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Successful Concrete Repair - Material and Technique Selection

Engineering design, and specification, of suitable materials for concrete protection and repair

The key to successful concrete repair works and explaining why failures occur

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WHY WE REPAIR CONCRETE

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WHAT IS DEFECTIVE CONCRETE

- Concrete which does not meet design needs
  - Poor placement techniques
  - Damage due to corrosion or chemical attack
  - Fire and natural disasters
  - Structurally overloaded elements
  - Ageing and environmental effects

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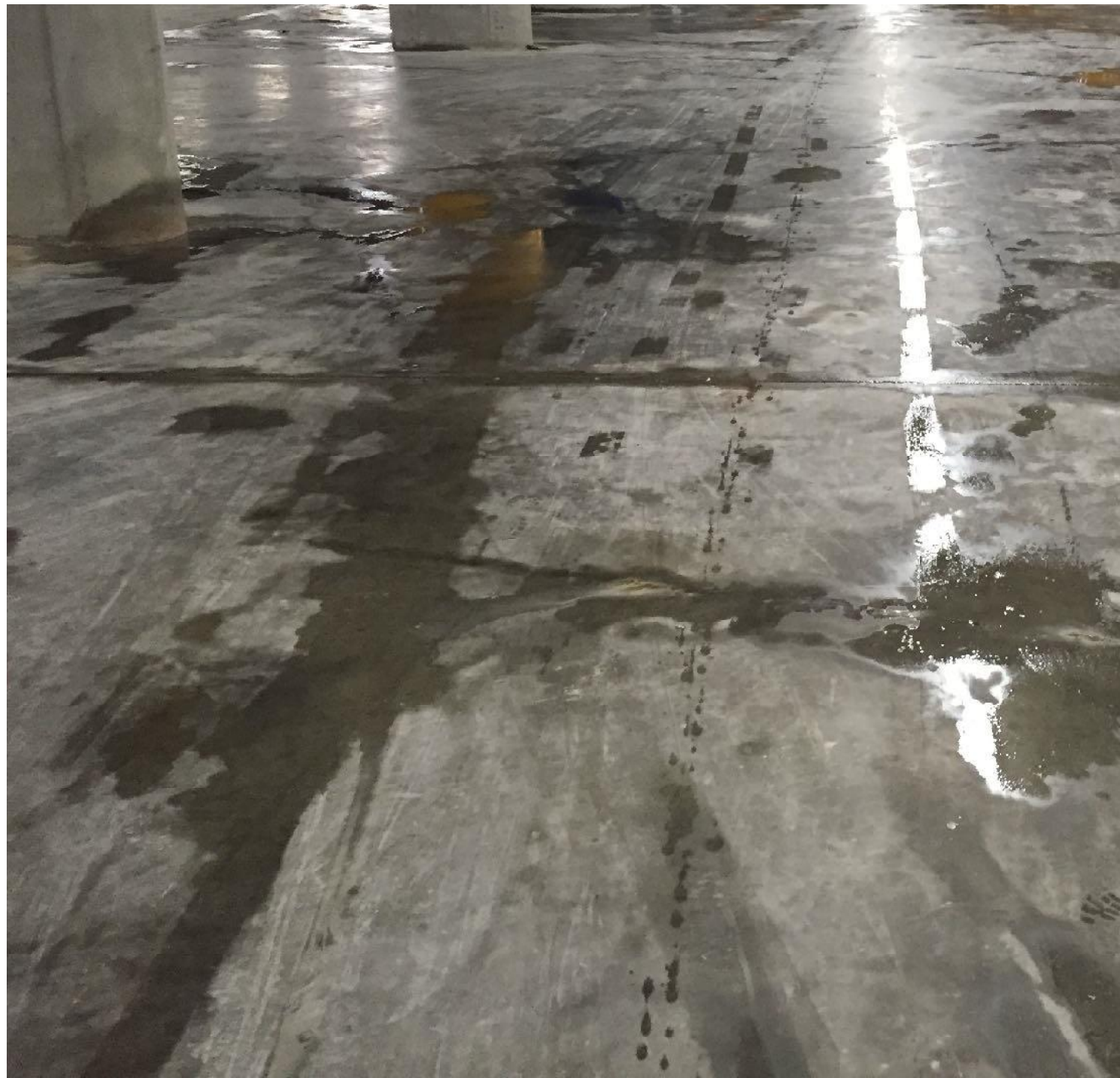
WHY REPAIR CONCRETE?

- Aesthetics (appearance and safety)
- Durability of the Structure
  - Future corrosion potential
  - Current visible corrosion
- Structural capacity increase



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WE SHOULD GIVE MORE CONSIDERATION TO REPAIR

- To save building new structures
  - Reduce carbon emissions
  - Protect natural resources
- Every m^3 of concrete repaired may save up to 300kg of CO_2 being emitted into the atmosphere

*Figures according to the National Ready Mixed Concrete Association of America

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COMMON STRUCTURES REQUIRING REPAIR

- Marine infrastructure
- Sewer and wastewater
- Bridges
- Underground structures
- Buildings

