, cathodic protection systems, strengthening systems, crack repair

Roadways

- $4+B
- Slab on Grade, curb and gutter, sidewalks
- Freeze thaw deterioration, asr attack, d cracking and abrasion wear. Work includes remove and replace, slab subsealing, doweling, partial depth repairs, overlays

Piers and Wharfs

- $ 0.2B
- Piles, bents, decks
- Exposure to chlorides and vessel impact
- Use of cathodic protection surface repair systems, jacketing, protective coatings

Buildings

- $2B
- Facades, Balconies, Plaza Decks, Exposed concrete
- Repair and protection of concrete facades both precast and cast in place due to airborne chloride, carbonation, design and construction errors. Seismic retrofits, Foundation waterproofing, plaza deck waterproofing, balcony repair

Parking Structures

- $0.5-1B
- 18,000 structures in U.S.Precast, Post-tensioned, Cast in place, Composite ($50-100k/yr/structure)
- Spalling concrete resulting from chloride ingress. Leakage through cracks and joints. Use of waterproofing membranes and joints to control water Strengthening systems for design and construction errors, Surface repair systems for spalling damage

Locks & Dams

- $ 0.2B
- Repair, rehabilitation of dam structures resulting from freeze thaw, abrasion /erosion, structural modifications, leakage. Systems include overlayment, grouting, spall repair, strengthening (anchors)

Residential

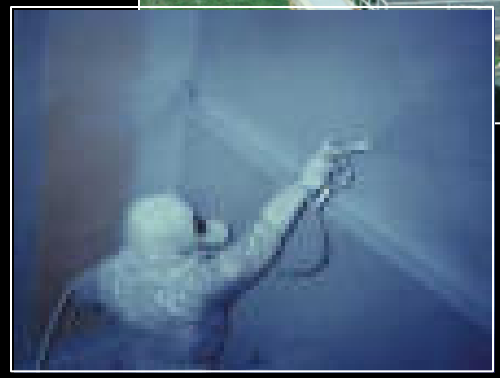
- $ 0.3B
- Sidewalks, Driveways, Patios, Foundations
- Freeze thaw action of poorly constructed slab on grade structures, settlement
- Use of remove replacement, slab jacking, aesthetic overlayments, surface repairs

Industrial Facilities

- $ 0.3B
- Foundations, slabs, structural frames, containments, vessels, tanks
- Chemical attack, spalling, disintegration, structural overloadsUse of surface repair techniques, coatings, liners, membranes, strengthening systems

Water Treatment

- $0.5B
- Tanks,
- Leakage, spalling, disintegration, settlement. Use of surface repair techniques, coatings liners and membranes



Pipelines

- $1B
- Sewer Pipes, Pressure Pipes, Aqueducts, Canals, Tunnels
- Chemical attack, erosion, abrasion, spalling, settlement. Use of liners, coatings and membranes, overlays, spall repair, specialized trenchless pipe rehab technology

Misc Structures

- $1B
- Stadiums, Runways, Chimneys, Towers and more

The Industry Players

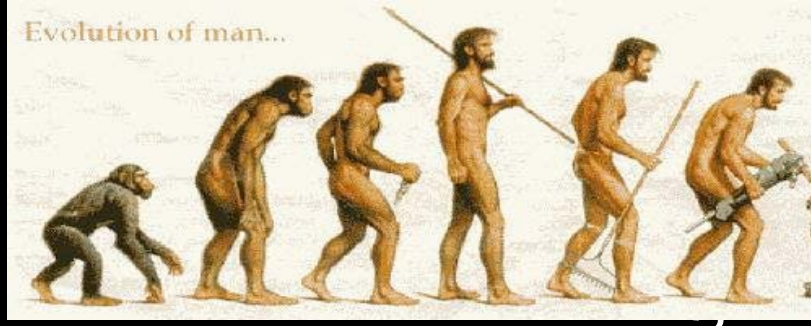
- Owner – This is my structure
- Engineer – investigator, solution builder
- Contractor- the implementer
- Technology Provider- products

- Research / Educational Institutions-next generation of technology and professionals
- Municipal Building Departments

Drivers For Improvement

- Problems that Cost Us $$$$
  - Not working like it should
  - Takes significant energy to change
- Changes that Save Us $$$$
  - Wow that will make the job easier and cost less. May even save time and last longer
  - Changes that cost less (first cost) move with great force into the market.

Industry Evolution-Technology



Industry Evolution

Time

Predictive Modeling

?