DEFECT IDENTIFICATION

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CONCRETE APPLICATION ISSUES

- Honeycombing
- Cold Joints
- Rain damage
- Incorrect curing techniques

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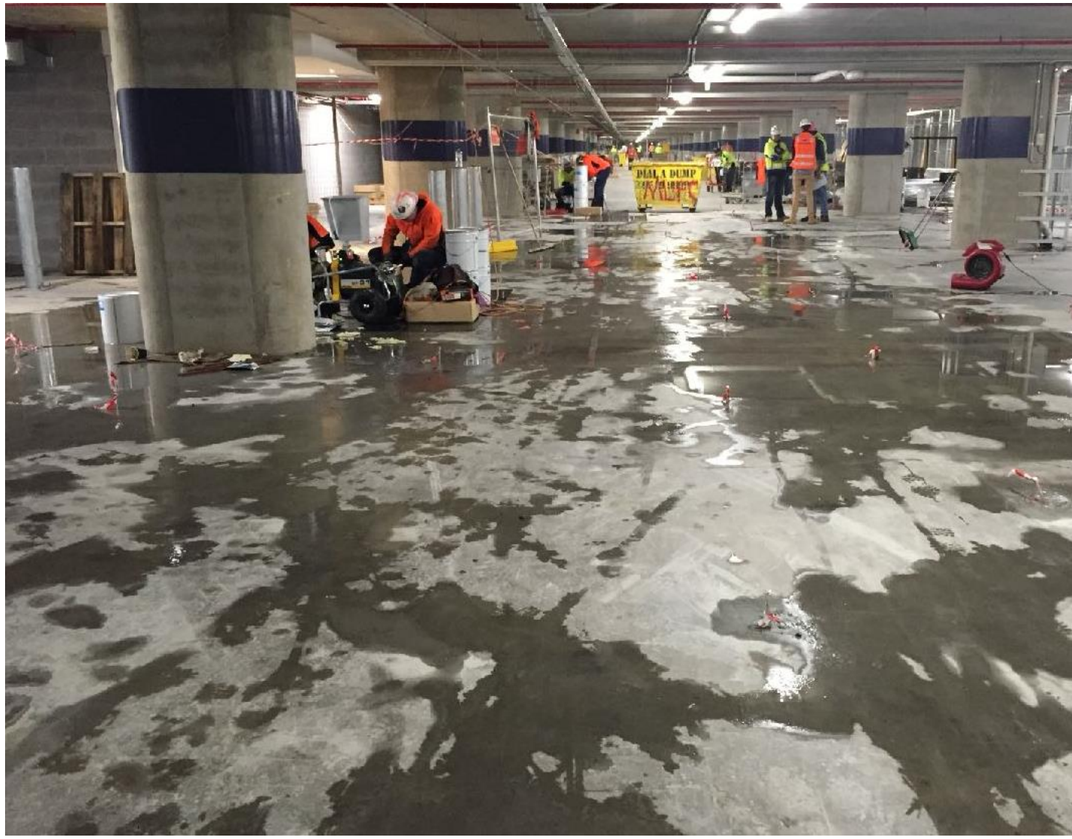
DESIGN DEFECTS

- Structural and shrinkage cracking
- Inadequate concrete cover to reinforcement
- Low structural capacity



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SERVICE LIFE DEFECTS

- Overloading
- Carbonation
- Chloride and chemical attack
- Spalling and corrosion of reinforcement

SPECIFYING REPAIR MATERIAL

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SPECIFICATION CONSIDERATIONS

1. STRUCTURAL PROPERTIES
2. DURABILITY PROPERTIES
3. DIMENSIONAL STABILITY
4. CONCRETE PREPARATION
5. APPLICATION CHARACTERISTICS
6. APPLICATION TECHNIQUES

Packaging	20kg, 1000kg, 1200kg bags
Water Addition	2.0 - 2.4 litres per 20kg bag
Yield	9.4 litres per 20kg @ 11% water
Build Scope	Up to 300mm in one pass vertical; up to 150mm in one pass overhead
Workability Time	30 minutes @ 20°C
Maximum Particle Size	3.0mm

TESTED CHARACTERISTIC	STANDARD	RESULT
Portland Cement	AS3972	Complies
Aggregates	AS2758.0	Complies
Potable Water Applications	AS/NZS4020	Certified
Compressive Strength	AS1478.2 Appendix A	2.2 litres water per 20kg 4MPa @ 8 hours 20MPa @ 24 hours 50MPa @ 7 days 65MPa @ 28 days
Chloride Ion Content	AS1012.20	0.01%
Elastic Modulus	AS1012.17	34.5GPa
Drying Shrinkage	AS1012.13	330μstrain @ 7 days 550μstrain @ 28 days
Electrical Resistivity	Taywood-Warner 4 Probe	7000ohm-cm @ 7 days 9000ohm-cm @ 28 days 10000ohm-cm @ 56 days
Flexural Strength	AS1012.11	6.9MPa @ 7 days 7.3MPa @ 28 days
Setting Time	AS1012.18	Initial set - 110 minutes Final set - 180 minutes
Fresh Wet Density	AS1012.5	2270kg/m^3

1.0 STRUCTURAL PROPERTIES

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MECHANICAL PROPERTIES

- Structure must respond to loading as per design
- Uneven loading and stress concentrations can occur if repair properties are not compatible
- UCS and modulus are primary considerations

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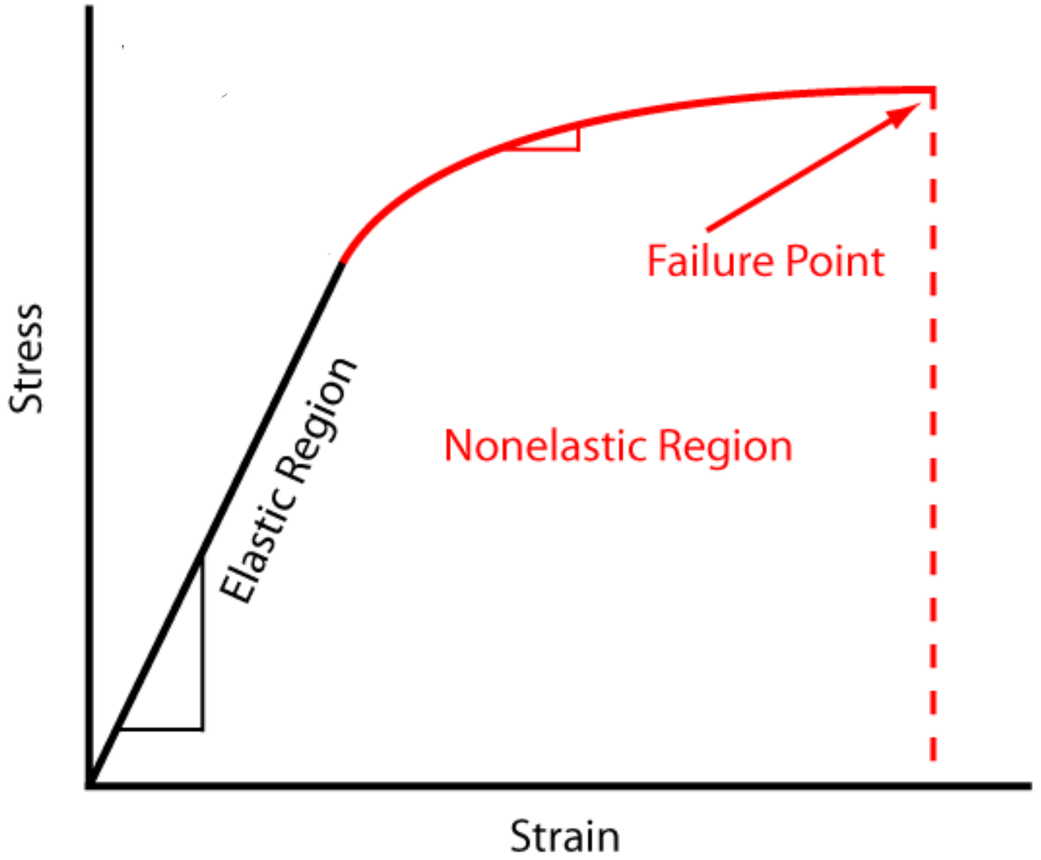
COMPRESSIVE STRENGTH

- The failure point of the material
- Strength is not stiffness
- Only important to ensure minimum strength achieved
- Practically irrelevant if mortar compressive strength is greater than host concrete



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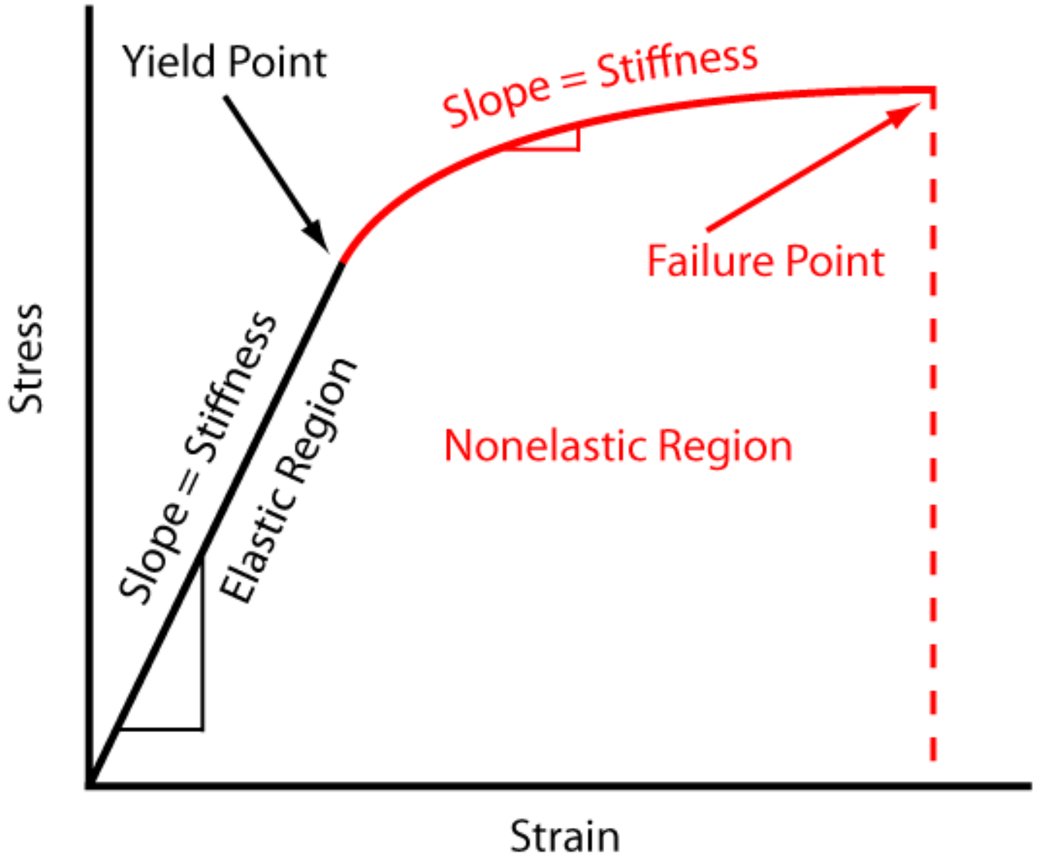
MODULUS

- Modulus is the deformation relative load
- The most important property to match with host concrete
- Requires repair to deform at same rate under load
- Despite the critical importance, Modulus is rarely specified



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MODULUS OF ELASTICITY

- Compatibility of stress strain
- Prevents load concentrations
- Structure reacts as per design

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LOW MODULUS REPAIR

- Repair mortar takes no load
- Higher bending forces in structure
- Causes eccentricity in columns

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HIGHER MODULUS REPAIR

- Mortar takes additional load
- Stress concentration occur
- Causes eccentricities in columns
- Additional tensile forces in host structure