Today-2013

SCC 1995

Migrating CI ~1990

FRP Strengthening ~1986

Galv CP Systems ~1988

Hydrodemolition ~1984

Silica Fume Concrete ~1980

ICCP Systems ~1984

Hydraulic Concrete Pump ~1980

Steel Plate Strengthening ~1965

Epoxy Mortars ~1964

Polymer Coatings/Membranes ~1960

Latex Concrete ~1955

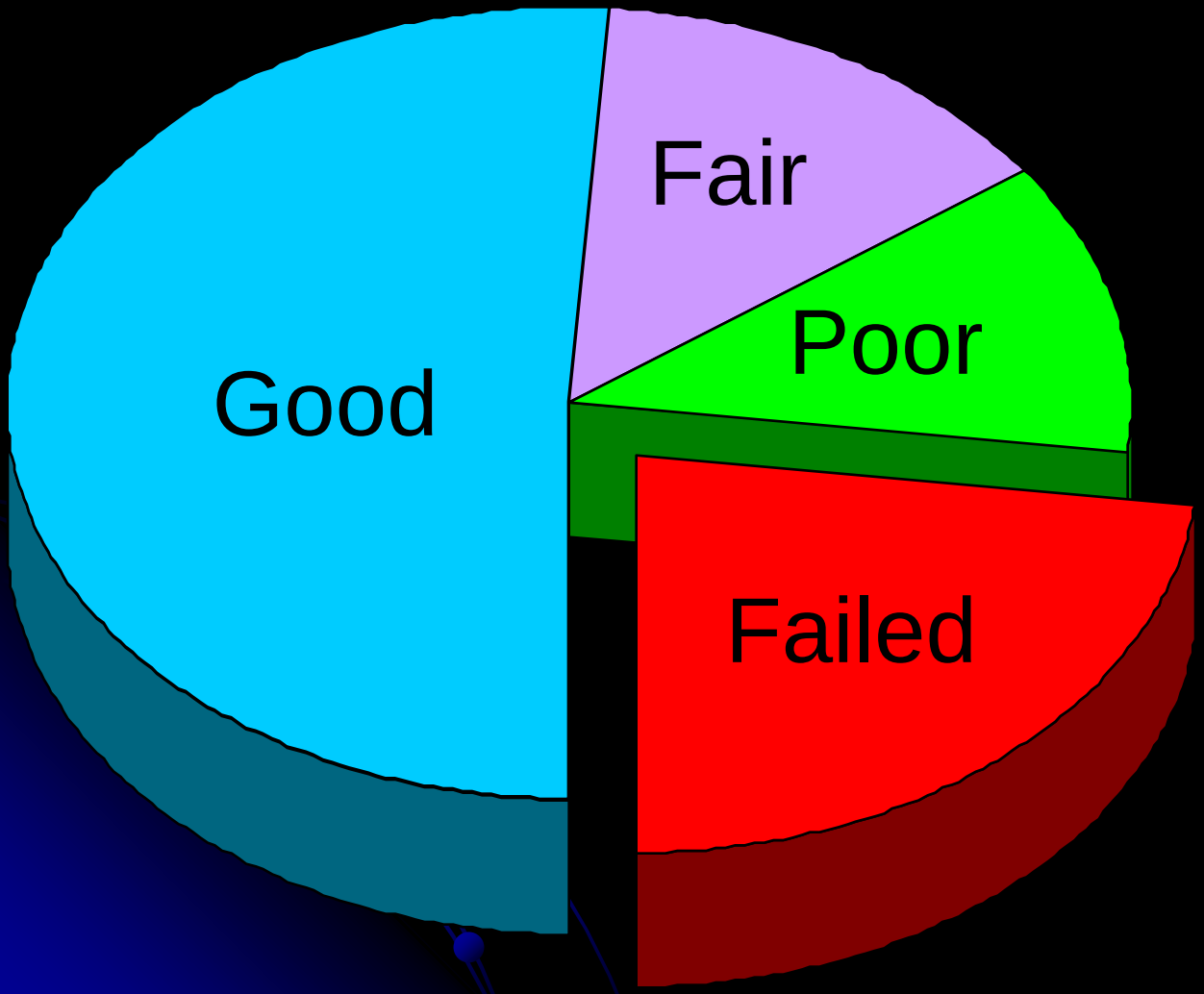
Epoxy Injection ~1960

Shotcrete ~1900

Formed Repairs

Dry packing

Repair Performance



Source- USACE J McDonald, USA

Causes

Investigation

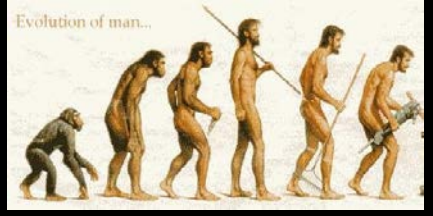
Design

Installation

Affect of Failure (The Problem)

- Unhappy customers
- Limits industry growth
- Wasted time dealing with unhappy customers
- Costs $$$ and Time

Industry Evolution- Organizational Efforts



Industry Evolution

Time

Today 2013

?