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2.0 DURABILITY PROPERTIES

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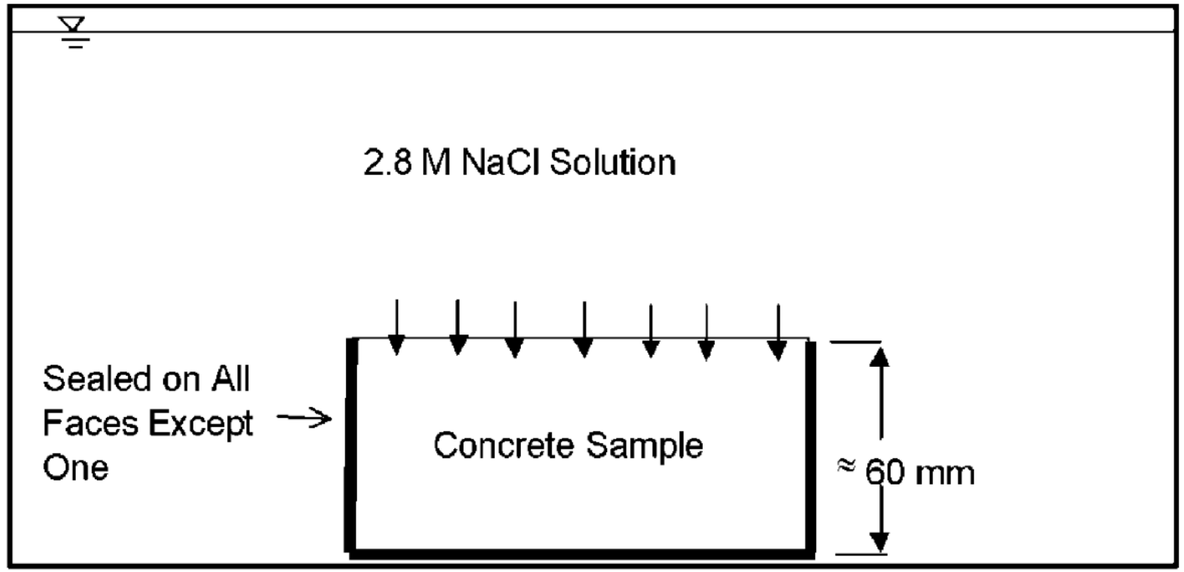
LOW CHLORIDE DIFFUSION

- Measurement of Chloride migration
- Rapid Chloride Diffusion is only an empirical estimate
- Measured accurately and directly by Nord Test
- Nord results should always be specified for marine structures



Nord Test Setup

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LOW ELECTRICAL RESISTIVITY

- Measures the conductivity of the repair mortar
- Low resistance to current required for cathodic protection
- Electrical resistivity in mortars varies significantly over first 24 months
- Long term measurement required
- Minimum 500-day ER results should be

3.0 DIMENSIONAL STABILITY

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CONCRETE REPAIR AREAS

- High exposure to drying shrinkage open face
- Long section - restrained on rear and sides
- High risk of cracking
- Requires volumetric stability

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THE MYTH ABOUT SHRINKAGE

- There is no such thing as a ‘non-shrink’ mortar
  - All cement products will change in volume over time
  - Some change can be limited
  - Some change can be compensated
- Shrinkage is the total dimensional change after casting
- Shrinkage timing and magnitude is variable depending upon temperature and water addition

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SUCCESSFUL COMPENSATION AND LIMITATION

- Shrinkage is reduced by limiting water addition
- Shrinkage is commonly compensated by
  - Gas expansion in plastic phase
  - Ettringite formation in drying phases
- Volumetric stability over time, in the applied environment is most critical

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TIMING OF SHRINKAGE IN CEMENT

Shrinkage Type	Timing	Control Measures
Plastic	24 hours	Curing techniques
Drying	56 days	Reduced water content
Thermal	7 days	Application thickness

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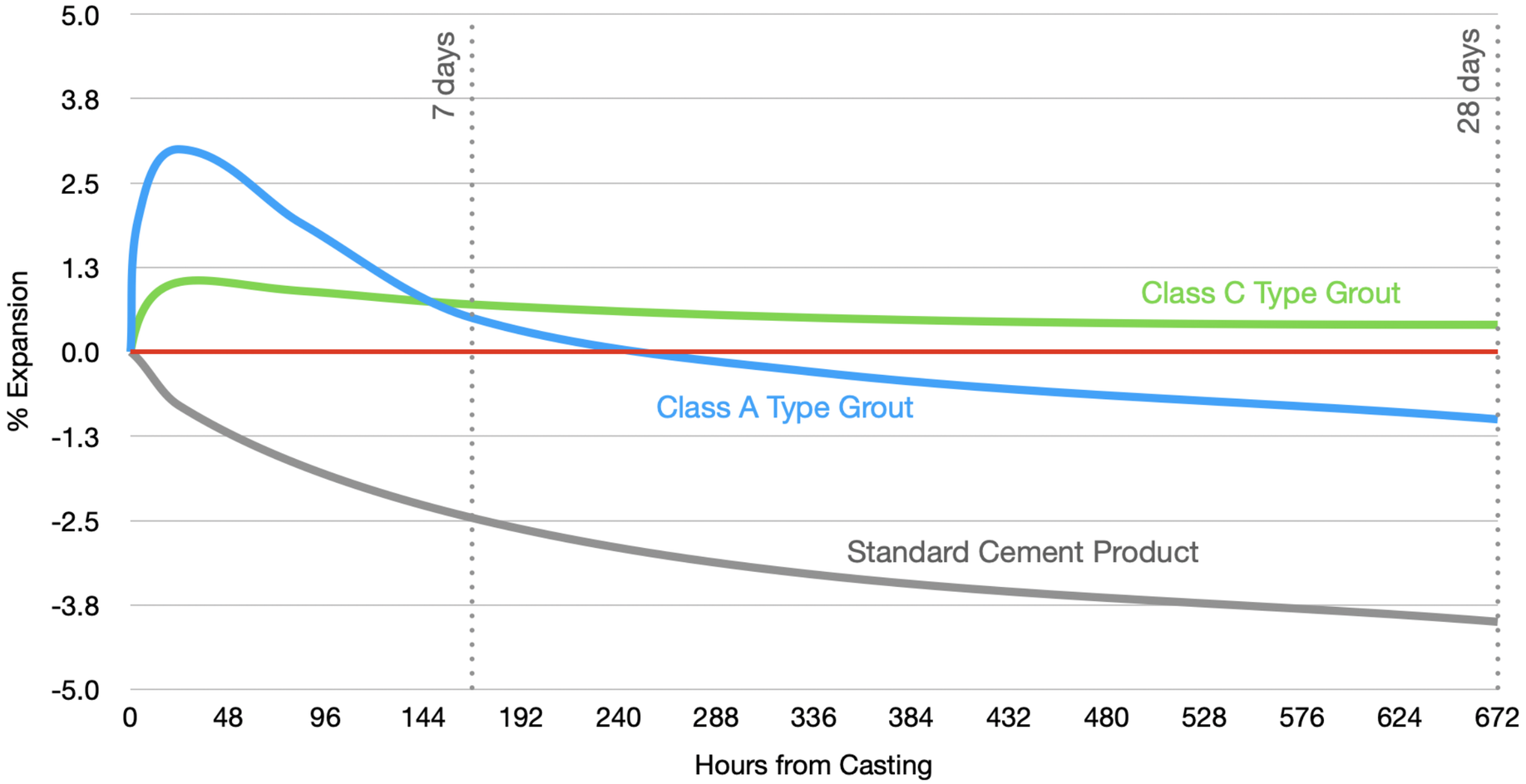
EXPANSION AND SHRINKAGE OVER TIME



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FAILURE OF REPAIRS DUE TO SHRINKAGE

- Concrete repairs are unconfined
- Shrinkage test data not often representative
- Type of shrinkage compensation is critical

Casting of Grout

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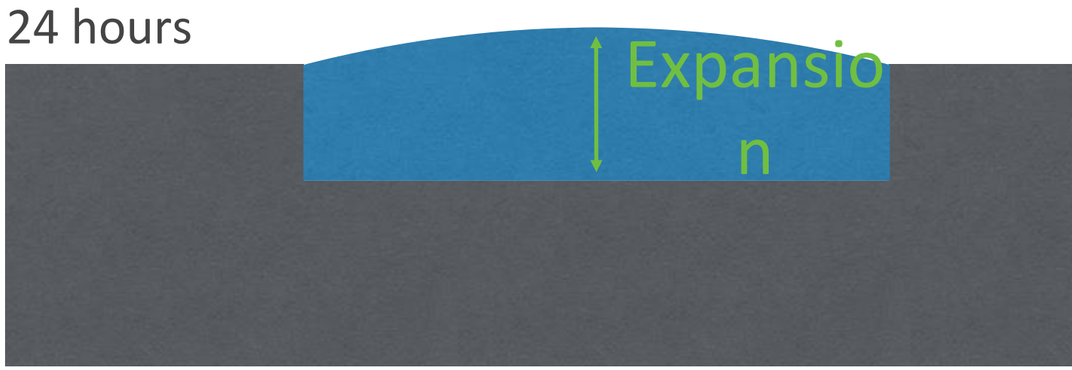
FAILURE OF REPAIRS DUE TO SHRINKAGE

- Gas expansion occurs in plastic phase
- Unconfined mortar expands
- Expansion systems disguise volumetric stability



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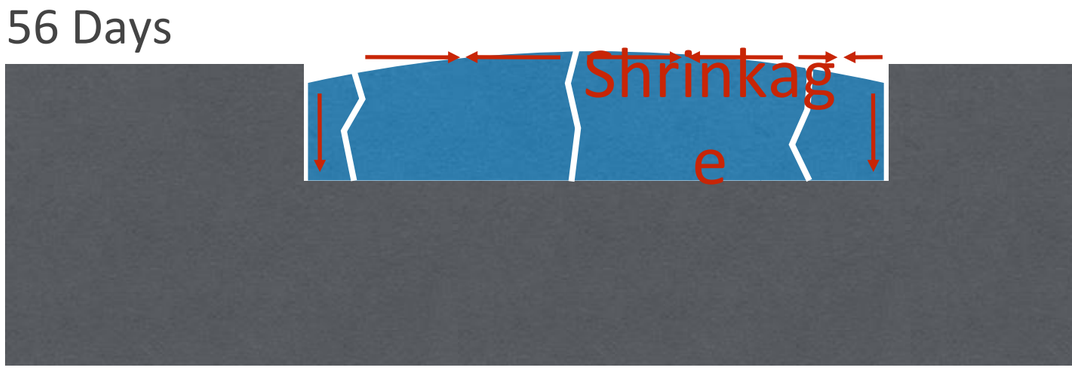
FAILURE OF REPAIRS DUE TO SHRINKAGE

- Expansion and contraction at different times
- Restraint in base causes widespread cracking
- Delamination likely to occur
- Repair does not act to protect the structure



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SUCCESSFUL SHRINKAGE COMPENSATION

- Requires ‘dual shrinkage compensated’ mortar
- Timing of expansion and shrinkage must be closely matched
- Consider total volumetric stability
- Specify maximum expansion
- Specify limits on 56 day shrinkage (consider dry v saturated also)