562 - 2015

STd 2012

ACI 562, 563

Vision 2020 2006

EN 1504 2002

WW Repair Manual 2003

ACI 440F 2002

ACI 548 Polymer 1971

ACI 546 Repair 1969

ACI 503 Adhesives 1960

ACI 506 Shotcrete 1942

ACI 515- Protective Coatings 1936

ACI Formed 1904

Safety Manual 2009

Data Sheet Protocol 2006

Pulloff Testing Stds

ASTM C1581-Shrinkage

Fixconcrete.org 2002

ICRI Formed 1988

WOC Seminars 1979

SWRI Formed 1976

SSPC Formed 1950

NACE Formed 1944

What's Required For Success

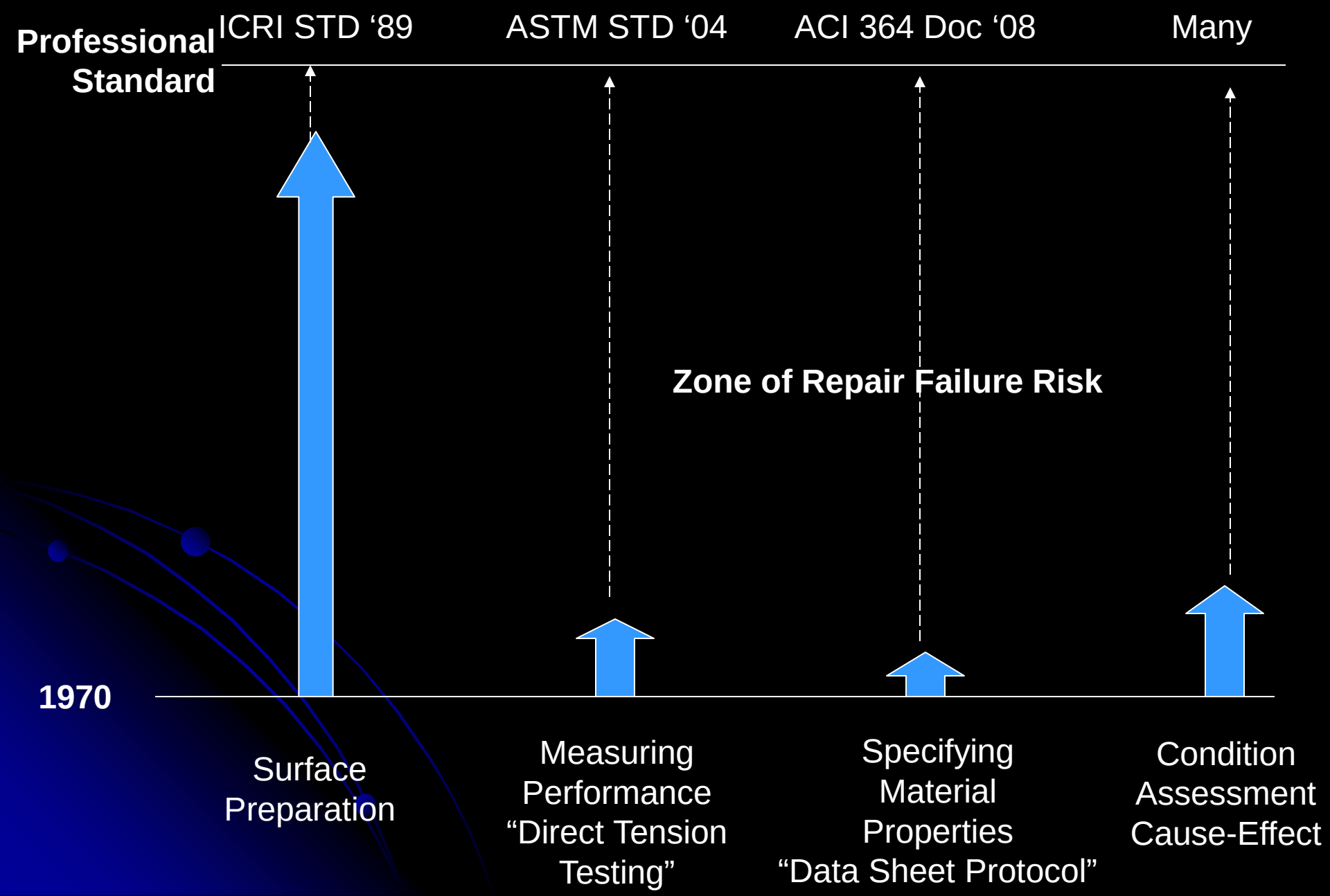
Engineer

- Investigate
- Design for Structural Needs
- Design for Durability
- Specify Materials
- Specify Performance Requirements
- Specify General Procedures
- Measure Performance

Contractor

- Implementation Skills (Matl, Labor, Equip)

Some Examples



Typical Data Sheet

Typical Data *(Material and curing conditions @ 73°F (23°C) and 50% R.H.)*

Shelf Life	One year in original, unopened packaging.
Storage Conditions	Store dry at 40°-95°F. Condition material to 65°-75°F. before using. Protect Component 'A' from freezing. If frozen, discard.
Color	Concrete gray when mixed.
Mixing Ratio	Plant-proportioned kit.
Application Time	Approximately 15 min. after adding Component 'B' to Component 'A'. Application time is dependent on temperature and relative humidity.
Finishing Time	20 to 60 min after combining components: depends on temperature, relative humidity, and type of finish desired.
Density (wet Mix)	132 lbs./cu. ft. (2.2 kg./l)

Flexural Strength (ASTM C-293)	28 days	2,000 psi (13.8 MPa)
Splitting Tensile Strength (ASTM C-496)	28 days	900 psi (6.2 MPa)
Bond Strength* (ASTM C-882 modified)	28 days	2,200 psi (15.2 MPa)

Compressive Strength (ASTM C-109)

1 day	3,500 psi	(24.1 MPa)
7 days	6,000 psi	(41.4 MPa)
28 days	7,000 psi	(48.3 MPa)

Shrinkage?
Cracking Resistance?

Permeability (AASHTO T-277)
28 days Approximately 500 Coulombs. Electrical resistivity (ohm-cm) 27,000

Freeze/Thaw Resistance (ASTM C-666) 300 cycles 98%

Engineer ?

Shoddy work by contractor caused overlay failure at Maryland Bay Bridge

Conclusions included:

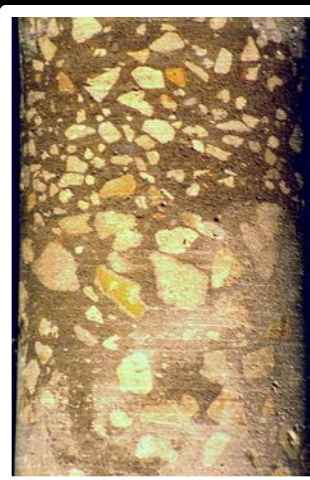
"1. The deterioration in the concrete overlay is extremely premature and extensive.

"2. Surface preparation methods ... did not adequately remove bruised portions of the substrate concrete.

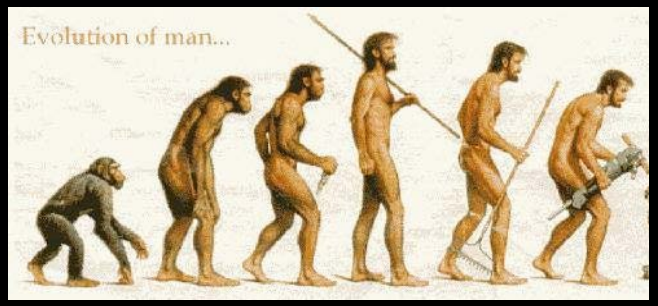
"3. The matrix restorer compound was not applied (to) the specifications and manufacturer's recommendations...