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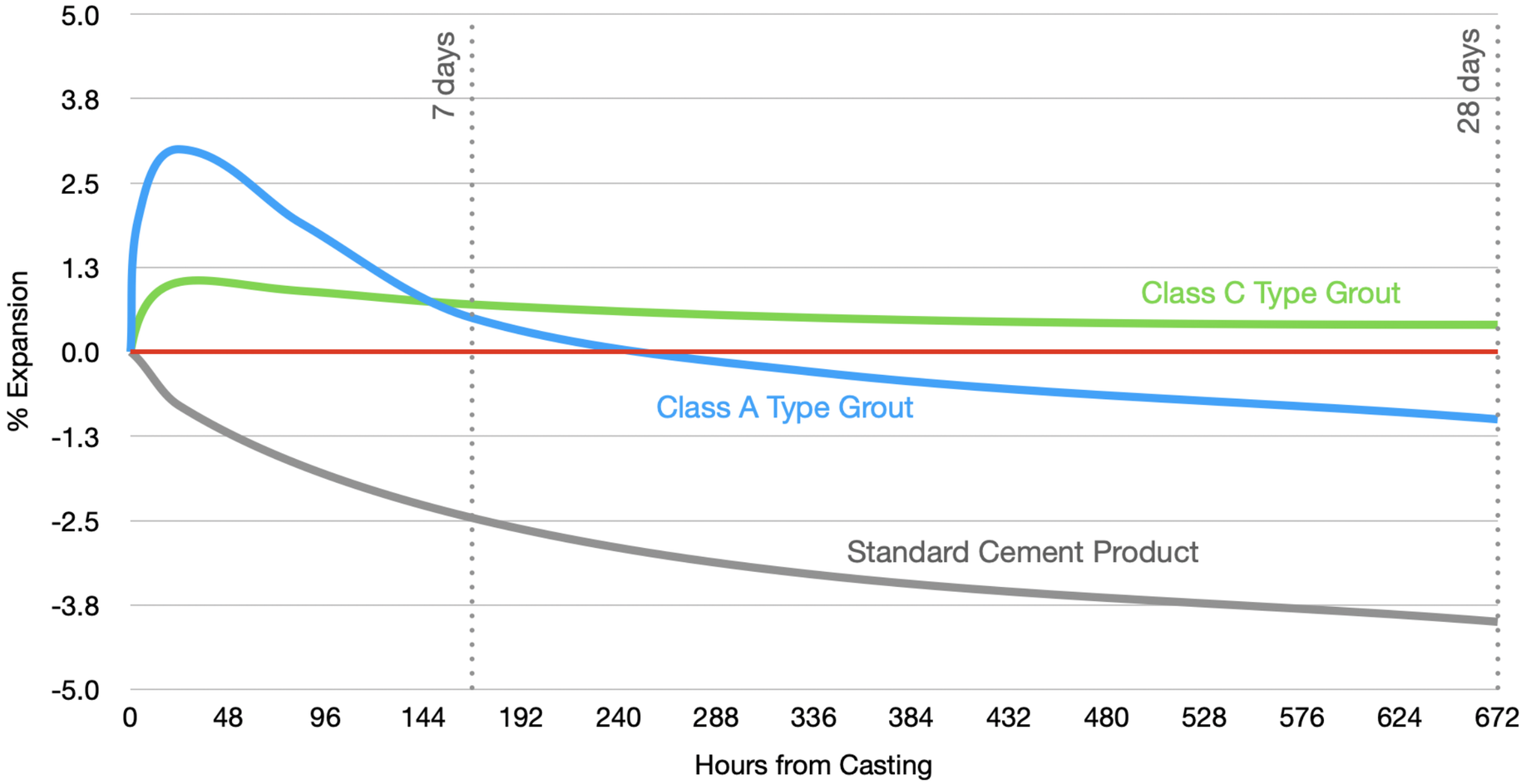
EXPANSION AND SHRINKAGE OVER TIME



4.0 HOST CONCRETE PREPARATION

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Concrete Removal

- Damaged concrete must be fully removed
- Often the damage may not be visible
- Only through testing can we confirm that the concrete may be failing to protect the reinforcement.

If steel reinforcement is corroding then ask… “what is wrong with the concrete?”

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CONCRETE REMOVAL METHODS

- Pneumatic hammer
- Ultra high pressure water blasting
- Saw Cutting
- Shot-blast or scarifier
- Grinding