"4. The bonding agent was not applied (to specifications)

"5. The microsilica concrete was not placed, finished and cured in accordance with industry standards."



6 miles long x 3 lanes
18 lane miles
270 cores taken after debonding
0 tests performed during repairs



Industry Evolution

Rules to Play By
-Best Practices Available to Everyone
-Investigation-Design-Implementation

Industry Evolution

Time

Today-2012

1975

Field Art

Engineered Systems

Cause Effect

Standards

Service Life Extension Industry

?

Effective Life Extension
-Protective Strategies
-Repair Strategies
-Strengthening Strategies

Purpose of Vision 2020

Make the Concrete Repair Industry More Efficient

- **Quality**
- **Effective**
- **Fun**
- **Safe**
- **Green**

Industry Effort

Managed Evolution

Goals

1. Industry Cooperation
2. Accelerate Industry Documents
3. Create Code
4. Create Specifications
5. Improve Repair Materials
6. Friendly Repair methods/Materials
7. Predict Performance
8. Research Clearing House
9. Increase Professionals
10. Improve Project Relationships
11. Educate Owners
12. Accurate Assessment
13. Specific Repair Systems

Facilitated By

SDC

1 *By the year 2010 the industry will have established mechanisms for industry cooperation to facilitate better faster worldwide creation and dissemination of concrete repair and protection technology.*

- The repair industry is not just within the U.S., nor is it contained within one industry association, it is a worldwide effort involving many organizations. By coordinating closely between the many organizations, we can eliminate duplication of efforts, improve sharing of resources, coordinate projects to eliminate conflicting recommendations and improve the education process of industry players.

The repair and protection industry envisions:

1. Establishing a repair and protection council made up of members from various associations and institutes to monitor and manage Vision 2020 initiatives, the Repair Manual project and coordination and assignment of needed documents, educational programs, etc. *(By 2005)*
2. Developing a Manual of Repair and Protection Practices. Next step beyond the current Repair Manual (ACI, ICRI, CS, BRE …) *(By 2007)*
3. Identifying and developing more joint industry documents thus improving speed and best practices *(Ongoing)*

3

Create a repair/rehabilitation code to establish evaluation, design, materials, field and inspection practices which raise the level of performance of repair and protection systems, establish clear responsibilities and authorities for all participants and provide the local building officials a means of issuing permits. (By 2015)

- Repair and protection practice varies widely based upon individual beliefs, understandings, experiences and motivations. It is very hard to say what current practice is. The current ACI 318 Building Code does not deal with repair and protection issues. Practitioners are left to themselves to do the best job they can. When repair and protection projects fail to deliver the intended results, damages, claims and lawsuits are created. By establishing a Code of Practice, especially on projects evolving life safety, the practitioner will have support to provide proper design, material and construction considerations, but will also have a basis for using industry practice. This effort will raise the whole industry to a higher level of performance.

The repair and protection industry envisions:

1. Establishing a focused team to create a project plan for the "R/RCode" *(By 2005)*
2. Creating a multi part document that ultimately becomes a complete code. Parts may include:
   - Defining performance requirements for repairs
   - Establishing Material Performance Requirements
   - Defining considerations for structural safety during repair
   - Developing guidelines/standards for inspections of repairs

4

Develop performance based, guide specifications for specific and generic designs to improve specifications. (By 2010 and ongoing)

- A performance-based specification should detail requirements for the work in accordance with service parameters and other specific criteria. It should not provide instructions to the contractor on how to achieve these requirements Many specifications are incomplete, ambiguous, and may establish a basis for claims, poor quality performance and increased costs. Many specifications are created from product manufacturer guide specifications.

The repair and protection industry envisions:

1. Establishing a list of needed specifications *(By 2006)*
2. Creating specifications outlining responsibilities and performances expected, QA and QC methods and promoting the use of preconstruction mockups and field trials. *(Ongoing after 2006)*

ACI 563 Repair Specifications

563 - Specifications for Repair of Structural Concrete in Buildings
563-0A General Requirements
563-0B Shoring
563-0C Excavation/Surface Preparation
563-0D Formwork
563-0E Reinforcement
563-0F Concrete Mixtures
563-0G Placing/Curing
563-0H Architectural/Precast Concrete
563-0I Proprietary Grouts/Concrete
563-0J Crack Repair
563-0K External Reinforcement
563-0L Prestressed Concrete
563-0M Polymer Concrete/Overlays
563-0N Protection Systems
563-0P Corrosion

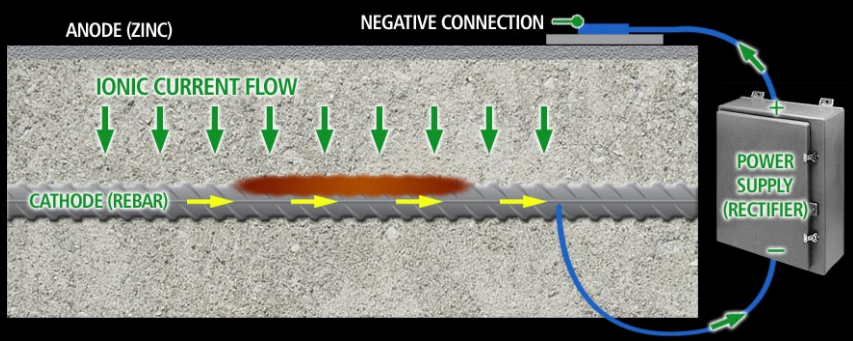
Develop a means for predicting repair system performance to reduce the use of improper materials, design details and installation methods.