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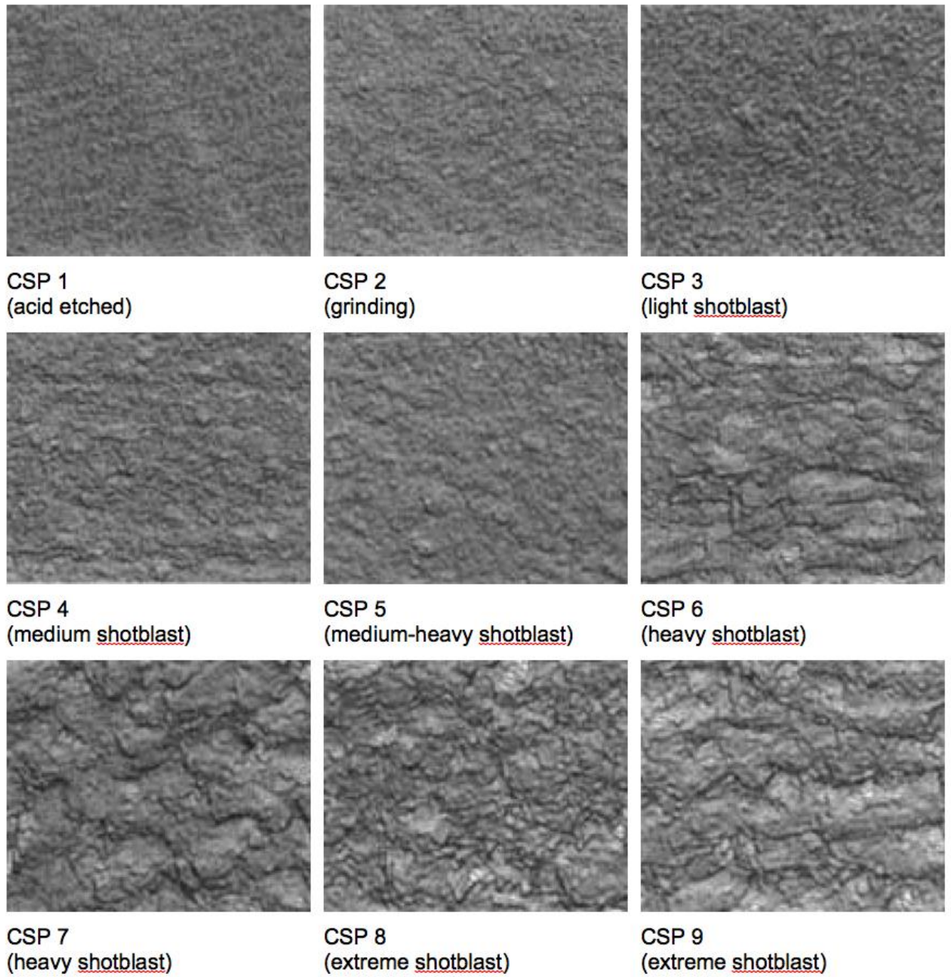
SURFACE PROFILE

- ACI Guidelines
- Larger profile provide greater ‘key’
- Different repair materials require specific minimum and maximum preparation



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REPLACEMENT OF REINFORCEMENT

- Replacement required where:
  - More than 20% of diameter is lost
  - Cover inadequate
- Cut out and replace
- Remove concrete 20mm behind the bar
- Clean remaining reinforcement

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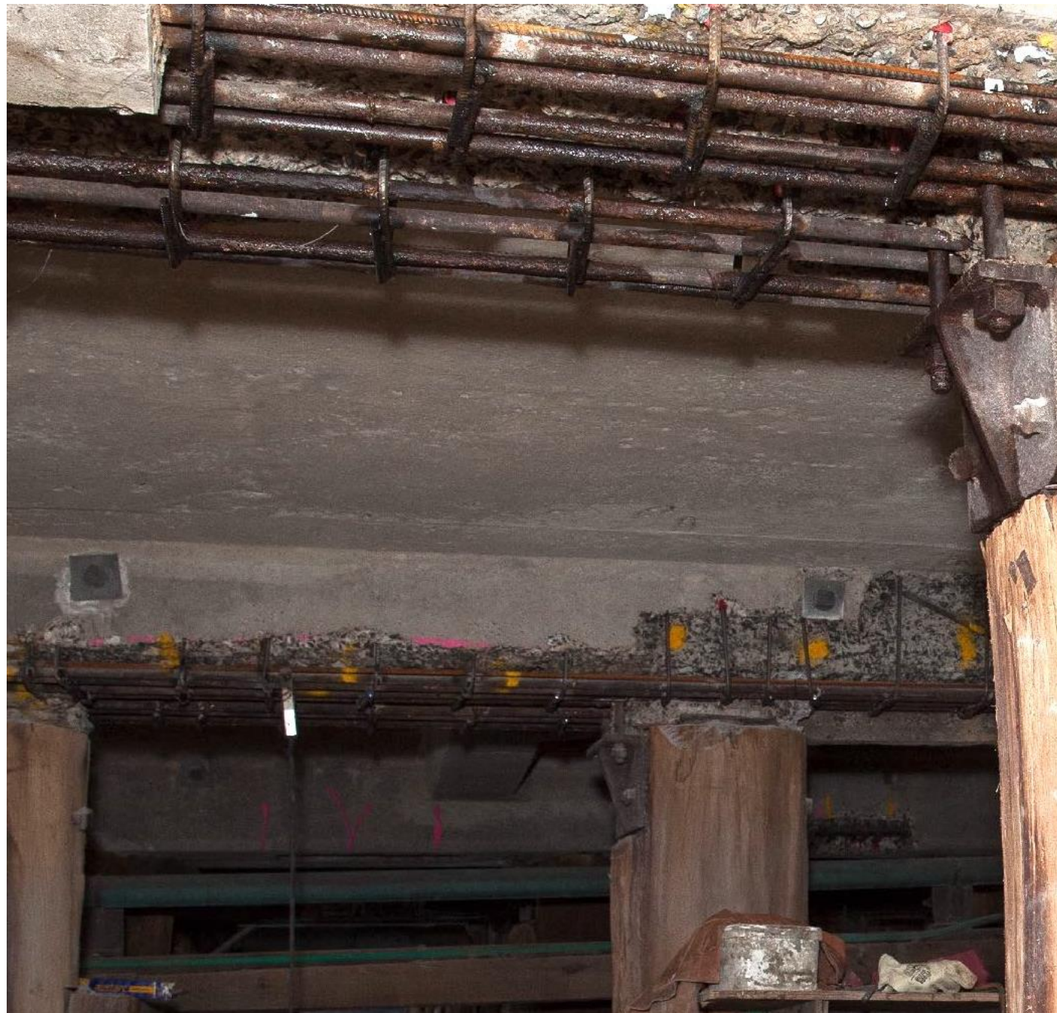
CONCRETE PRIMING

- Prevents moisture loss
- Improves connection to host surface
- Must be vapour permeable (not epoxy)
- Acrylic or plain water saturation
- Lowest viscosity for high permeation



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STEEL PRIMING

- Zinc coating often specified
- Not a necessary requirement
- Can add to incipient corrosion effects
- Creates a barrier to alkaline environment

5.0 MATERIAL APPLICATION CHARACTERISTICS

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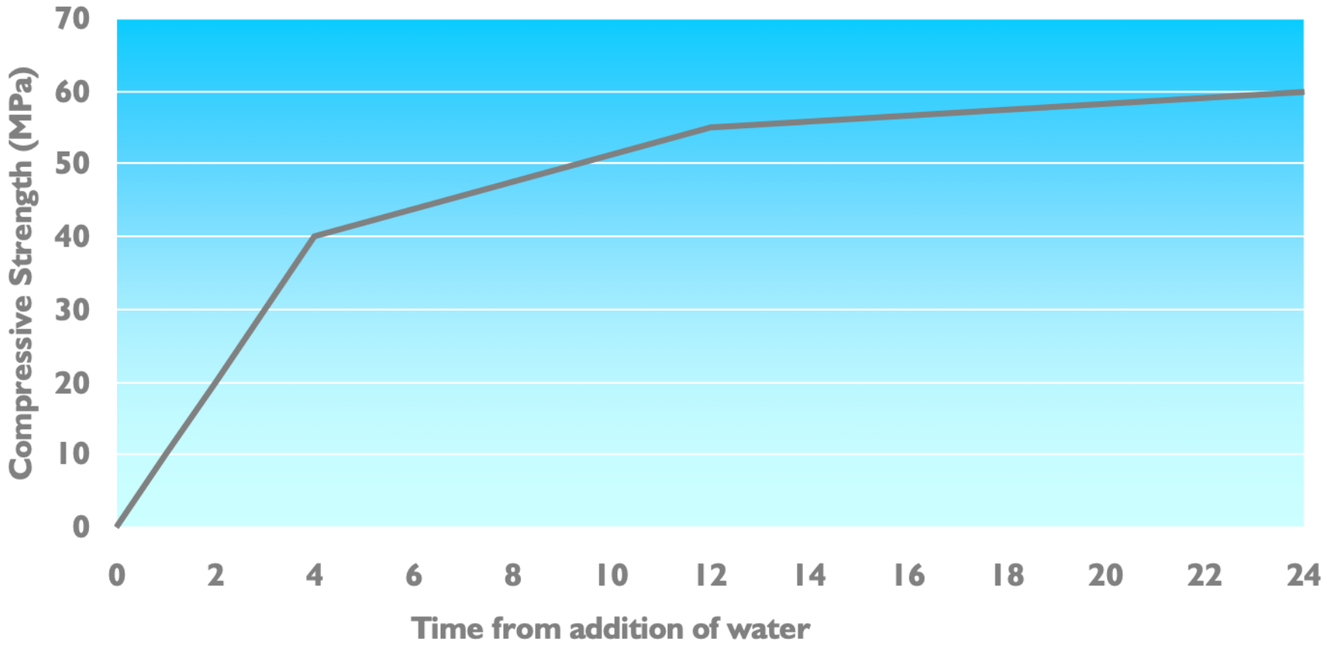
SET TIME AND STRENGTH DEVELOPMENT

- Fast set times and curing are important for marine and other ‘live’ environments



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REBOUND AND DUST CONTROL

- Both wet and dry spray
- Airborne silica particles
- Clean-up and pollution control
- Many products now developed to eliminate rebound and minimise dust

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BUILD SCOPE

- Thermal shrinkage
- Slump
- Compaction
- Specify maximum thickness in one pass
- Allow at least 24hrs between layers unless trials conclude otherwise

6.0 APPLICATION TECHNIQUES

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APPLICATION SPECIFICATION

- Application methodology has a significant impact on final repair properties
  - Cement hydration
  - Compaction density
  - Build scope
  - Compressive strength
  - Drying and thermal shrinkage

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DRY SPRAY

- Powder is mixed with water at the nozzle
- Fast application of large volume
- Low water cement ratio
- Reduced drying shrinkage
- Better compaction for high density
- Up to 150mm in one pass (overhead)

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WET SPRAY

- Powder is premixed with water
- Mortar then sprayed onto surface
- Mix requires more water for pumping
- Lower density final product
- Typically up to 100mm in one pass

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HAND TROWEL

- Powder premixed with water
- Slow process
- Low compaction density
- Suitable for small repairs

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CURING METHODS

- Provides high quality surface
- Minimises plastic cracking
- Water based wax emulsion or acrylic
- Applied soon after finishing

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SURFACE COATINGS

- Applied for the purpose of:
  - chemical protection
  - slip resistance and safety
  - aesthetics, signage, line marking
- Surface preparation is critical
- Apply 28 days after curing

SUMMARY

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SUMMARY

- Concrete repair will play a significant role in construction industry sustainability efforts
- Appropriate material selection by analysing suitability of test data will ensure success
- Interaction of materials with the repaired structure needs to be carefully considered
- Application techniques should be specified to achieve desired outcome


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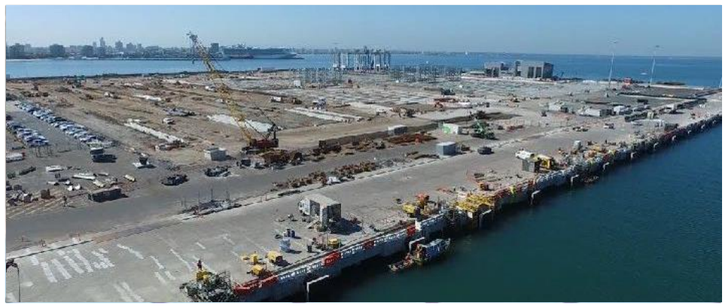


Thank you