The repair and protection industry envisions:

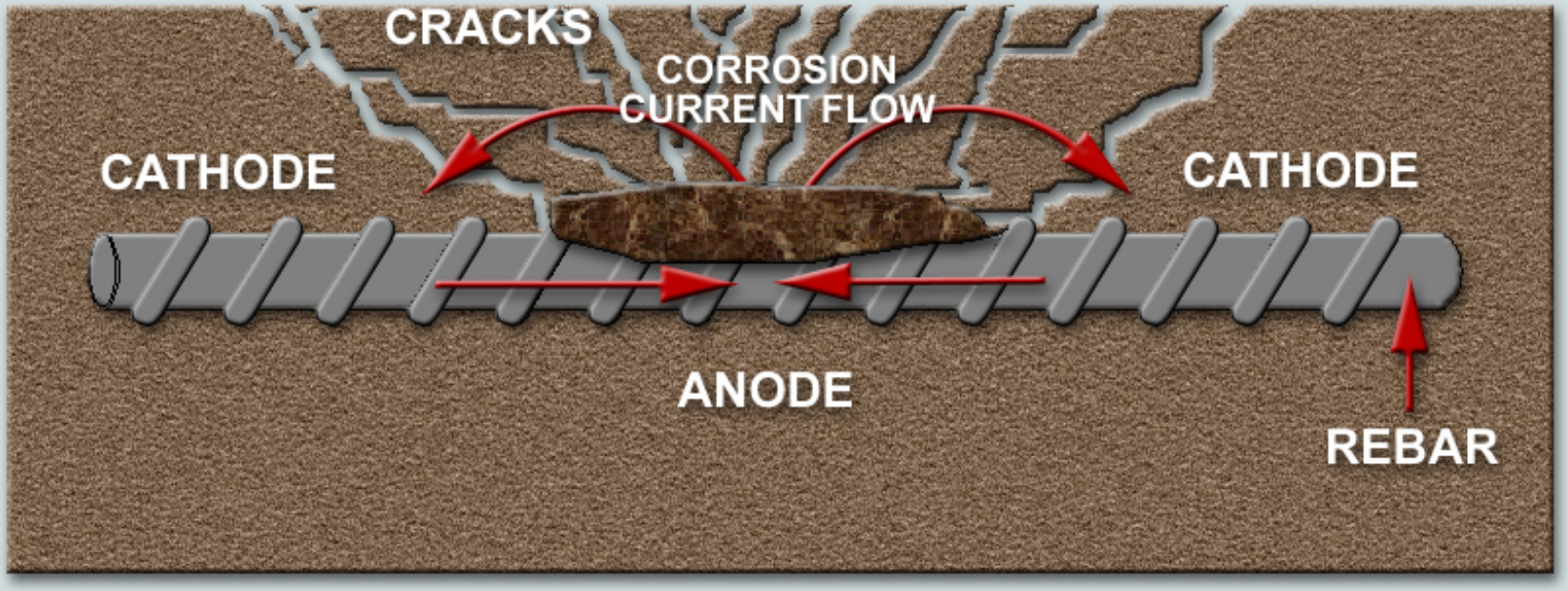
1. Establishing an infrastructure for collection of projects detailing historical performance, combining experiences of U.S., Europe and Asia. Establish a motivation for contributing *(*
2. Develop Industry evaluation protocols for technology performance measurement. (2012)
3. Developing a monitoring (observation) protocol for repaired structures to properly compare project results
4. Developing predictive modeling of service life of repairs *(By 2020)*

Technology vs Performance

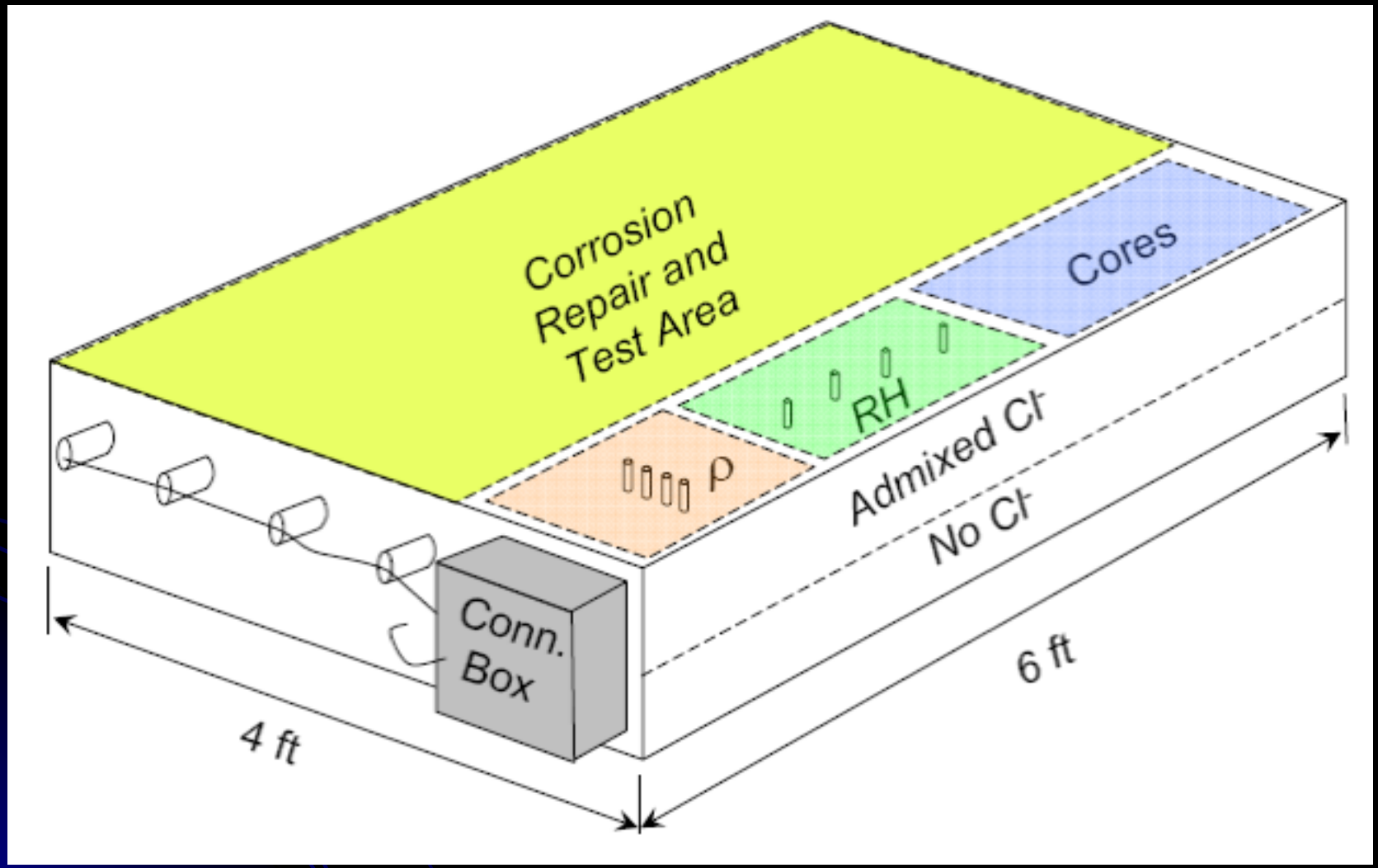
- How do corrosion protection technologies actually perform?
- *Sealers, Membranes, ICCP, Galvanic Anodes, Bar Coatings, Inhibitors …..*
- How Can We Predict Performance?



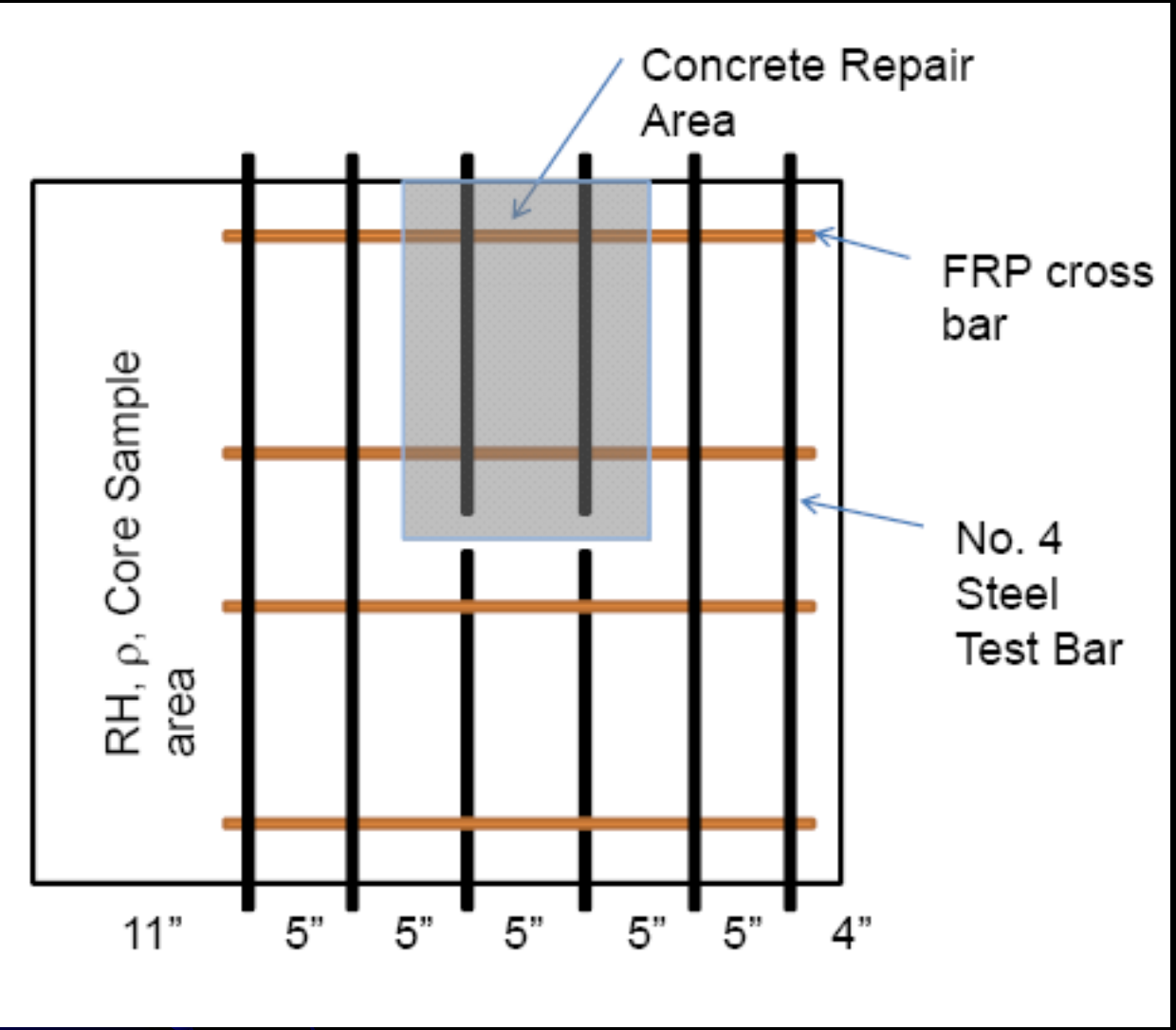
Corrosion of Steel in Concrete



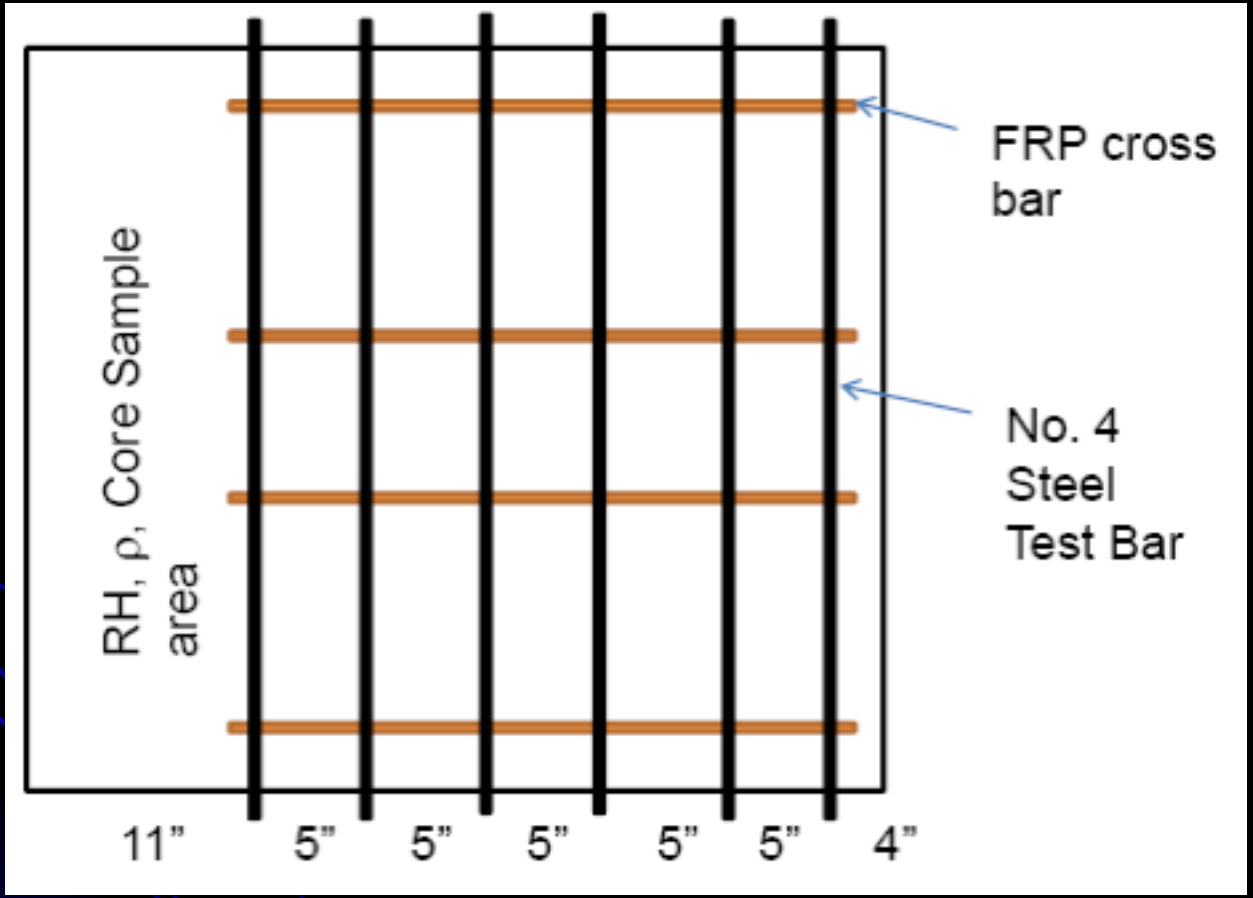
Prototype Slab Schematic



Concrete Repair Specimen Type



Surface Treatment Specimen Type



Future 2020

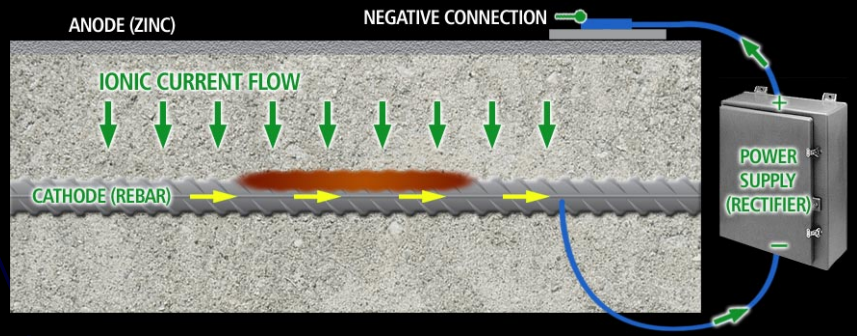
What will be different in 2020

Future Trends- Owner

- Increase understanding of life cycle cost
- Investing in prevention and protection
- Adaptive reuse of existing building

Trends Trends- Technology

- Increase understanding of life cycle cost
- Investing in prevention and protection
- increase us of cathodic protection

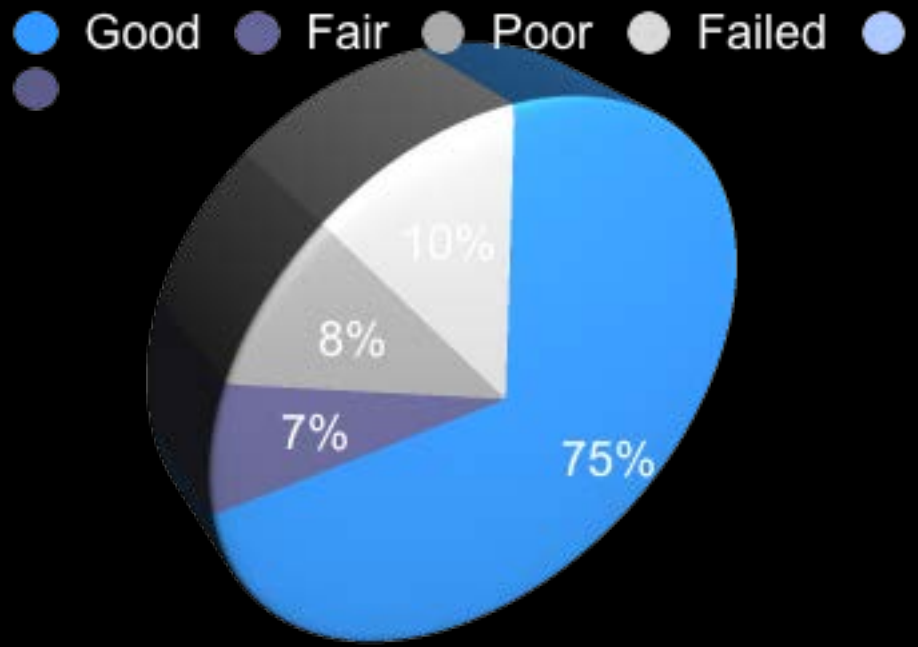


Future Trends - Field Quality

- Better In Place Quality of Performed Repairs
  - Inspector Certification
  - Pull testing used routinely

Future Trends- Design

- Less design related failures
- Code/standard 562,
- specification 563
- Engineer education via 562/563



Future Trends- Repair Products

- Product system solutions understood
  - performance expected and results
  - Corrosion Product research results
- Binder systems- volume change improvement

Future- Procurement

- design build procurement expanded
  - teaming of design professionals and contractors for complex or fast track solutions

Future- Safety

- Silica
- Ergonomics
- More effort/cost to maintain safe work place

Future- Education

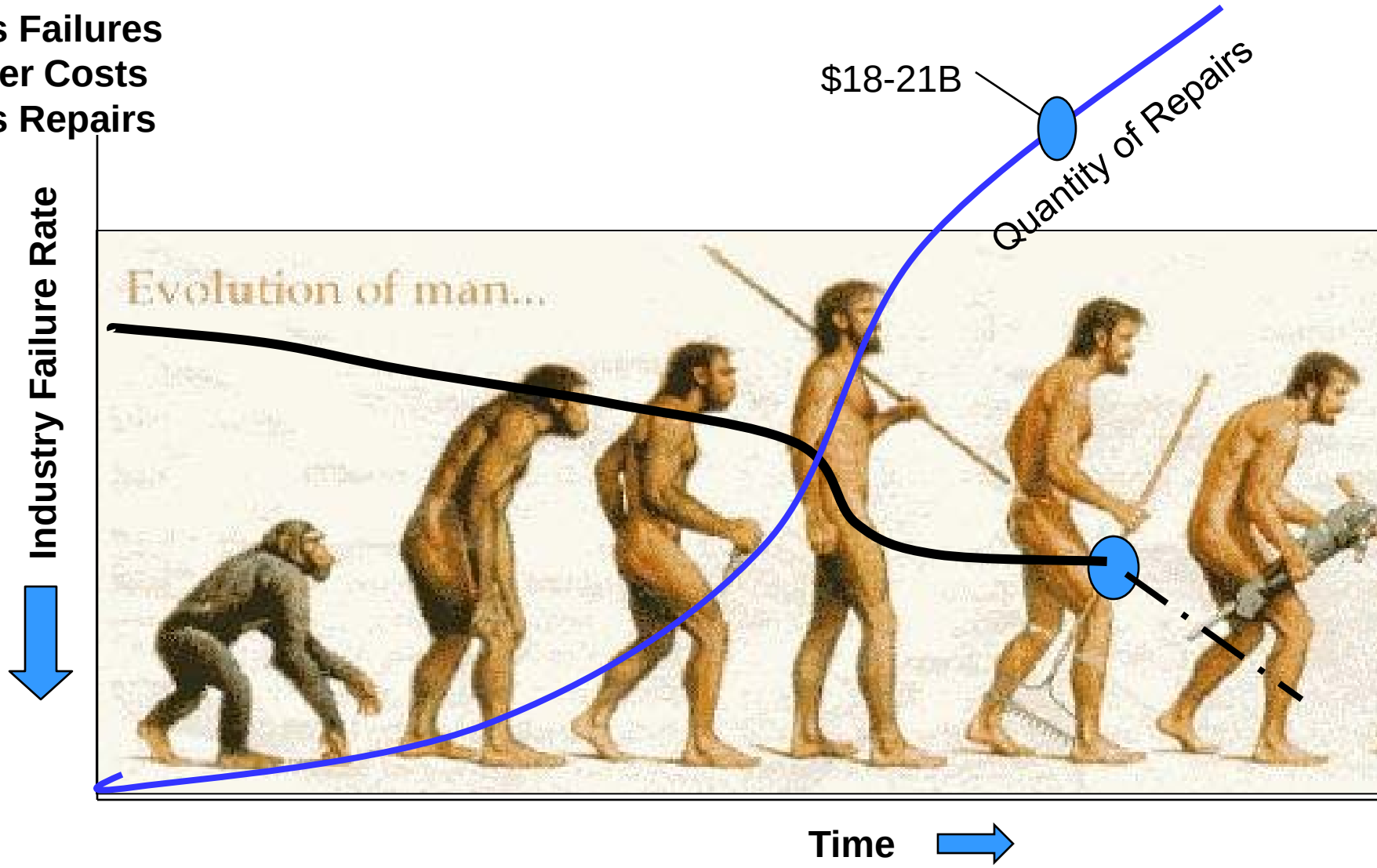
- Dedicated Industry School Established
- CPI
- Increased supply of industry personnel

Future- Environment

- Sustainability -What we stand for
- extending service life of structures

Industry Evolution - Effectiveness

Less Failures
Lower Costs
Less Repairs



Thank you for your valuable contributions to our industry

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